Developing and road testing a novel and robust method for trading off ecological interventions for the recovery of native fish communities

NSW Department of Primary Industries

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FRDC Project No **2016-052**

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Abbreviations

MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
SDL	Sustainable Diversion Limit
SDLAM	Sustainable Diversion Limit Adjustment Mechanism
BN	Bayesian Networks
CMs	Complementary Measures

Executive Summary

The Murray-Darling Basin Plan water recovery objectives through the Sustainable Diversion Limit (SDL) show outstanding potential to be accelerated through complementary measures. A complementary measures program encompasses a range of non-flow related investments to achieve ecological improvements for native fish, resulting in an associated adjustment to the SDL. Present adjustment methods do not consider non-flow related complementary measures. However, these are works, interventions or actions that will complement water recovery effort to date and further drive ecological outcomes independent of water recovery aspirations. The challenge is therefore to assess the expected benefit of various measures seeking to facilitate recovery of native fish, and compare these against the equivalent amount of flow required to achieve the same outcomes.

Background

Native fish communities in the Murray-Darling Basin are highly degraded due to declines in habitat and water quality, barriers to migration, invasive pests and diseases (Baumgartner 2005; Barrett, 2004). Recent initiatives seeking to control Carp through biocontrol, and recover/deliver water through implementation of the Basin Plan represent significant potential towards the recovery of Basin waterways and fish communities.

However to maximise the outcomes from current and future investment, there is also a need to address a range of additional threats and limitations that are impacting upon the health and ecology of Basin waterways. This includes the rehabilitation of native fish habitat, addressing cold water pollution, re-establishing populations of locally extinct native species, preventing the loss of native fish, eggs and larvae to pumps and canal diversions, and the restoration of migratory pathways for native species. On-ground actions such as these that seek to address these threats and improve ecological outcomes have been broadly considered under the term ‘complementary measures’.

Integrated complementary measures offer potential to deliver enduring outcomes from environmental watering and pest fish control, and ensure that native fish thrive as Carp numbers decline. There is recognition that the parlous state of native fish communities in the Basin is a result of a range of threats and poor land and water management decisions over many decades. Additionally, increased frequency in extreme events, including those experienced over recent years such as floods causing hypoxic events and extensive droughts affecting water quality and quantity have the potential to have significant impacts on fish communities. As such, our attempts to address these threats needs to be suitably nuanced and diverse.

At its November 2016 meeting (MinCo Meeting 18; Item 6.3), the Murray-Darling Basin Ministerial Council agreed the potential to use complementary measures to improve ecological outcomes and associated objectives of the Basin Plan should be explored, provided they achieve triple-bottom-line outcomes. If non-flow measures could be included into the suite of projects that reduce the volume of water required to achieve ecological outcomes, then they may be able to form part of the SDL Adjustment Mechanism.

Aims/objectives

This project aims to develop a robust method for calculating water savings that could be applied to a range of complementary measures, allowing the individual and cumulative water savings derived through these measures to be modelled. The establishment of the Basin Plan through the Commonwealth *Water Act (2007)* proposed reductions to the Baseline Diversion Limit (or BDL) of water resources within the Murray-Darling Basin of up to 2,750GL. This would bring average long-term extractions within a Sustainable Diversion Limit (SDL) of approximately 10,873GL per year (MDBA, 2018).

The Australian Government has proposed to meet the 2,750GL water recovery target through a combination of purchasing water entitlement from willing sellers and funding efficiency and water recovery projects. The Basin Plan also includes the capacity to adjust the SDL if environmental outcomes within the Plan can be achieved through alternative means that utilise less water through both *supply* and *efficiency* measures. This has given rise to a suite of potential projects under the Sustainable Diversion Limit Adjustment Mechanism (SDLAM).

Calculating the equivalent water recovery savings of complementary measures could allow their implementation (and subsequent reconciliation of water recovery volumes) to be considered as part of any potential activities to adjust the SDL whilst still achieving environmental outcomes of the Basin Plan (e.g. supply or efficiency measures).

The first step in determining the potential for non-flow measures to be considered under Basin Plan implementation activities is to determine a process for establishing a robust and repeatable framework with which to consider the relative contributions of various complementary measures to water recovery targets. It was proposed to develop a methods paper that incorporates the key elements of a rapid synthesis of existing evidence to generate model structures for calculating ecological equivalence of complementary activities as part of Basin Plan implementation.

Proposed approach

We outline a three step procedure for synthesizing evidence to yield quantitative estimates of the amounts of water savings achievable with complementary measures. Importantly, these steps adhere to the strongest definitions of *evidence-based practice* in that they provide a means for *transparent* and *repeatable* process which combines evidence that avoid *bias* and *overconfidence* in the results. This three step process includes;

Step 1: Rapid synthesis of existing evidence to generate model structures

Step 2: Bayesian Expert Elicitation to determine water savings

Step 3: Population models to predict ecological outcomes

Keywords

Murray-Darling Basin; Complementary Measures; Sustainable Diversion Limit; Water Recovery; Native Fish

Introduction

The Murray-Darling Basin Plan (Basin Plan) includes a long-term Sustainable Diversion Limit (SDL) that seeks to optimise social, economic and environmental outcomes arising from the use of Basin water resources. The SDL was underpinned by the best science available in 2009 and represents a recovery of 2,750 GL from consumptive/productive use for environmental use. SDLs have been determined for all water resource units in the Murray-Darling Basin and take effect on 1 July 2019.

The ability to adjust the SDL will largely be achieved through supply and efficiency measures. Supply measures are intended to deliver enhanced socio-economic outcomes whilst maintaining environmental outcomes equivalent to those anticipated under the Basin Plan. Efficiency measures on the other hand are intended to enhance environmental outcomes with no adverse socio-economic impacts. Measures to achieve these outcomes assume a strong relationship between flow and fish, waterbirds and vegetation; the target indicators. Present adjustment methods do not consider non-flow related complementary measures. However, these are works, interventions or actions that will complement water recovery effort to date and further drive ecological outcomes independent of water recovery aspirations. Such complementary measures may include, but are not necessarily restricted to programs such as: releasing a virus to kill Carp, enhancing fish passage to allow greater movement opportunities, re-snagging a waterway to improve habitat, planting riparian vegetation to improve water quality and habitat, addressing cold water pollution, or reducing impacts of terrestrial species on floodplain environments. These are all actions which could provide ecological outcomes but not require additional water recovery.

