USING AN ENVIRONMENTAL RISK ASSESSMENT APPROACH IN DETERMINING PRIORITIES RELATED TO THE IMPACT OF IRRIGATION RETURN ON RIVER ENVIRONMENTS. A CASE STUDY OF THE ORD RIVER IRRIGATION AREA

Mark Lund[1] and Andrew McCrea[2]

[1]School of Natural Sciences, Edith Cowan University, 100 Joondalup Drive,Joondalup, WA 6027
[2]Policy and Planning Division, Water and Rivers Commission, 3 Plain St, East Perth, WA 6004

Abstract

The National Program for Irrigation Research and Development has established a research project to develop and test a generic framework for assessing the ecological risks associated with irrigation return. Three irrigation areas are involved in the study, Goulburn-Broken, Fitzroy (Qld) and the Ord River. This paper reports on the Ord River project.

The aim of the study was to identify likely ecological risks associated with irrigation systems within the Lower Ord River catchment and rank the risks based on the use of conceptual models. The Ord River catchment under consideration was bounded by the Ord River Dam (Lake Argyle) and the upper extent of the salt wedge at Carlton Crossing.

Despite limited availability of flow and water quality data for the irrigation area or the Ord River, a mass balance model was produced and general trends observed. A key finding was that irrigation return water was a substantial contributor of Phosphorus (P) and nitrate/nitrite to the Lower Ord River.

Initial stakeholder meetings held in Perth and Kununurra identified weeds, channel infilling, biota kills, algal blooms and loss of biodiversity as key ecological consequences of irrigation. Two simple conceptual models were then produced. One shows the role water quantity plays in the risk of ecological consequences occurring. The other model takes a different approach and identifies what factors biota require for their continued health and looks at the risks irrigation poses to those factors. Risks were assigned and then averaged to produce a risk assessment matrix.

Subsequent stakeholder meetings ranked the consequences in terms of priority, with biota kills and loss of biodiversity first, followed by weeds. Algal blooms and channel infilling were seen as being of least importance or not substantially impacted by irrigation.

Plans for ongoing project work and how results from this study contribute to other community and research activities in the Ord will be discussed.

Introduction

Despite more than thirty years of agricultural production, the ecological effects of land and water management practises in the Ord River Irrigation Area (ORIA) has received little attention (see Walker 1992). Limited research, inconsistent sampling methodologies and specific foci of existing studies in the area (e.g., Rosich and Partridge 1988; EMS 1989; Jones 1997; Doupé 1997) limit our understanding of the ecological processes within the ORIA. The potential ecological consequences of irrigation return were highlighted in 1997 with significant fish kills in the Dunham River and D4 drain due to Endosulphan poisoning. The first water quality survey of the area was undertaken by Doupe et al (1998). Although only a short-term study, it highlighted the poor state of water quality within the irrigation channels and possible threats to river water quality.

Since 1998, water quality monitoring of the drains and river has been undertaken by the Ord Irrigation Co-operative (OIC) in conjunction with the Water and Rivers Commission. The Water Corporation of Western Australia has installed flow gauging stations on the main drains of the Ivanhoe Plains irrigation area. Proposals to develop new irrigation areas in Weaber, Knox and Keep Plains (collectively referred to as Ord Stage II) and other proposals for irrigation on Carlton Plains and Mantinea Flats has lead to increased Agency and research interest in the area. In particular the Water and Rivers Commission of Western Australia (WRC) has had to evaluate the potential effects of Stage II development including determining the amount of water required by the environment and what is available for Stages I and II Irrigation diversions. This has resulted in the production of the Interim Ord River Water Allocation Plan. Current ecological water requirement (EWR) planning focuses on maintaining and enhancing the post dam modified environmental conditions rather than attempting to return the river to a more natural condition.

The most significant consequence of irrigation in the Ord catchment was the construction of the Kununurra Diversion Dam (KDD, 1962) and Ord River Dam (ORD, 1973) , which changed the Lower Ord river from a seasonally dry tropical river to a permanent flowing river. Flows are now highly regulated. Consequently there have been substantial changes in river dynamics, sediment transport, channel morphology, biodiversity, and riparian vegetation. The Lower Ord is now currently evolving to suit its new flow conditions, a process which will continue for many years. Currently, water is drawn from Lake Kununurra to support two irrigated areas - Ivanhoe Plains and Packsaddle Plains. Designed as flow-through systems these areas return significant quantities of drainage waters to the river either directly (drains) or via Packsaddle Creek into the Dunham River.

