OPTIMIZATION TO SUPPORT SEASONAL ENVIRONMENTAL WATERING DECISIONS

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A growing awareness of the impact of changed flow regimes on the environment has led to increasing recognition and legal allocation of environmental water. Where the allocation mechanism allows for active and adaptive management of this environmental water (such as the environmental water entitlements in Australia), environmental water managers must manage this water in a way that leads to the best possible ecological outcome. In this paper we present an optimization tool that supports seasonal watering decisions. While there are a number of existing decision support tools for environmental water management, these have tended to focus on long term planning rather than active seasonal watering decisions.

1 INTRODUCTION

Development of the world's water resources is placing increasing strain on the natural river systems and environment [1]. A growing awareness of the impact of changed flow regimes on the environment has led to increasing recognition and legal allocation of environmental water. Where the allocation mechanism allows for active and adaptive management of this environmental water (such as the environmental water entitlements in Australia), environmental water managers must manage this water in a way that leads to the best possible ecological outcome. While our understanding of flow-ecology relationships is improving [2], there is a clear challenge in translating this knowledge into management decisions [3,4].

When making seasonal watering decisions, environmental water managers must access the relative merits of providing water to the environment at one time step over another, to one location over another or between different ecological endpoints [5]. This requires the analysis of complex temporal and spatial options for watering. Decision support tools provide one approach for systematically and transparently assessing these watering decisions [6].

In this paper we present an optimization tool that supports seasonal watering decision. While there are a number of existing decision support tools for environmental water management, these have tended to focus on long term planning rather than active seasonal watering decisions [7]. Conditional probability networks are used as a way of incorporating existing ecological knowledge, whilst still recognizing uncertainties [8,9]. The tool is applied to the Yarra River (Victoria, Australia) and used to demonstrate the potential of such tools in translating our ecological knowledge into environmental management decisions.

2 OVERVIEW OF OPTIMIZATION APPROACH

An environmental water manager aims to make release decisions to achieve the best environmental outcome possible, given (a) what is known about the link between flow and ecological endpoints, (b) the river system and operation constraints, (c) the flow in the river due to other users and inflows (exogenous flows), (d) antecedent conditions, and (e) the volume of environmental water available. The optimization tool links this information together and determines the optimal volume, timing and location of environmental water releases over a season (Figure 1).