The Murray-Darling Basin Ministerial Council (MinCo) agreed in 2018 that the potential to use complementary measures to improve ecological outcomes should be explored, provided they achieve triple-bottom-line outcomes. If non-flow measures could be included into the suite of projects that reduce the volume of water required to achieve ecological outcomes, then they may be able to form part of the SDLAM.

The feedback was provided to help determine whether the implementation of complementary measures provides a basis for the Murray-Darling Basin Authority to propose an adjustment to SDLs under Section 23 of the Water Act 2007. Significant investment in complementary measures is being considered as a means of meeting Basin Plan outcomes without unduly impacting rural and regional communities.

This report identifies a robust method for calculating water savings that could be applied to a range of measures, with the individual and cumulative water savings derived through these measures to be modelled.

Objectives

This project had the objective to develop a robust method for calculating water savings that could be applied to a range of measures, with the individual and cumulative improvements derived through these measures being modelled to create a comparable water recovery figure. A complementary measures program encompasses a range of non-flow related investments to achieve ecological improvements, resulting in an associated adjustment to the SDL. A summary of these measures that could be implemented across the Basin can be found at Attachment A; however, it should be noted the proposed method is not specific to one or more measure.

It was proposed to develop a methods paper that incorporates the key elements of a rapid synthesis of existing evidence to generate model structures, utilising expert elicitation in the development of Bayesian networks and ultimately the application of above-mentioned population models for individual species to demonstrate the feasibility of a robust and repeatable model for calculating ecological equivalence of complementary activities as part of Basin Plan implementation.

Proposed approach

Below, we outline a three step procedure for synthesizing evidence to yield quantitative estimates of the amounts of water savings achievable with complementary measures. Importantly, these steps adhere to the strongest definitions of *evidence-based practice* (Sackett et al. 1996) in that they provide a means for *transparently* and *repeatedly* combining evidence using methods that avoid *bias* and *overconfidence* in the results. This is a substantial conceptual advance over informal methods that are currently used, and which are less defensible and more open to challenge.

Step 1: Rapid synthesis of existing evidence to generate model structures

Literature reviews are commonly commissioned by government agencies, but for the most part do very little to increase our understanding of the state of knowledge regarding a management issue. Reviews are normally 'narrative reviews', which summarise a body of research and identify any broad patterns, but almost never test specific hypotheses regarding the effectiveness of different management options (Roberts et al. 2006). 'Systematic literature reviews' are an approach developed in medical research to treat the literature as data and test hypotheses regarding the efficacy of medical treatments (Khan et al. 2003a). They have driven an 'effectiveness revolution' in patient outcomes in the last 40 years (Stevens and Milne 1997). Unfortunately, these reviews are resource intensive, and can take years and cost hundreds of thousands of dollars (Dicks et al. 2014).

Members of our team have been at the forefront of efforts to develop 'rapid evidence synthesis' methods for environmental management applications. These methods achieve the same substantive outcome as systematic reviews (objective, transparent, repeatable, defensible, and above-all, *evidence-based* conclusions regarding the effectiveness of management interventions), but at a fraction of the time and cost (Webb et al. in press). The Eco Evidence method and software (Norris et al. 2012, Webb et al. 2015b) was developed specifically to undertaken reviews of this nature, and can be used to test for general causal relationships across collections of case studies (Figure 1). It is well established as a method in the international literature, and has been used to assess the effectiveness of flow regimes (e.g. Greet et al. 2011, Miller et al. 2013, Webb et al. 2013b), complementary measures (e.g. Wilkes et al. in review), and invasive species (Vilizzi et al. 2015) on ecological outcomes in rivers.

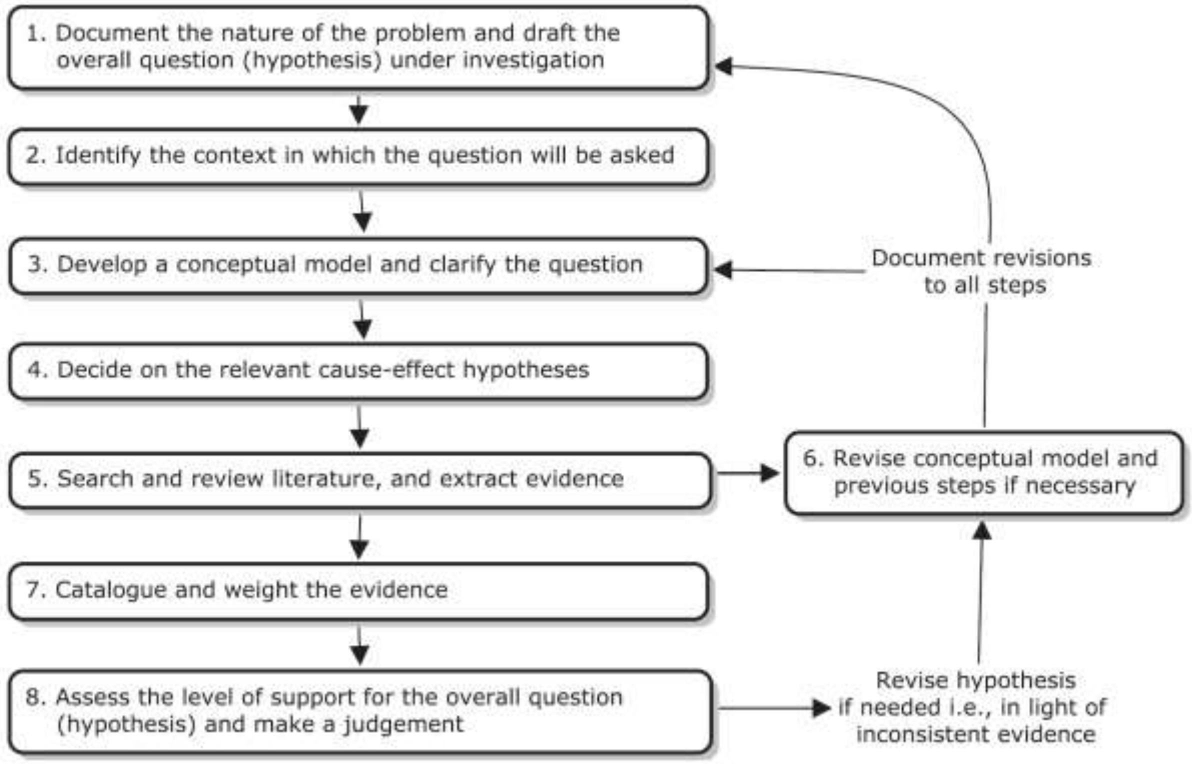

Figure 1. Steps in the Eco Evidence rapid evidence synthesis framework. Reproduced from (Norris et al. 2012).