Ecological Risk Assessment is a recent variant on the well established process of Environmental Impact Assessment. It focuses on the assessment of risk of environmental damage occurring (see Hart et al, 1999). One particular advantage of this approach is that it aims to provide a quantitative assessment rather than a purely qualitative one. The National Program for Irrigation Research and Development (NPIRD), after considerable review, agreed to fund three research projects that use the Ecological Risk Assessment approach to aid in the development of a generic framework applicable to other irrigation areas in Australia. Three catchments chosen were, the Ord River, the Goulburn-Broken and the Fitzroy (Qld). These areas differ in scale of knowledge and stakeholder involvement. The Ord River was the least understood system with relatively limited stakeholder involvement.

This project aims to identify potential ecological risks associated with irrigation return in the Lower Ord River catchment. Specifically; a) in consultation with relevant catchment stakeholders, to develop and prioritise a list of six ecological consequences of development in the ORIA where irrigation is likely to have a significant impact; b) produce a nutrient mass balance model for the ORIA; c) develop conceptual models for each of the ecological consequences listed; and, d) complete a matrix table to help establish priorities for Phase 2 of the project.

Methods

Study site

The Ord River Irrigation Area (ORIA) Stage 1 consists of 15,000 ha of irrigated land on the Ivanhoe Plain (13,000 ha) and the Packsaddle Plain (2,000 ha) (Jones 1997). The impoundment (Lake Kununurra) created by the Kununurra Diversion Dam (KDD) supplies irrigation water to both areas. The water enters the Ivanhoe Plain area via a gravity fed main channel (M1), from which a series of smaller channels carry water to the farms (S channels). The waters are then collected in a series of drains (D channels) and returned to the Ord River. Water is pumped onto the Packsaddle Plain, gravity fed to farms, and collected by drains leading to the Packsaddle Creek, which drains into the Dunham River. The Dunham joins the (lower) Ord River a short distance below the KDD.

It is on this basis of a modified system that the ecological consequences of irrigation were determined in this study. As the river is highly modified after passing through the ORD, this was taken as the upper boundary for the study, although most effort was concentrated downstream of the KDD where the effects of irrigation return occurs. The lower limit of the study was taken as Carlton Crossing (the approximate extent of saltwater intrusion up the river). Possible impacts of Stage II developments will be assessed, although water allocations have not been finalised.

Approach

A series of informal meetings were held with a group of scientific experts (Water and Rivers Commission (WRC) and 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, attended by representatives from Agriculture WA (AgWA), OIC, and local WRC staff. In addition to comments received on the list of potential ecological consequences of irrigation, a key priority was seen as the development of the mass balance model for the Lower Ord catchment.

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 models were then presented in a workshop in Kununurra held on the 16th March 2001. In addition to those who attended the previous meeting, a representative from the Ord Land and Water Community Group was also present. At this meeting, the mass balance was presented and final revisions were made to the models and potential risks determined.

Mass Balance Model

The paucity of water quality and flow data for the ORIA necessitated a variety of assumptions which are fully detailed in Lund and McCrea (2001). Available data was collected from the WRC, OIC, AgWA, Water Corporation, and hydroelectric commission. In summary, Ivanhoe Plains (no data available for Packsaddle Plains) water quality data were collected by OIC/ WRC at approximately monthly intervals from a number of river and irrigation drain sites between April 1998 and August 2000. Gauged flow data was collected from the main drains over the same period. Flow was also measured in the upper Dunham River and for releases from ORD and KDD. Data for the Ivanhoe Plains was estimated daily for 1998 to 2000 and then reduced to monthly averages. The gauging station data (1970-1999) on the upper Dunham was used to estimate average monthly runoff coefficients as a function of rainfall at the Kimberley Research Station that were then used to calculate flows in ungauged tributaries. Water quality values for grazed catchments (e.g. Dunham) were estimated using average values from the Spring and Valentine Creeks.

Results and Discussion

The development of the Interim Ord Water Allocation Plan and EWRs for the Lower Ord River, led to reports from a Scientific Panel (Deegan, 2000) and an associated Community Reference Group in June 2000. These reports provided a strong foundation for the development of a list of ecological consequences of irrigation. Key issues raised by the Community Reference Group was the need to maintain the current ecological and social values of the area. The Scientific

Panel recommended that water levels should be adequate to prevent pool formation, weed proliferation, and sedimentation causing excessive channel infilling and loss of habitat. These findings were incorporated into a list and discussed at the initial workshop and refined into the following list of potential ecological consequences:

- Algal Blooms – blooms of mainly cyanobacteria, although could include green algae.
- Biota kills – refers to the death of fish and other biota either through loss of dissolved oxygen or through high concentrations of biocides. It was decided the highest risk was posed by biocides.
- Loss of biodiversity – was used to cover loss of fish, crocodiles, wading birds and macroinvertebrates. To a lesser extent loss of significant plants (riparian or submerged) was also included here.
- Channel Infilling – refers to the loss of channel width and depth through sedimentation and the stabilisation of deposited material.
- Weeds – includes invasion by exotic plants and to a lesser extent exotic fauna.