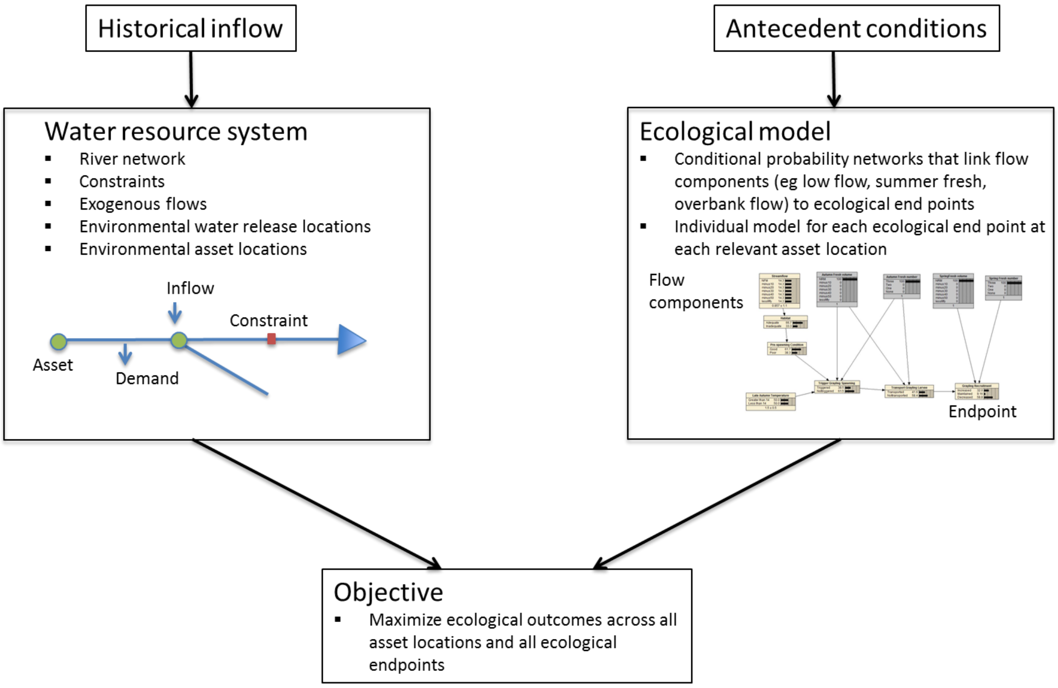


Figure 1: Overview of optimization approach

3 MODEL OUTPUTS TO SUPPORT MANAGEMENT DECISIONS

The benefits of using a optimization tool to assist in developing management decisions are in its ability to process a large number of scenarios in a transparent and consistent manner; to determine the marginal benefit of providing additional environmental water in a season; to look for similarities or differences in recommended environmental water release patterns over various seasons and years; and to determine the main ecological drivers behind the optimal decisions. In the remainder of this section we discuss the benefits of the proposed optimization approach in detail, which are demonstrated using modeling outcomes for the Yarra River (Victoria, Australia). The optimization model was run for six years of flow and temperature data. Four investigations were completed with details of each discussed below.

1. The tool can be used to look at the *marginal benefit of providing additional environmental water* under different climate conditions by running the model with increasing volumes of available environmental water. In Figure 2 below, the slope of the curve shows the marginal value (the additional environmental benefit per unit of additional water). In this example, the figure shows that with 10 GL of environmental water, the majority of environmental outcomes possible is achieved across all climate conditions analyzed. The curves plateau after this point showing little additional gain for extra environmental water.
2. Using an optimization tool means the model *selects exogenous flow pulses in the river which environmental flow releases can "piggy back" and maximize ecological outcomes*, as shown in Figure 3.
3. An assessment can be made as to *which flow components are prioritized* across different climatic conditions based on the ecological models included (Table 1).
4. The use of conditional probability networks shows a clear link between the decisions available to an environmental water manager (in this case, which flow components at which location to release) and the management objectives. This *allows intermediate steps to be assessed*, such as spawning and juvenile recruitment. The example shown in Table 1, which also demonstrates the importance of factors not in the environmental mangers control (in this case temperature) in affecting outcomes.

4 DISCUSSION AND CONCLUSIONS

The outcomes from modeling of the Yarra River have been used to demonstrate the potential of optimization tools to provide a systematic approach to help translate existing ecological knowledge into management decisions. Importantly, the tool can be used with altered inputs (climate, conditional probability networks representing ecological outcomes, system constraints) to assess the sensitivity of watering decisions to different inputs. In particular, it is acknowledged that there remain uncertainties around the links between different flow components and their relative importance to a given ecological endpoint. Management decisions still need to be made with the current state of knowledge, but a decision support tool such as this allows an assessment of the relative importance of these uncertainties on watering decisions.

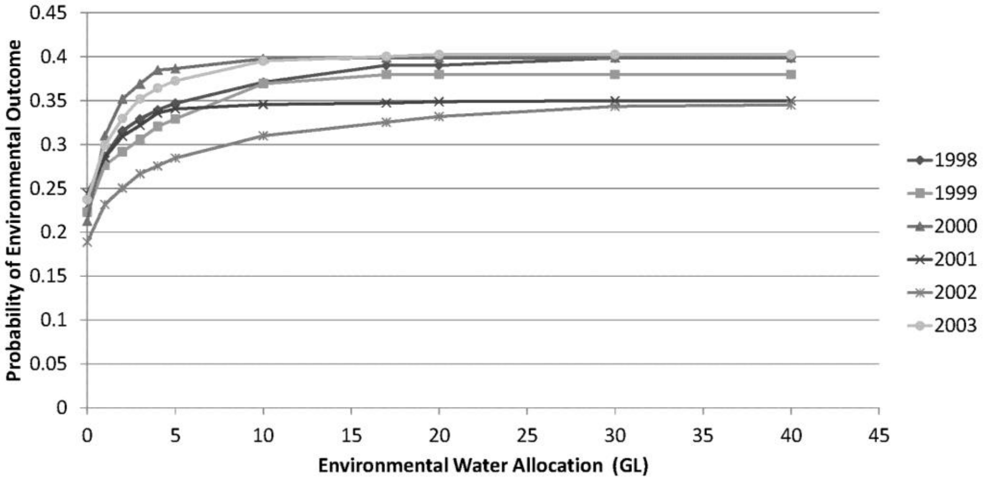


Figure 2: The average environmental outcome for Australian Grayling and River Blackfish in the Yarra River in different years with increasing volumes of environmental water available.