In a rapid evidence assessment, the literature is used to test a set of hypotheses that collectively represent a conceptual model of how an ecological response (e.g. golden perch) can be expected to respond to flow-restoration and complementary measures, either singly or together. The process can be used to eliminate hypotheses that are not supported by the literature, identify the most pressing knowledge gaps within conceptual models (hypotheses that require further research) and which hypotheses are supported and amenable to quantification either through direct incorporation of data or through expert elicitation (see Step 2 below). The output is a defensible evidence-based conceptual model of the ecological response to flow restoration and complementary measures, which can then form the basis of an expert-quantified Bayesian network (Step 2), and from there to a dynamic population model (Step 3).

Step 2: Bayesian Expert Elicitation to determine water savings

While the evidence-based conceptual model produced by a rapid evidence synthesis is a powerful tool, it does not allow direct quantitative estimation of the effects of flow restoration or complementary measures. Bayesian networks (BNs; Pearl, 2000) represent an ideal tool for combining information sources of different types, and are capable of incorporating professional judgement as an interim measure in the absence of empirical data (see Aguilera et al., 2011, and references therein). BNs are well established in the international literature, and have been extensively used in natural resource management applications. BNs can be combined with sensitivity analysis to identify key uncertainties and provide direct advice on appropriateness of complementary measures to achieve desired outcomes. They can also be used to estimate the quantity of water required to deliver equivalent outcomes in the absence of the complementary measure.

BNs represent a powerful and flexible framework for knowledge management (Stewart-Koster et al., 2010). Development of the network involves the specification of nodes representing causal and response variables (Pfister & Zalewski, 2008). Each variable has discrete states defining all possible conditions or outcomes. Nodes are connected by arcs representing probabilistic dependency relations among the variables. These relations are described by conditional probability tables that can be populated using empirical data, transferable knowledge and expert judgement. In a highly influential publication, Poff et al. (2003) called for the use of BNs in decision making for ecologically acceptable flow regulation, one of the utmost priorities for conservation of freshwater biodiversity. This call has been heeded in Australia, where the approach has been used to predict the ecological consequences of damming and abstraction (e.g. Chan et al., 2012; Stewart-Koster et al., 2010)(

Figure **2**), and to estimate environmental flow requirements for native fish species (Shenton et al. 2011, Shenton et al. 2014).

For assessment of the effects of environmental flows and complementary measures, the different relevant aspects of the flow regime (flow components) and the different complementary measures being assessed, would be included as ‘parent’ driving nodes in the model. The effects of these variables then propagate through the network structure to assess the individual and interactive effects of different drivers on ecological outcome.

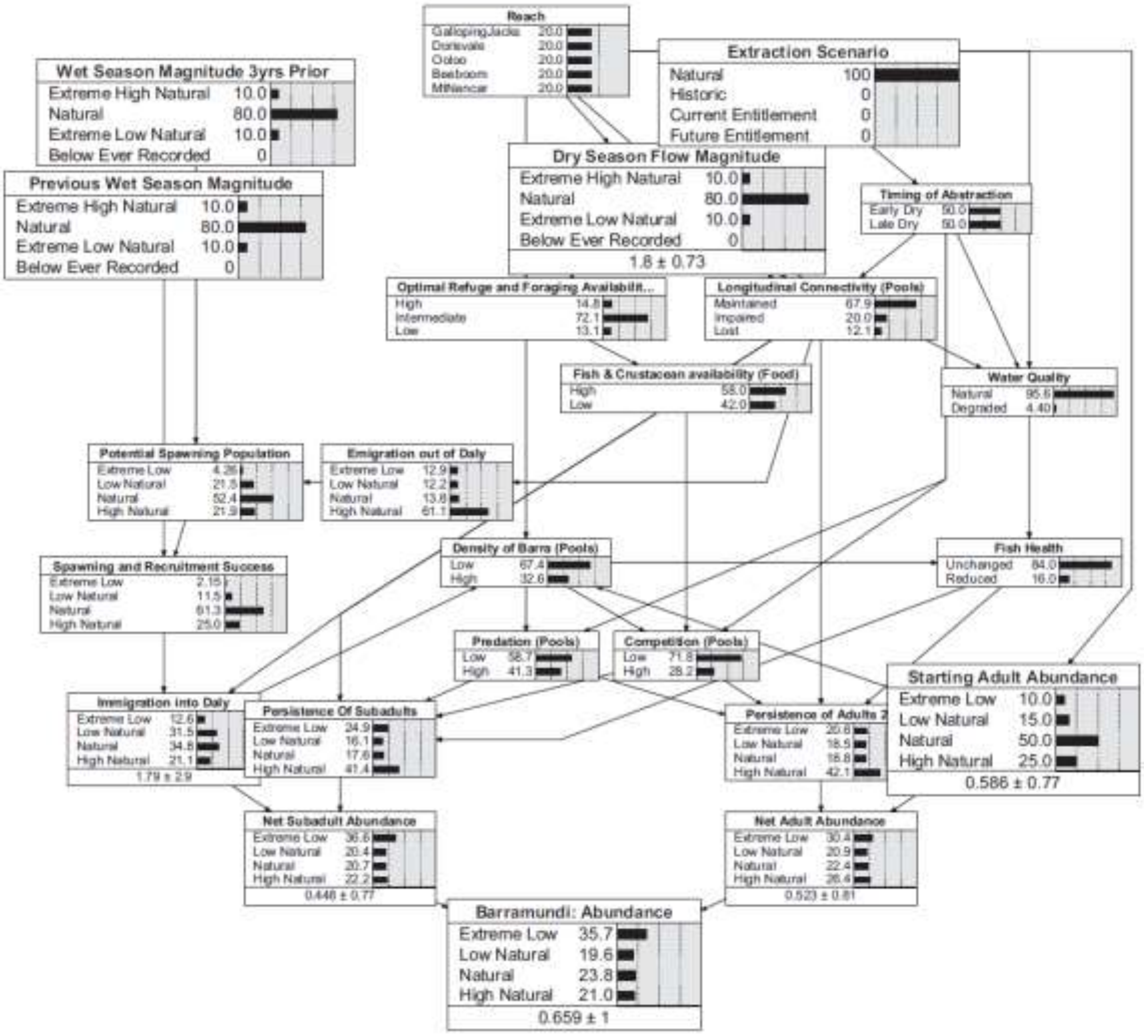

Figure 2. An example of a Bayesian network applied to the prediction of Barramundi (*Lates calcarifer*) abundance in five reaches of the Daly River, Northern Territory, Australia. From Chan et al. (2012).

