Environmental flows and ecological health of the lower Wimmera River

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Abstract

Twenty years of ecological monitoring has shown that flow and water quality issues are critical factors affecting the health of the lower Wimmera river. The Wimmera CMA recognises the high value of the waterway, threats to waterway health and have identified the lower Wimmera as a high priority for management. Environmental flow management is believed to be central to restoring water quality and ecological health in the River. The aim of this ecological risk assessment (ERA) is to provide predictive tools and information to assist the Wimmera Catchment Management Authority in managing environmental flow allocations. The results of the analyses so far show that summer fresh environmental flows result in a clear improvement in macroinvertebrate community diversity in the lower Wimmera River, primarily through a reduction in salinity. The next step in the ERA will be flow/salinity modelling and to build a Bayesian Network. An important application of the Network will be to test the predicted outcomes of different environmental flow scenarios in improving the health of the Lower Wimmera River.

Keywords

Catchment management, biodiversity

Introduction

The Wimmera River lies in the semi-arid, north-western part of Victoria. It is Victoria's largest endoreic river and one of it's most variable rivers with regard to annual discharge. The Wimmera River has been regulated since the 1840's, resulting in a considerably reduced flow and altered regime (Anderson & Morrison, 1989). Twenty years of ecological monitoring has shown that flow and water quality issues are critical factors affecting the health of the Wimmera river (Anderson & Morrison, 1989; EPA Victoria, 1993; WCMA, 2006). Reduced flow and saline groundwater intrusions have resulted in saline stratified pools in the lower Wimmera. The bottom waters of these pools have electrical conductivity (EC) concentrations reaching up to 30,000-60,000 EC and dissolved oxygen levels dropping to less than 5% saturation (Anderson & Morrison, 1989).

The lower Wimmera River is defined as the section of river downstream from Horsham to lake Hindmarsh. It is of high environmental value and contains many sections of relatively intact riparian and instream vegetation, a Heritage River section and many threatened fauna species (WCMA, 2006). Environmental flow management is believed to be central to restoring water quality and ecological health in the River (SKM, 2002; WCMA, 2006). Environmental flow recommendations for the Wimmera Catchment were determined as part of the Stressed Rivers project and Bulk Entitlement Conversion Process (SKM, 2002; Gov. of Vic., 2004). As part of this process, environmental flow objectives were determined to facilitate the restoration of biological, chemical and physical functions in the lower Wimmera River. Under the Wimmera-Mallee Bulk Entitlement arrangements, the Wimmera CMA is responsible for managing these environmental flow allocations (Gov. of Vic., 2004).

EPA Victoria and the Wimmera CMA are currently conducting an Ecological Risk Assessment (ERA) in the Lower Wimmera River. The aim of the ERA is to undertake an ecological assessment of the River and provide predictive tools and information to assist the Wimmera CMA in managing environmental flow allocations. Stakeholders identified that the risk analysis needed to focus on both the risks to the values to be managed with environmental flow allocations and also the risks associated with the provision of environmental flow allocations (for example, prevent flushing salt slugs downstream from saline stratified pools). Addressing these concerns required the monitoring of environmental flows and assessing its effects on river health as indicated by water quality, habitat quality and macroinvertebrate community diversity. The results of this monitoring are presented in this paper, followed by a discussion of future work needed in the ERA and how these data and information will be used in the development of predictive tools to assist in management.

Environmental flow delivery and field sampling

Wimmera environmental flow delivery

During the ERA study one environmental flow regime was delivered between December 2004 and March 2005 (WCMA, 2005). The total flow allocation over that period was 4867 ML for the Wimmera River and 454 ML for the mid-MacKenzie River (which flows into the Wimmera upstream of Lower Norton). Release rates varied from between 35ML/day to 142ML/day. An environmental flow delivery scheduled for Spring 2006 was postponed due to water shortages.