The contribution of irrigation return to nutrient and sediment loads in the Lower Ord has always been a ‘hotly’ debated topic, given the potential dilution effect of large scale floods that can occur in the wet season. To provide some estimate of the relative contributions from irrigation and the other major catchment landuse (rangelands) a mass balance model was produced from all limited nutrient data available (for details see Lund and McCrea, 2001).

Results indicated that the Ivanhoe Irrigation Area contributes appreciable quantities of nutrients, particularly P (Filterable reactive and Total) and total oxidised N (nitrate/nitrite) to the Ord River. These nutrients are typical of areas that are fertilised. Interestingly, an unexplained observation was that the peak loads of these nutrients occurred in September to December- the start of the wet season, rather than soon following fertiliser application. This indicates a short-term storage in the irrigation area. The relative contribution by rangelands to total river loads within the catchment (KDD to Carlton Crossing) was significantly lower on a per area basis (Table 1) and in total, especially for P and total oxidised N. Interpretation of the rangeland data is however complicated by the absence of data points in September to November (assumed dry) and as there is no gauged flow data with corresponding water quality data. It is believed that rangelands have increased nutrient export to the Ord River in the wet season.

Table 1: Relative contributions to Ord River loads by rangelands (based on Valentine Creek) and irrigated areas (based on Ivanhoe Irrigation Area) and total loadings (Irrigated areas - 148 km^2; Rangelands - 4760 km^2)

Parameter	**Irrigated Area**		**Rangelands**	
	tonnes 100 km^{-2}	*Total (tonnes)*	**tonnes 100 km^{-2}**	*Total (tonnes)*
Total Suspended Solids	16849.1	24937	136.4	6493
Total P	14.83	22	0.23	11
Filterable Reactive P	7.07	10.5	0.05	2.4
Total Kjeldahl N	59.83	88.5	3.3	157.1
Ammonia	7.65	11.3	0.29	13.8
Total Oxidised N	20.15	29.8	0.08	3.8
Total N	86.79	128.5	3.21	152.8
Total Organic Carbon	52.53	77.7	55.5	2641.8

Two simple conceptual models were constructed. The models produced were designed to put the assumptions of risk into context rather than explain all possible interactions. The production of the conceptual models includes some important assumptions:

- The main effect of Ord Stage II is in reducing water quantity in the lower Ord River rather than changing current nutrient loadings (due to the proposed design and on-farm recycling).