Here we propose extending this approach to determine:

a) The expected outcomes of complementary measure delivery; and

b) Determining the equivalent volume of water required to achieve similar outcomes

While BNs provide a strong method for combining information, current informal approaches to populating models with expert opinion are prone to bias and overconfidence (Speirs-Bridge et al. 2010, Fidler et al. 2012, Morgan 2014), and are not transparent or repeatable. This potentially leads to models that provide incorrect forecasts, but with high confidence – potentially the worst possible outcome. Fortunately, members of our team have developed approaches to quantify causal relationships for environmental interventions in Bayesian networks using *formal expert elicitation*. (Figure 3, de Little et al. 2012, Webb et al. 2013a, de Little et al. in prep). We have used these to good effect to predict responses to flow restoration in the Murray-Darling Basin (see Webb et al. 2015a for an outline of the approach).

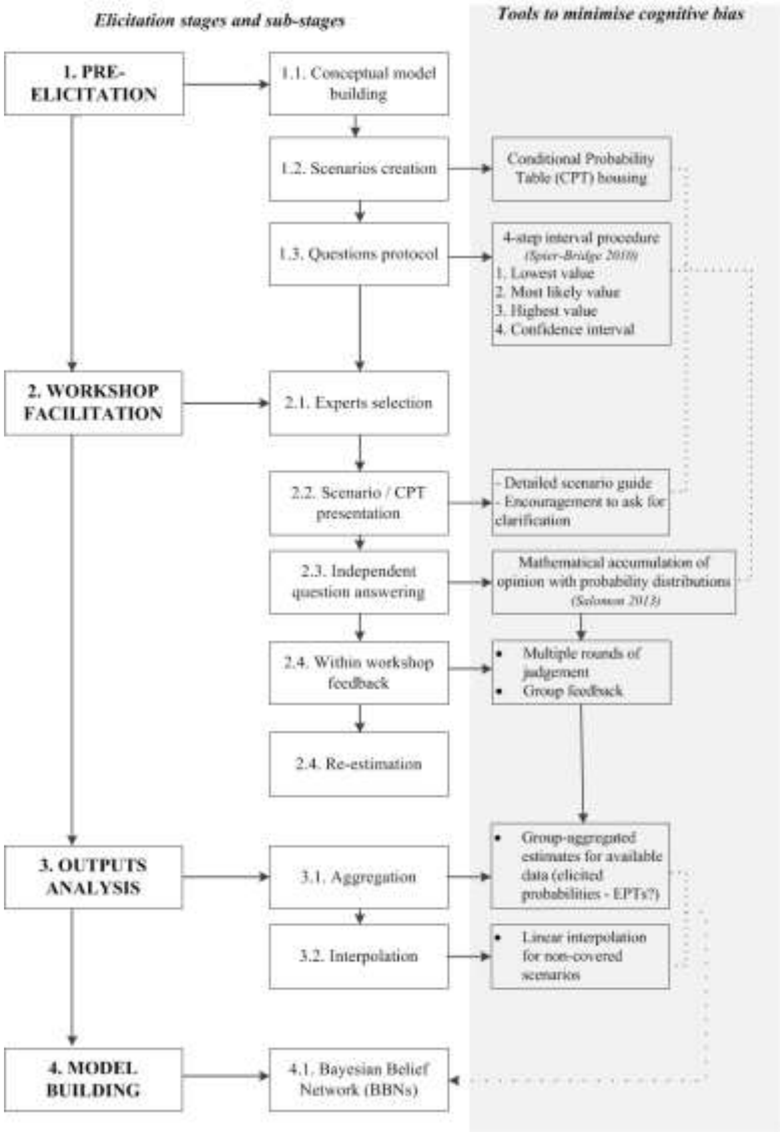

Figure 3. Workflow for the expert elicitation-based approach to developing Bayesian Networks (reproduced from de Little et al, in-prep). The formal process maximizes transparency, robustness and repeatability.

Through an explicit, structured and fully documented technique developed by cognitive psychologists, the approach avoids the cognitive biases, overconfidence effects, information cascades and lack of transparency that plagues other expert elicitation methods (Fidler et al., 2012). The approach is designed explicitly to inform the construction of a BN. We propose to extend these tested and successful techniques to the complementary measures described in this proposal. We will apply BNs to predict responses, benefits and water equivalencies for actions proposed under complementary measures where direct water savings cannot be calculated. This will be undertaken in five stages, each with a distinct approach:

1. Review: Ideally, the structure of the BN would be an evidence-based conceptual model developed during application of Step 1. It is possible to use a less-stringently derived conceptual model, but this comes with attendant risks. At this stage, the scale of complementary measure application will be defined in the context of available budgets and anticipated outcomes.

2. Bayesian network construction: Prior and conditional probabilities will be populated using available data of sufficient quality, where such data exist.

3. Expert elicitation: Where data do not exist to parameterise the BN, the expert elicitation protocol will be used to harness professional judgement of key fisheries ecologists and river management specialists. Experts will be interviewed independently of each other on the expected scale of ecological responses and the amount of water that would be required to achieve such a response in the absence of environmental water. The

spread of responses received will then be analysed to inform a level of confidence (de Little et al. 2012, de Little et al. in prep). Elicitation takes place within a structured workshop environment that consists of individual phases to;

a. Consider and revise/accept the conceptual model that will be populated using expert opinions
b. Provide familiarization and orientation with the question formats used through familiar examples
c. Independent elicitation of opinions of the individual experts
d. Visualization of the round 1 estimates and discussion of choices made
e. The opportunity to revise estimates in light of discussion
f. Consolidation of expert estimates into group-level predictions with associated uncertainty

2. Prediction: The parameterized BN will be used to predict the effectiveness of complementary measures for selected native species in comparison to the effects of flow restoration. Predictions will be based on (a) What might be expected if the complementary measure was applied and (b) What volume of water would be required to achieve a similar outcome if the complementary measure was not applied. The difference between (a) and (b) would represent the quantum of water saved by applying the complementary measure.
3. Sensitivity analysis: We will systematically vary the input parameters of the BN and examine the sensitivity of predictions in order to identify key uncertainties and knowledge gaps arising from the expert elicitation process.