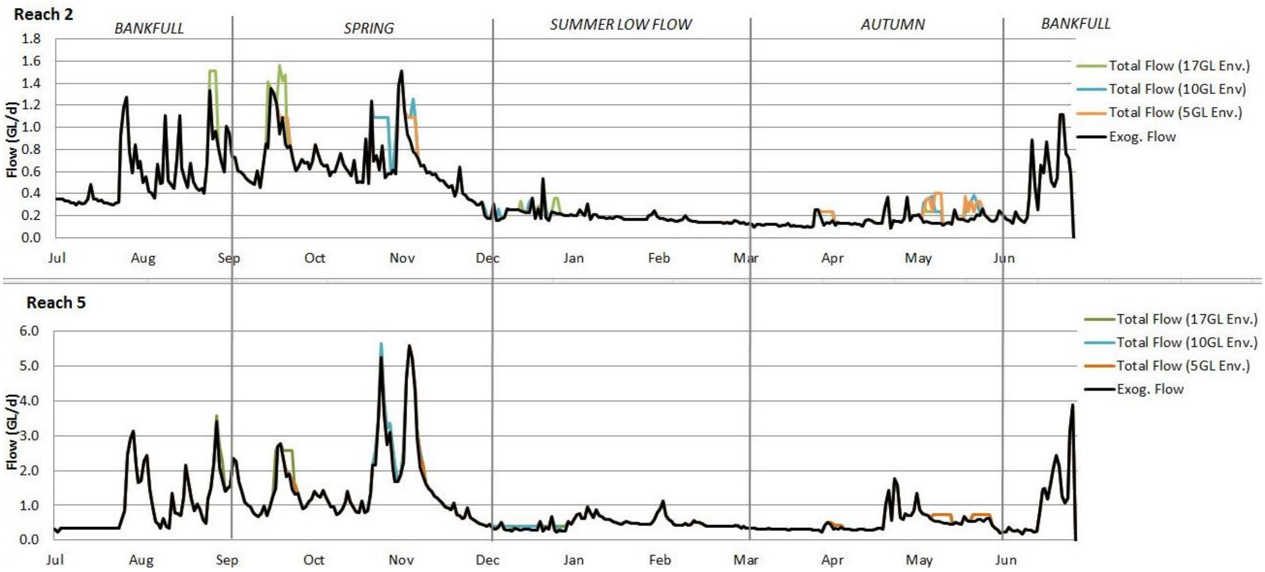
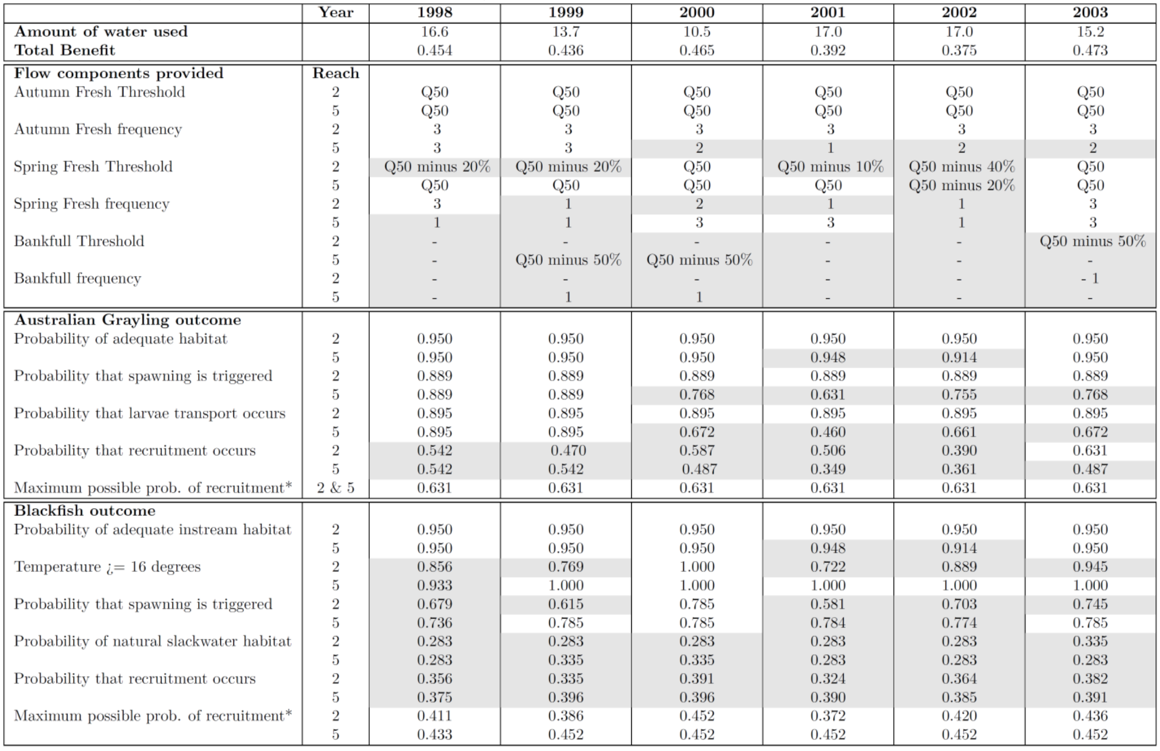