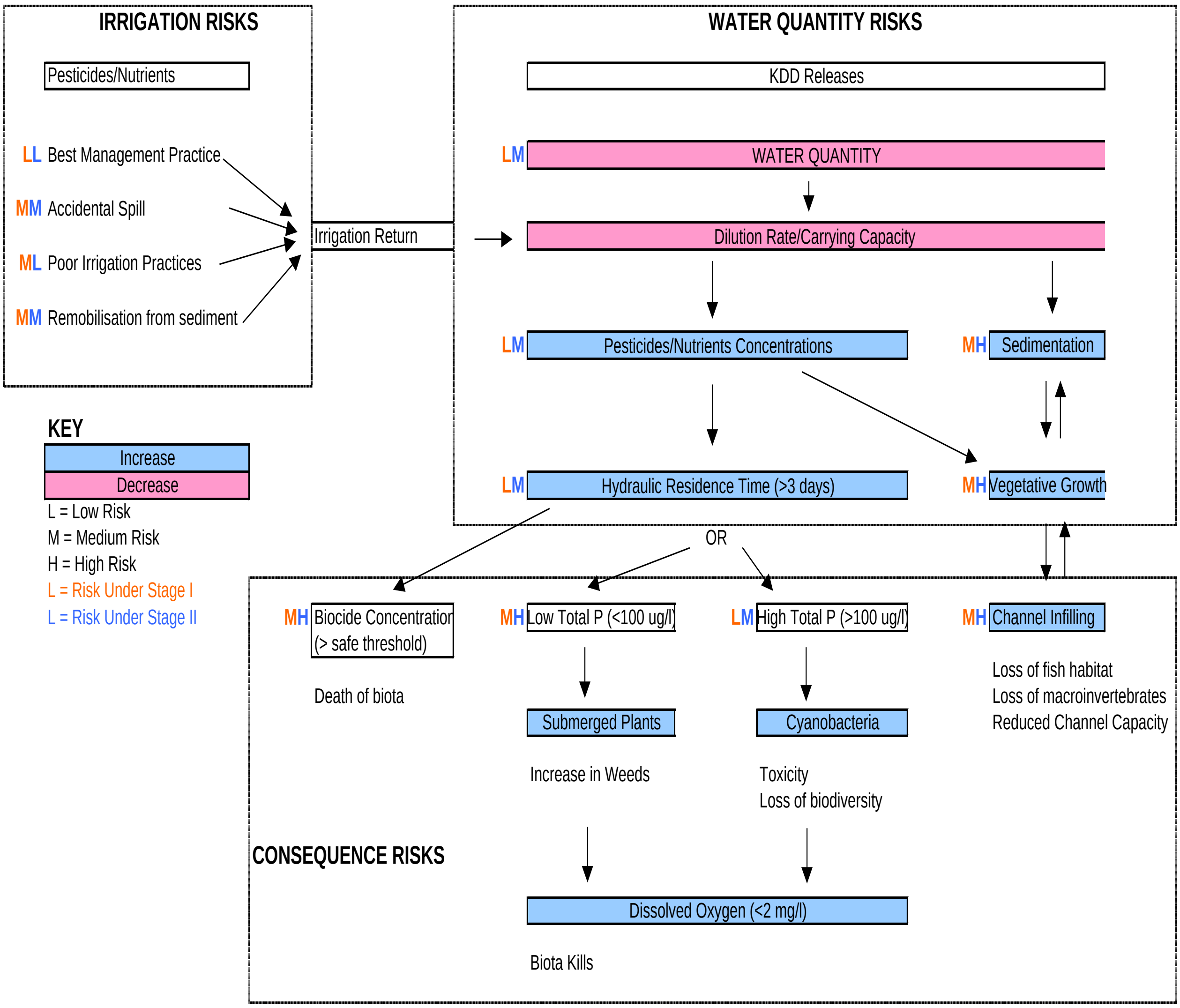

Figure 1: Conceptual model illustrating potential risks of stressors responsible for causing ecological consequences associated with irrigation in the Lower Ord River. The risks associated with water quantity changes are illustrated under Stage I and Stage II developments.

- Although current WRC water allocation planning will aim to prevent the formation of pools in the river, this still remains a risk.

The first model (Figure 1) focuses on the effects of altering water quantity within the Lower Ord River. This will occur due to diversion of water to Ord Stage II irrigation and/ or due to a period of extended low rainfall. The first model is divided into three risk components, those associated with on farm practices, those due to flow and lastly those of the ecological consequence. In the first model, as water quantity drops either through increased irrigation usage or below average rainfall or both, that this has two effects. The first is the reduction in the dilution rate of incoming irrigation return, increasing 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 could potentially lead to a variety of ecological consequences depending on the P concentration. 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 may result in the fish death and other biota in the water. The presence of moderate nutrient concentrations and moderate hydraulic residence may provide a favourable environment for the proliferation of many weed species. Reduced dilution and longer hydraulic residence times will increase the chances of biocides reaching toxic levels. As the quantity of water declines, the rivers capacity to carry sediment will also tend to be reduced (assuming that velocity declines), which will encourage sedimentation. As sediment accumulates within the channel, it is stabilised by vegetative growth (emergent followed by riparian). Growth may be promoted by elevated nutrient concentrations in the river associated with reduction in flow. This is predicted to result in loss of habitat for benthic macroinvertebrates and fish.

The second model (Table 2) lists the requirements of biota (fish, crocodiles and invertebrates) in general terms, with specific needs highlighted (reasons). The impact of irrigation on each of these reasons is assessed and the risk determined. A healthy environment for biota requires adequate flows, habitat (physical and vegetative) and suitable water quality. Low water levels can result in physical barriers restricting the migration and distribution of certain species. Channel infilling is likely to reduce habitat for biota and wading birds. Another potential problem in the Ord River, identified by Dr Andrew Storey (University of Western Australia), is that the infilling can promote the growth of emergent C4 plants, which are not believed to contribute to aquatic food chains. Proliferation of these plants can reduce the availability of food sources for biota.

Table 2: Conceptual model of key requirements for the continued maintenance of healthy communities of biota in the Lower Ord River, why they are important and how they are likely to be impacted by irrigation return.