The result of this process is a quantified BN model that is able to make predictions of ecological outcomes under different scenarios of environmental drivers. This will enable the initial quantification of the equivalent ecological response between provision of a given level of environmental water and alternative complementary measures. It is important to note that the conditional probability network structure of BNs means that uncertainties and knowledge gaps in the driving processes are not ‘hidden’ within the model or ignored in output. If the relationship between a driving variable and the ecological outcome is uncertain, then this will be reflected in reduced confidence in the outcome under different levels of that driver. Indeed, this is why BNs are an ideal vehicle for expressing combined expert opinion derived through a structured process to reduce unfounded overconfidence.

Step 3: Population models to predict ecological outcomes

The expected outcomes and ecological predictions from Steps 1 and 2 will be used to model population-based responses at a range of scales across the MDB. While the populated Bayesian Network models can provide predictions, they are not well suited to considering dynamic feedbacks over time, and generally do not consider scale explicitly. Population models can use the BN model output to address these issues. The main purpose of this step is to ensure that the amount of water expected to be saved, by not requiring additional watering, is justified by a detailed predicted ecological response in fish communities. The population model is vital from a benefit/cost perspective, to justify the investment in complementary measures.

The MDBA has invested heavily in the development of population models for a range of organisms to be predicted under a range of different management scenarios (Koehn et al. in review). Specific to fish, for example, this could include parameters such as manipulating fisheries enhancement efforts; habitat changes; thermal pollution; fishing harvest; carp control efforts, larval mortality due to weirs; larval losses via pumps and diversion, and benefits from environmental water. These models have already been used to inform management decisions. For example, the decision to implement slot limits for Murray cod in Victoria and NSW was informed by scenario testing using the population model for this species.

We will build on these models by introducing expected outcomes of the implementation of complementary measures as additional model inputs variables (Figure 4), drawing directly from the quantified BNs. Importantly, the analysis will include a range of different population dynamics parameters. Some of this development can be built on previous work undertaken to investigate recruitment dynamics of other species. Existing models have been based on existing datasets and have resulted in robust annual estimates of population size and biomass using a Bayesian hierarchical capture-recapture model (see Lyon et al. 2014a).

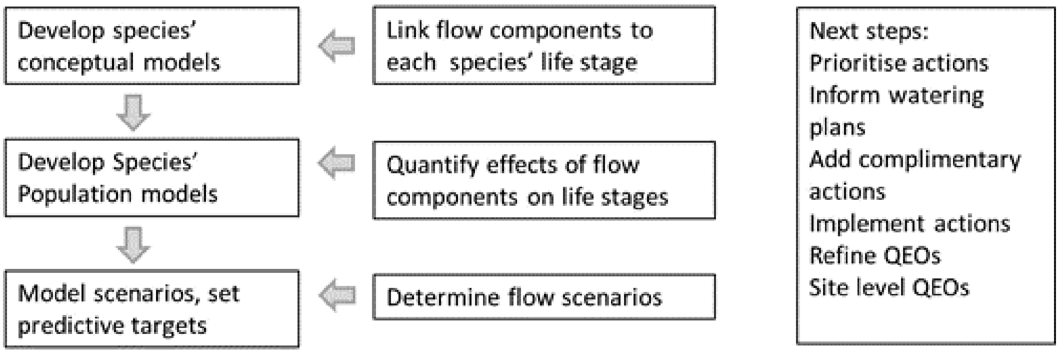

Figure 4. Workflow for population modelling. Conceptual models are preferably produced through Steps 1 and 2, with the detailed population model able to test detailed scenarios for multiple measures.

These models will enable comparison of predicted outcomes from different intervention scenarios to those that could be expected through delivery of environmental flows alone. The team will explore a range of linear and non-linear models as well as Bayesian hierarchical models relating abundance and condition to biotic and abiotic drivers, both with and without complementary measures being applied. These measures will be further compared with temporal patterns of population structure, abundance and biomass generated using Bayesian hierarchical capture-recapture models and other methods. We envisage the investigation of potential drivers of temporal variability in abundance; key biotic (e.g. adult and total population measures) and abiotic (measures of temperature and attributes of flow) to be achieved using linear and non-linear regression models. All work so far has been based on the most comprehensive dataset available and provides the unique opportunity to refine questions relating to population change in response to using complementary measures as management interventions. This dataset is already compiled and cleaned and is ready to be applied. All that is needed is the use of the rapid evidence synthesis to help establish the model structure, and the expert elicitation process to generate any model inputs not able to be satisfied through empirical data.

Calculating water savings associated with complementary activities

Greater ecological benefits will accrue when investment is simultaneously maximised in the delivery of both environmental water and non-flow related complementary measures such as habitat rehabilitation. Alternatively, in a resource-limited environment, the quantity of water required to be delivered to achieve a given ecological outcome can be reduced through delivery of complementary measures that also contribute to that outcome.

Figure 5 describes how this can be achieved using the evaluation framework described above. The example utilises a combination of expert elicitation and population modelling to systematically, and transparently quantify expected ecological responses that will result from delivery of non-flow related measures. Using this same process, likely ecological outcomes that could be delivered through environmental watering may also be derived, thereby enabling comparison and iteration until ecological equivalency is achieved but using less water. It will also be possible to assess combined benefits of combinations of different levels of environmental watering and multiple complementary measures (see below).