Field sampling

As part of the ERA risk analysis, macroinvertebrate, water quality and habitat sampling was conducted at 11 sites in the lower Wimmera River from spring 2004 to autumn 2006. Sampling took place in both spring and autumn at all sites and will continue until 2008. The parameters sampled were:

- Macroinvertebrates - EPA rapid bioassessment method (EPA Victoria, 2003).
- Water quality – electrical conductivity, dissolved oxygen, temperature, turbidity, pH, total phosphorus and total nitrogen.
- Habitat – including: stream and channel dimensions, identification of macrophyte structural types and reach coverage, descriptions of habitats sampled, general observations of the site and a characterisation of the riparian zone.

Analyses and results

Electrical conductivity (EC) concentrations

Results of the surface water electrical conductivity (EC) measurements taken at the time of macroinvertebrate sampling from Spring 2004 to Autumn 2006 are presented in Figure 1. The Autumn 2005 sample was taken after the environmental release (December 2004 to April 2005) and shows reduced EC concentrations at most sites, particularly the two downstream sites.

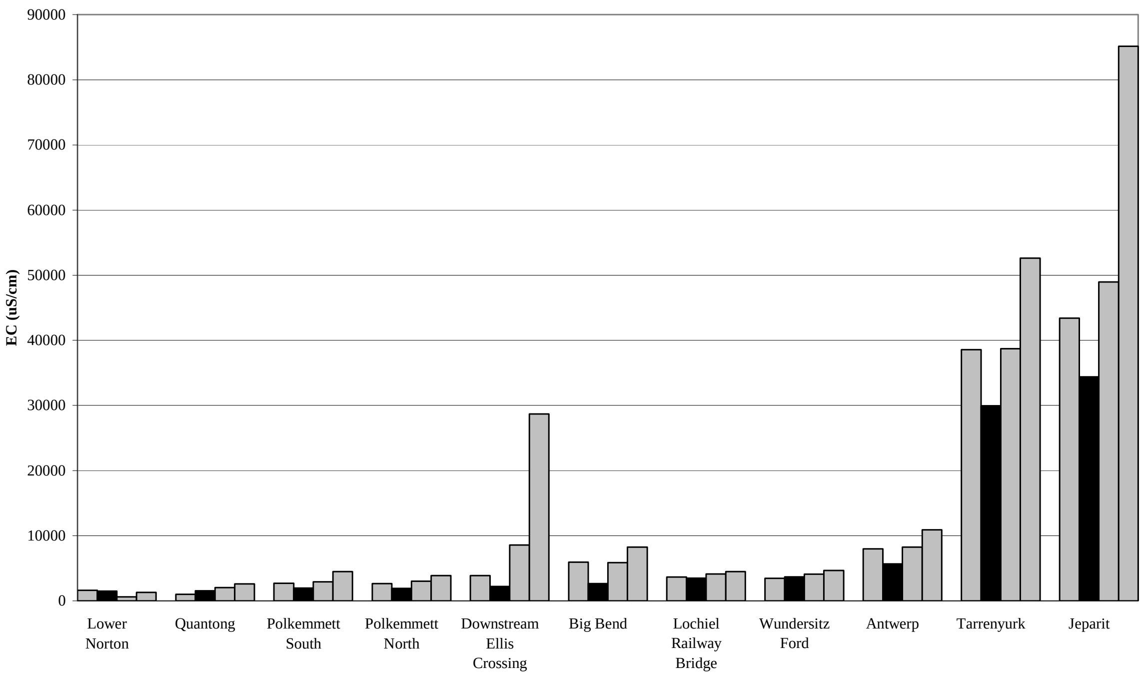

Figure 1. Electrical conductivity (EC) concentrations at each macroinvertebrate sampling site along the lower Wimmera River. Each site has a series of 4 columns representing the samples for spring 2004, autumn 2005 (■ - after the environmental flow), spring 2005 and autumn 2006.

Macroinvertebrate indices
The macroinvertebrate indices AUSRIVAS (Davies, 2000), SIGNAL (Chessman, 1995) and Number of Families (Barbour *et al.* 1992) were calculated for single season data. An aggregated score of these indices called the Macroinvertebrate Biotic Index (Box 1) was calculated using the individual index results.