Figure 3: Exogenous flow and environmental releases in reach 2 and 5 for year 2003

Table 1: Targeted flow components for each year (1998 – 2003)



	Year	1998	1999	2000	2001	2002	2003
Amount of water used		16.6	13.7	10.5	17.0	17.0	15.2
Total Benefit		0.454	0.436	0.465	0.392	0.375	0.473
Flow components provided	**Reach**						
Autumn Fresh Threshold	2	Q50	Q50	Q50	Q50	Q50	Q50
	5	Q50	Q50	Q50	Q50	Q50	Q50
Autumn Fresh frequency	2	3	3	3	3	3	3
	5	3	3	2	1	2	2
Spring Fresh Threshold	2	Q50 minus 20%	Q50 minus 20%	Q50	Q50 minus 10%	Q50 minus 40%	Q50
	5	Q50	Q50	Q50	Q50	Q50 minus 20%	Q50
Spring Fresh frequency	2	3	1	2	1	1	3
	5	1	1	3	3	1	3
Bankfull Threshold	2	-	-	-	-	-	Q50 minus 50%
	5	-	Q50 minus 50%	Q50 minus 50%	-	-	-
Bankfull frequency	2	-	-	-	-	-	- 1
	5	-	1	1	-	-	-
Australian Grayling outcome							
Probability of adequate habitat	2	0.950	0.950	0.950	0.950	0.950	0.950
	5	0.950	0.950	0.950	0.948	0.914	0.950
Probability that spawning is triggered	2	0.889	0.889	0.889	0.889	0.889	0.889
	5	0.889	0.889	0.768	0.631	0.755	0.768
Probability that larvae transport occurs	2	0.895	0.895	0.895	0.895	0.895	0.895
	5	0.895	0.895	0.672	0.460	0.661	0.672
Probability that recruitment occurs	2	0.542	0.470	0.587	0.506	0.390	0.631
	5	0.542	0.542	0.487	0.349	0.361	0.487
Maximum possible prob. of recruitment*	2 & 5	0.631	0.631	0.631	0.631	0.631	0.631
Blackfish outcome							
Probability of adequate instream habitat	2	0.950	0.950	0.950	0.950	0.950	0.950
	5	0.950	0.950	0.950	0.948	0.914	0.950
Temperature ¿= 16 degrees	2	0.856	0.769	1.000	0.722	0.889	0.945
	5	0.933	1.000	1.000	1.000	1.000	1.000
Probability that spawning is triggered	2	0.679	0.615	0.785	0.581	0.703	0.745
	5	0.736	0.785	0.785	0.784	0.774	0.785
Probability of natural slackwater habitat	2	0.283	0.283	0.283	0.283	0.283	0.335
	5	0.283	0.335	0.335	0.283	0.283	0.283
Probability that recruitment occurs	2	0.356	0.335	0.391	0.324	0.364	0.382
	5	0.375	0.396	0.396	0.390	0.385	0.391
Maximum possible prob. of recruitment*	2	0.411	0.386	0.452	0.372	0.420	0.436
	5	0.433	0.452	0.452	0.452	0.452	0.452

5 ACKNOWLEDGMENTS

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