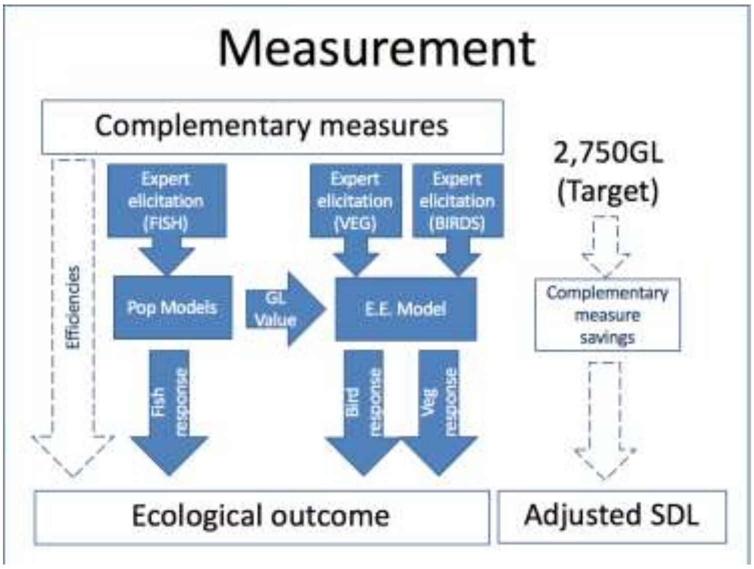

Figure 5. Schematic diagram describing a hypothetical example of the proposed method to be used to quantify environmental water savings achievable through the use of complementary measures along with environmental watering.

Complementarity of steps 1 -3 and adaptive improvement

Each of the three steps outlined above can be completed individually. However, as alluded to in the above sections, we believe that conclusions from the steps will be strongest when the steps are carried out in sequence. The output from the earlier step provides a stronger basis for the next step (Figure 6). Thus, while expert elicitation to create a BN can be done using a simply derived conceptual model, the result will be stronger if the conceptual model is the output of a rapid evidence synthesis. Similarly, while the structure and initial quantification of a dynamic population model can be done as part of the modelling process, the conceptual and numerical basis of the model will be stronger if based upon a quantified BN model.

The timelines for implementation of complementary measures, and the general lack of large-scale monitoring data that can test model predictions will preclude formal validation of the model predictions in the early stages of the program. However, individual stages or the entire three-step sequence can be repeated as part of an adaptive management framework as new data become available from monitoring the ecological benefits of complementary measures and environmental flows. In particular, the conditional probability networks that underpin the BN models can incorporate new data via the application of Bayes' theorem within the operating software. This does not discard the previous conditional probabilities, but updates them based upon the new knowledge.

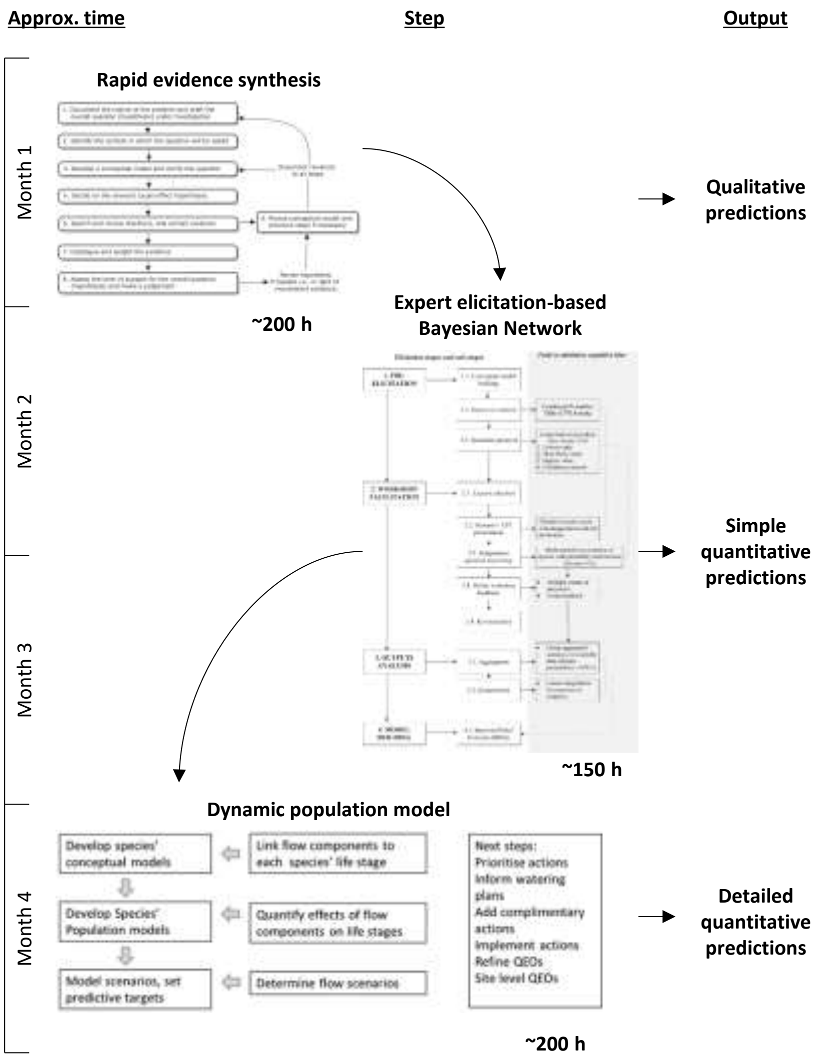

Figure 6. Complementarities of the three steps, from rapid evidence synthesis, through expert elicitation-based BN creation, and onto dynamic population modelling. Each panel includes an approximate time requirement in person hours for each step is shown, along with an indicative timeline for the entire process assuming that two workers are spending the majority of their time on each step.

Resource requirements

The three steps each require relatively small amounts of hours to complete. The estimates in Figure 6 are preliminary, but will be close to final figures. With two people working together on these tasks, and expending the majority of their time on them, we believe it feasible to produce an evidence based estimate of water savings for one complementary measure within a four-month period. An alternative pathway would be to conduct parallel evidence assessments and expert elicitation exercises for multiple complementary measures (Figure 7). Information exchange among the parallel processes would allow the elucidation of the interactions of complementary measures. All outputs would all feed into a more complex population model, with the consequent ability to test performance and trade-offs among multiple complementary measures against flows simultaneously.