Box 1: Macroinvertebrate Biotic Index (MBI)

EPA Victoria has developed a method for aggregating the individual Macroinvertebrate indices into one index called the Macroinvertebrate Biotic Index (MBI) score. This aggregated score gives one value, a score out of 10, which provides an easy comparison of all data. MBI scores are then translated into equal sized rating categories of condition, for ease of comprehension, as follows: 0-2 very poor; 3-4 poor; 5-6 moderate; 7-8 good; and 9-10 very good. The MBI is calculated in the same manner as the Aquatic Life score in the ISC (Ladson & White, 1999), however it incorporates all available macroinvertebrate indices (AUSRIVAS /Key families, SIGNAL, EPT (Ephemeroptera, Plecoptera and Tricoptera) and Number of Families).

The macroinvertebrate results (Figure 2) show that the environmental flows released from December 2004 to April 2005 clearly improved macroinvertebrate community diversity in the lower Wimmera River. More specifically, when looking at the MBI scores:

- 9 of the 11 sites showed an improvement in the index in the autumn after the environmental flow. The two sites not showing an improvement after the flow were Quantong and Jeparit, which stayed the same.

- 7 of the 11 sites showed an improvement in the index for the entire year after the environmental flow, compared to pre-environmental flow conditions.

- 9 of the 11 sites showed a deterioration in the index in Autumn 2006, compared to the previous Autumn 2005 season after the environmental flows. The exceptions are Lochiel Railway Bridge and Wundersitz Ford, which were the same for both seasons. The deterioration in macroinvertebrate community diversity reflects field observations for the Autumn 2006 season. Due to a lack of flow, the water levels in the Wimmera River were much lower than previous seasons, with many pools being substantially smaller, connectivity decreased and salinity levels elevated.

Multivariate analyses (Spring 2004 to Autumn 2006)
Multivariate analyses were performed on the macroinvertebrate presence/absence, water quality, habitat and flow data. PATN (Belbin, 1989) was used to ordinate (hybrid multi-dimensional scaling) and classify (unweighted pair group arithmetic average) the macroinvertebrate data based on an association matrix derived using the Bray-Curtis dissimilarity coefficient. The influence of environmental features (water quality, habitat and flow) was assessed using multiple regression analysis also in PATN (Principal Component Correlation (PCC) and the importance of individual taxa assessed using the SIMPER routine in Primer (Clarke & Gorley, 2001). The PCC analysis was performed using the water quality and habitat data from all 11 sites. Flow variables could only be included in PCC analyses for a subset of 5 sites, those at or relatively close to a gauging station. These were analysed separately.

The PCC regression analysis of all sites showed salinity to have the highest correlation (r^2 0.73) with macroinvertebrate community diversity, followed by macrophytes, measured as either structural types present (r^2 0.51) or number of taxa (r^2 0.45). Both showed substantially higher correlations than the remaining water quality and habitat parameters.

The analyses of the five sites for which flow variables could be calculated, also showed salinity (r^2 0.85) to be the key factor influencing macroinvertebrate community diversity. In these analyses dissolved oxygen (r^2 0.73) and macrophytes measured as either structural types present (r^2 0.53) or number of taxa (r^2 0.61), also had a relatively strong influence. The summer fresh events (r^2 0.38) and annual median flow (r^2 0.40) also showed a reasonable correlation to macroinvertebrate community composition compared to other parameters.

The SIMPER analysis was conducted on samples in two groups, above and below 30,000 EC. The analysis showed a high degree of dissimilarity between the two groups (72.5). The macroinvertebrate taxa contributing most to the average within group similarity in the high EC group were Tanypodinae, Chironominae and Dytiscidae. The macroinvertebrate taxa contributing most to the average within group similarity in the lower EC group were Acarina, Coenagrionidae, Leptoceridae and Corixidae. A second SIMPER analysis was conducted on samples in two groups, above and below 8,000 EC. The analysis showed a lower degree of dissimilarity between the two groups (62.6). The taxa contributing most to the average within group similarity were the same as the analysis for 30,000 EC.