Requirement	**Reasons**	**Impact of Irrigation**	**Risks**	
			Stage I	Stage II
Flows	Provides breeding cues Sufficient to allow migration	Physical Barriers	L	M
Physical Structure	Provides a range of depths and flow regimes	Infilling of channel	M	H
Vegetation (Riparian and submerged)	Provides range of habitats Provides inputs of Carbon Buffers nutrient concentrations Stabilises sediment	Infilling of channel Replacement of useable C3 inputs with that of C4 plants	M M	H H
Water Quality	Dissolved Oxygen (>2 mg/l)	Nutrient loads in concert with low flows and increased hydraulic residence time	L	M
	Safe levels of biocides	Derived from irrigation area	M	H

Risks of individual components of the conceptual models were determined by expert opinion and then assigned values (Low = 1, Medium = 2 and High = 3). A mean for each component was taken and then averaged to estimate the risk. The three major components were (1) likelihood of problem in irrigation return, (2) the impact of water quantity, and (3) the likelihood of consequence occurring (Table 3).

Table 3: Estimating the risk of ecological consequences using Conceptual Model 1.

Stage I				
Consequence	Irrigation risks	Water quantity risks	Consequence risks	Overall Risk
Algal Blooms	LMMM = 1.8	LLL = 1	L = 1	1.3 = L
Biota Kills	LMMM = 1.8	LLL = 1	M = 2	1.6 = M
Loss of biodiversity	LMMM = 1.8	LLLLMM = 1.5	LM = 1.5	1.6 = M
Channel Infilling	LMMM = 1.8	LMM = 1.7	M = 2	1.8 = M
Weeds	LMMM = 1.8	LLL = 1	M = 2	1.6 = M
Stage II				
Algal Blooms	LMLM = 1.5	MMM = 2	M = 2	1.8 = M
Biota Kills	LMLM = 1.5	MMM = 2	H = 3	2.2 = M
Loss of biodiversity	LMLM = 1.5	MMMMHH = 2.3	MH = 2.5	2.1 = M
Channel Infilling	LMLM = 1.5	MHH = 2.7	H = 3	2.4 = M
Weeds	LMLM = 1.5	MMM = 2	H = 3	2.2 = M

In comparison, a mean was taken of all the listed risks in Conceptual Model 2 to determine the risk of loss of biodiversity. The result was 1.7 (M) for Stage I and 2.7 (H) for Stage II, which closely match the risks obtained in Table 3, although the risk for Stage II was noticeably higher.

In addition to the risk of the consequence occurring, the risk posed by irrigation and the importance within the catchment was estimated (Table 4).

Table 4: Ecological effects ranking matrix table for Ord catchment and irrigation

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

There was general agreement amongst all stakeholders on the risk values associated with Table 4 and the consequences were prioritised as follows:

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

The current dilution rate within the Lower Ord and the moderate loads from the irrigation area indicate that although irrigation is an important contributor to the total load of nutrients within the river, it is unlikely to be having a substantial impact on water quality within the river (ie, low concentration). Under Stage II, however, this position could change substantially with reduced dilution rates. Currently WRC planning is to provide adequate flows to ensure, when coupled with Irrigation Best Use Practice, that there will be a minimal impact on water quality.

Project Linkages

Currently, there is considerable land and water resource research and planning activity in the Ord River catchment and estuary. In relation to water resources, most of this work can be generally grouped into (1) scientific research, (2) water allocation planning, and (3) water use improvement. The Kununurra community is actively involved in this work. In association with other groups, the Water and Rivers Commission is actively supporting the development of appropriate linkages between the diverse activities in the interest of improving waterways management in the Ord.

The NPIRD project has strong linkages to work by the Ord Land and Water Community Group, the Water and Rivers Commission's Interim Ord Water Allocation Plan (particularly in regards to ecological water requirements), and the Federal and State supported Ord Bonaparte Program. Results from NPIRD study will influence catchment and waterways planning and be used in the development of policies for commercial operations including codes of practice, licensing and approvals process.

Further Work

This paper describes results of Phase 1 of the NPIRD project. Phase 2 will attempt to produce a more detailed conceptual model for loss of biodiversity. A detailed nutrient sampling program is proposed. This will aim to allow us to determine what impact the current nutrient loads and concentrations are actually having on biodiversity within the system.

The CRC for Freshwater Ecology will pull out the generic elements from results of the ecological risk assessments for the three irrigation areas (Phases 1 and 2 to construct a generic ecological risk assessment framework. It is anticipated that the generic framework will be a guide to irrigation areas elsewhere on how to prioritise effort in moving from a comparatively poor knowledge system such as the Ord River to the detailed management models being developed in the Goulburn-Broken catchment.

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