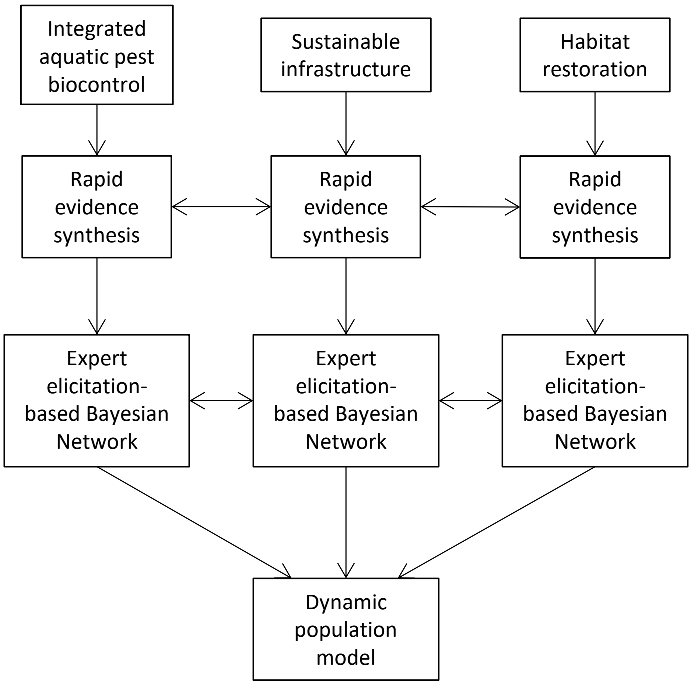

Figure 7. Alternative workflow for the assessment process. Here, three evidence assessments and BN generation processes take place simultaneously to assess effects of three of the complementary measures described in Attachment B. Exchange among the information streams would take place at during the parallel processes, with all outputs feeding into an integrated dynamic population model.

This alternative workflow would have longer than a four-month timeline, which would depend largely upon the number of people working on the parallel assessment tasks. However, it would be overall quicker than conducting the sequence described in Figure 6 multiple times in sequence and would have the added advantage of being able to better assess interactive effects of multiple complementary actions in achieving water savings.

Discussion and conclusion

A complementary measures program could encompass a range of non-flow related investments to achieve ecological improvements, resulting in a contribution to Basin Plan objectives and an associated adjustment to the SDL. The three-step sequence outlined above provides a robust, transparent, and repeatable method for employing evidence from the literature, experience from the minds of experts, and expertise in dynamic population modelling. The sum of these activities allows for an assessment of the benefits and water savings achievable from a program of complementary measures. With the public scrutiny being applied to Basin Plan environmental watering and the SDL in particular, our method represents an opportunity to adopt best-practice principles from an evidence-based process to assess the contribution that complementary measures could make to the SDL adjustment process.

Implications

Native fish communities in the Murray-Darling Basin are highly degraded due to declines in habitat and water quality, barriers to migration, invasive pests and diseases. A complementary measures program could encompass a range of non-flow related investments to achieve ecological improvements for native fish, and result in an associated adjustment to the SDL. Importantly it provides an option for investment under the Basin Plan that delivers on the objectives of improved ecological condition without removing additional water from productive use.

The proposed three step procedure for synthesising evidence to yield quantitative estimates of the amounts of water savings achievable with complementary measures warrants consideration by state and Commonwealth agencies responsible for the implementation of the Basin Plan. Importantly, these steps adhere to the strongest definitions of evidence-based practice (Sackett et al. 1996) in that they provide a means for transparently and repeatedly combining evidence using methods that avoid bias and overconfidence in the results. This is a substantial conceptual advance over informal methods that are currently used, and which are less defensible and more open to challenge.

Recommendations

Non-flow based complementary measures are actions which could provide ecological outcomes but not require additional water recovery in the Murray-Darling Basin. We recommend the adoption of the above proposed three step procedure for synthesizing evidence to yield quantitative estimates of the amounts of water savings achievable with complementary measures. This would allow a more thorough consideration of the merits of a complementary measures program and the potential pathways for investment as part of Basin Plan implementation.

A complementary measures program could encompass a range of non-flow related investments to achieve ecological improvements, resulting in an associated adjustment to the SDL and enhancing the triple bottom line benefits of the Basin Plan implementation. We further endorse those complementary measures outlined within Attachment A of the attached accompanying report as a mechanism to achieve ecological improvements for native fish.

Further development

Benefits attributable to complementary measures would need to be assessed against any reduction in environmental scoring associated with reduced over bank flows. The summation of this work, considering both benefits and disbenefits would allow a more thorough assessment of environmental equivalence associated with complementary measures. The unique nature of ecological processes within the Basin and the prior establishment of metrics against which hydrological impacts on the environment are considered would necessitate the development of a fit-for-purpose model for making this assessment. The level of scientific uncertainty regarding the scale and longevity of benefits provided by potential complementary measures would need to be considered when assessing any potential SDL benefit. The SDLAM provides the opportunity to enhance the triple bottom line benefits of the Basin Plan under a different framework.

Planning under the SDLAM has thus far been done using the Ecological Elements method. However, that method in its current form is not sufficiently flexible for considering complementary measures. To ensure a scientifically robust and transparent process, other methods need to be considered. Under the SDL adjustment mechanism, any approach proposed would need to be an agreed alternative method under 7.15(2) of the Basin Plan, with MDBA’s strong preference is that any assessment method is agreed by all jurisdictions

The debate regarding the full implementation of Basin Plan targets and the capacity to meet both water recovery and efficiency targets presents a significant opportunity for the development of a more flexible methodology for assessing the ecological impact of complementary measures. Methodology focused on assessing contributions towards Basin Plan outcomes would help inform decision-making and allow thorough consideration by each of the jurisdictions. The impacts of extreme events such as hypoxic flooding events and extended drought, and the associated fish deaths across the Basin heightens the interest in specific measures to support native fish recovery. Many of the actions currently proposed as complementary measures have been highlighted in programs such as the Native Fish Strategy (NFS) as being a critical part of future management decisions. The development of an assessment methodology that considers benefits of complementary measures either as part of broader Basin Plan implementation processes or as a stand-alone investment package for the implementation of program similar to the NFS has significant merit.

Additionally, an opportunity exists through the current development of the Northern Basin Toolkit to analyse the contribution of complementary measures towards Basin Plan outcomes without the need to identify the specific environmental equivalence of water recovery. Analysis and evaluation of the potential impacts of the Toolkit package (when finalised) would serve as a ‘real-world’ example of the benefits that could be derived for native fish species through targeted works and measures. Such an analysis would help inform parallel considerations in the southern Basin and provide a more substantial evidence base for future decisions.

Extension and Adoption

The methodology described above was presented to the MDBA Complementary Measures Working Group in December 2016 and has been considered in subsequent discussions at MDBA MinCo and Basin Senior Officials Committee meetings. Additionally, there are contemporary processes underway that the method developed through this project could also be adopted and applied to in addition to the SDLAM program, including the Commonwealth Environmental Water Holder’s (CEWH) process to explore a new investment framework for funds generated by water trading.