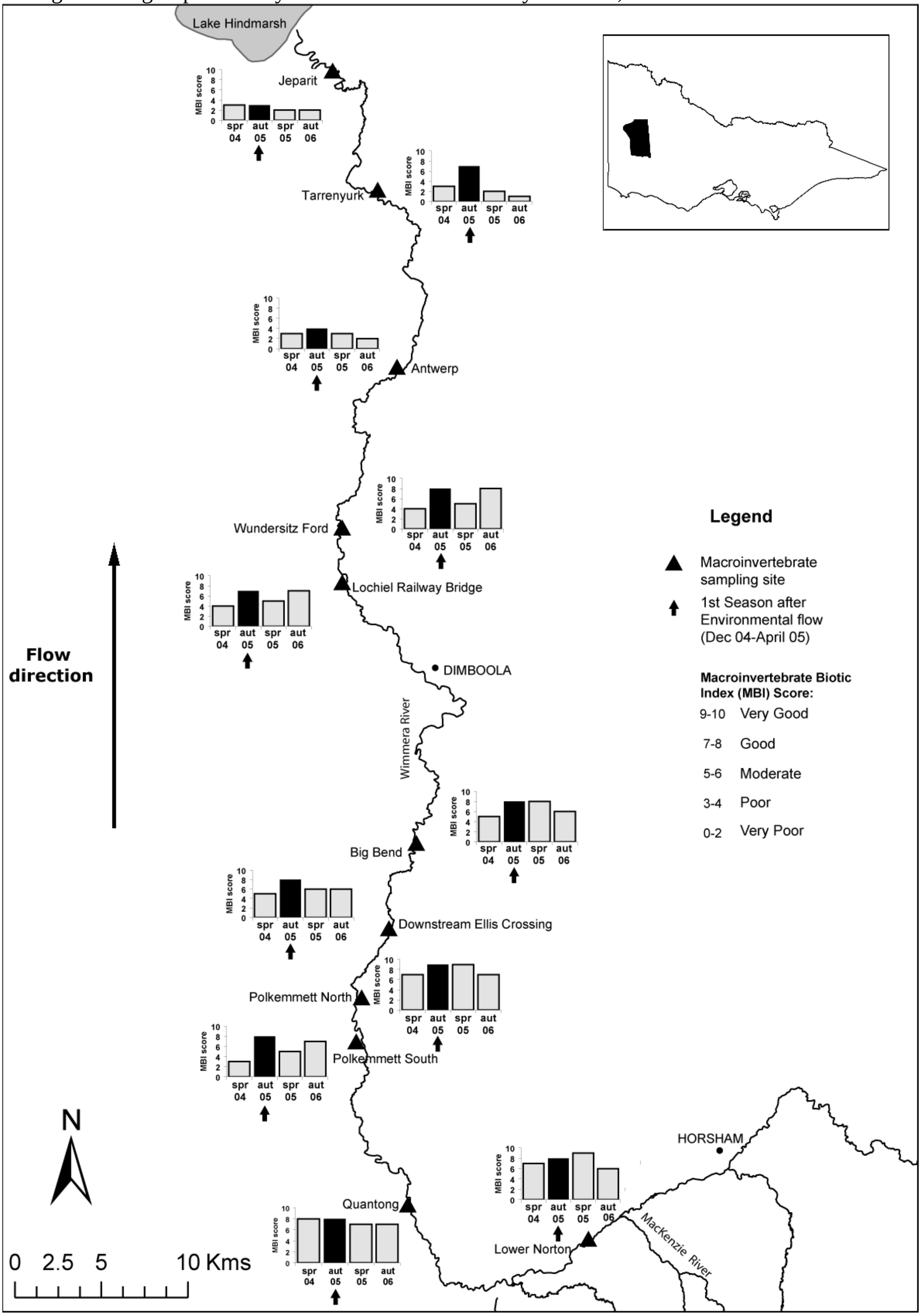

Figure 2. Macroinvertebrate Biotic Index results Spring 2004 to Autumn 2006 along the lower Wimmera River.

The key influence of salinity indicated in the multivariate analyses was clearly seen in scanning the raw data. There was a substantial increase in the number of taxa at most sites as EC decreased after the environmental flow. With more salinity sensitive species being introduced. For example, EC at Tarranyurk was reduced from 38580 to 29930 EC after the environmental flow. This resulted in almost a doubling in the number of families present and a shift to more salinity sensitive families such as Leptoceridae, Aeshnidae, Corduliidae, Synlestidae, Corixidae and Notonectidae (Kefford *et al.*, 2003). However once salinity levels were back up to 38,700 EC, the number of families declined with a disappearance of these more sensitive families. Similarly, at the lower end of the salinity gradient, downstream of Ellis Crossing had an increase in taxa and more sensitive taxa present (e.g. Tipulidae, Ancylidae), with a reduction of EC from 3397 to 1792. Similar increases in sensitive taxa were found at other sites with the reduction in EC after environmental flows.

The results of the analyses so far show that environmental flows (freshes) result in a clear improvement in the lower Wimmera macroinvertebrate community diversity, primarily through a reduction in salinity. They also show macroinvertebrate rapid bioassessment (RBA) to be useful for the assessment of environmental flows in the lower Wimmera River. The results also indicate a potential for macroinvertebrate RBA to be useful in the assessment of environmental flows in lowland systems where degraded water quality is a key issue. It is not possible from the results of this study to assess the usefulness of macroinvertebrate RBA in systems where there is no substantial change in water quality from environmental flows.

ERA: the next step

Flow/saline pool modelling
Sydney University School of Aeronautical, Mechanical and Mechatronic Engineering are developing a three dimensional computational fluid dynamic (CFD) model for selected stratified pools in the lower Wimmera. This will assess the fluid dynamics associated with the freshing, purging and mixing of these pools generated by the delivery of environmental flows. The outcomes of this model will provide information on likelihood of risks associated with the delivery of environmental flows, such as mixing of pools and salt slugs being sent downstream, and also the benefits of freshing and purging of pools. Results of this modelling will be available by mid 2007. The CFD model will be validated against scaled curved laboratory flumes with density stratified cavities and various geometries. Field validation of these models will be undertaken during the next environmental flow delivery to the lower Wimmera system.

Management tools and information – development of a Bayesian Network
Bayesian Networks are useful tools for understanding how natural systems work, and how particular management decisions can affect the system. They are particularly useful where there are several possible management actions, and many criteria on which to base decisions about which are the best management actions. They are also used to increase our understanding of the relationships between components making up an ecosystem. For these reasons, Bayesian Networks are increasingly being used by natural resource managers to assist them in making decisions, particularly in cases where the problems are complex and the available data is scarce.

The Bayesian network modelling for this ERA will be carried out using the Netica software (Norsys Software Corp. 1997-2003). The network will be developed based on biological/water quality data from the study above, information from the computational fluid dynamic model, data and information from previous studies in the Wimmera catchment, scientific literature and expert knowledge. All of this data, information and knowledge will be integrated to build the Bayesian network. A sensitivity analysis will be run to assess the relative influence each individual network variable has in determining ecological health, as measured by macroinvertebrate community diversity. This will provide information on key variables and knowledge gaps.

The predictive accuracy of the Bayesian network will be quantitatively assessed (i.e. validation of the network). This will be done by comparing the predicted outcomes of the network variables to a subset of the measured data collected after autumn 2006, and calculating the frequency with which the network predictions are correct. The remaining data collected after autumn 2006 will be used to update the network using a Netica data learning technique. The new data and information will be incorporated into the Bayesian network using algorithms in the Netica software. This enables the network to 'learn' more about the relationships represented for the Wimmera River, and the network updates itself accordingly. This will improve the robustness of the network, reduce the uncertainty, and provide a better understanding of the Lower Wimmera system overtime as more data becomes available.

An important application of Bayesian Networks is their use to test the predicted outcomes of various management scenarios. Variables in the network can be updated to reflect certain management actions, and the network run to ascertain the probabilities of improvement in other variables. In this way, various management actions can be tested for their relative effectiveness and predicted outcomes. This will be done for the macroinvertebrate network, to assess the relative effectiveness of different environmental flow scenarios in improving the health of the Lower Wimmera River.

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