Project materials developed

See associated MDBA Ministerial Council report prepared by Charles Sturt University and University of Melbourne.

Appendices

Attachment A:

Overview of potential complementary measures

Detailed overviews of the complementary measures are discussed below in the context of how each method could fit within the SDLAM framework and help to achieve Basin Watering Strategy outcomes.

Integrated aquatic pest biocontrol

The problem

Common Carp are a pest fish species now widely established throughout the Murray-Darling Basin and now present in all states and territories except the Northern Territory. Carp are considered ‘ecosystem engineers’ that alter fundamental characteristics of the ecosystems they invade. This occurs primarily through the way they feed; the bottom-feeding habit of carp increases turbidity and uproots aquatic vegetation (Fletcher et al. 1985, Roberts et al. 1995, King et al. 1997, Robertson et al. 1997, Schiller and Harris 2001, Zambrano et al. 2001). This, in turn, reduces sunlight to aquatic plants, inhibits feeding by visual aquatic predators (Newcombe and MacDonald 1991, Lougheed et al. 1998, Schiller and Harris 2001, Zambrano et al. 2001) and results in smothering on demersal native fish eggs (Schiller and Harris 2001). Destruction of aquatic plants also reduces habitat values and so impacts on juvenile fish (Hume et al. 1983), amphibians (Gillespie and Hero 1999) and waterfowl (King and Hunt 1967, Hume et al. 1983, Haas et al. 2007). Eggs from bottom nesting fish such as the eel-tailed catfish are also impacted through direct predation (Schiller and Harris 2001), as are zooplankton, which can result in increased algal blooms through reduced zooplankton grazing (Gehrke and Harris 1994, Lougheed et al. 1998, Khan 2003, Khan et al. 2003b, Parkos III et al. 2003). These ecological impacts have social and economic implications, through reduced quality of recreational fishing experiences and nature-based tourism.

The solution

A strategic release of Australia’s first Carp biocontrol agent – Koi Herpes Virus – into the Murray-Darling Basin has the potential to address one of the Basin’s most pressing and long-term problems. It is a once in a lifetime opportunity to transform the health of waterways and the fisheries they support. Preparation for potential release of the virus is underway. Further planning under the Australian Government’s National Carp Control Plan including community education and engagement, risk assessments, targeted performance monitoring, and on-ground clean-up activities after the release of the virus to protect native aquatic fauna and water quality. A detailed business case has already been prepared. Releasing the Carp virus will augment water recovery efforts by:

- ensuring Carp do not breed on managed flow events
- providing benefits for native fish that flow alone cannot provide

Alignment with Basin Watering Strategy outcomes

This activity will directly contribute to several planned outcomes of the Basin Watering Strategy (MDBA 2001), including:

- Maintaining the current extent of non-woody communities near or in wetlands, streams and on low-lying floodplains
- Maintaining current species diversity of all current Basin waterbirds and migratory shorebirds at the Coorong
- Achieving a 20-25% increase in waterbirds by 2024
- Delivering up to 50% more breeding events for colonial nesting waterbird species, and a 30-40% increase in nests and broods for other waterbirds
- No loss of native species currently present in the Basin
- Improved distribution of key short and long-lived fish species across the Basin
- Improved breeding success of short-lived fish species (every 1-2 years) and long-lived species (at least 8/10 years at 80% of key sites)
- Improved populations of short-lived species (numbers at pre-2007 levels), and long lived species (with a spread of age classes representatives

Sustainable infrastructure

The problem

Existing pump and diversion systems throughout the Murray-Darling Basin are having unintended environmental impacts. Millions of native fish are removed from the Murray-Darling Basin every year when they are sucked into pumps and diverted into channels. This provides somewhat of a paradox for environmental water management as the very supply and efficiency measures used to deliver SDL adjustments may well be undermining environmental benefits. Whilst substantial efforts are invested into providing flows for fish to breed, many of the new recruits to fish populations can either be (1) extracted in large numbers into irrigation diversions or (2) die when they interact with the very infrastructure that is being used to deliver environmental flows.

The solution

Both issues can be completely mitigated, but require a suite of engineering works. At pumps and diversions, diversion screens can be installed to prevent entrainment of fish and other aquatic life, such as turtles. Diversion screens solve this problem and there’s strong is evidence of their effectiveness in both the U.S. and Australia. The fact that screens are underutilised in Australia creates a large opportunity. Undershot weirs can be replaced with overfall tilting weirs to prevent fish deaths. If these works are undertaken in a coordinated manner, fish losses at infrastructure can be completely mitigated. Environmental watering can then be undertaken with confidence that efforts to encourage fish to breed and recruit won’t be nullified by fish being transferred into irrigation systems. If endorsed to business case stage, a detailed list of priority sites, locations, outcomes and budgets will be prepared. Tangible benefits will be expected by 2024. All solutions will have an 80+ year working life.

Alignment with Basin Watering Strategy outcomes

This activity directly addresses several planned outcomes of the Basin Watering Strategy (MDBA 2001), including:

- No loss of native species currently present in the Basin
- Improved distribution of key short and long-lived fish species across the Basin
- Improved breeding success of short-lived fish species (every 1-2 years) and long-lived species (at least 8/10 years at 80% of key sites)

- Improved populations of short-lived species (numbers at pre-2007 levels), and long lived species (with a spread of age classes representatives
- Improved populations of Murray cod and Golden perch (10-15% more mature fish at key sites)
- More native fish using fish passages

Habitat Restoration

The problem

Fish need access to essential habitat to breed, feed and seek refuge. The ability for fish to persist in the long term is largely dependent on having access to critical habitat when needed. Due to substantial constraints, it is completely unfeasible to provide water too many areas of habitat that were historically inundated frequently (e.g. large floodplains now developed for agriculture). In addition, many habitat components were removed (such as snags) during the peak of river trade. So this presents water managers with two problems. Firstly, environmental water cannot inundate remaining habitat due to delivery constraints. Secondly, in many instances the suitable habitat is just not there, so no amount of environmental water will create benefits for fish until the habitat is returned.

The solution

In order to overcome this limitation, it is planned to reinstate and enhance habitat in areas that can be easily reached by a managed event, through the provision of engineering works. Local communities want to be involved in taking care of our waterways, and this is especially so when it comes to helping improve fish populations. Engagement with the community to deliver enhanced habitat will support efficient delivery of river health outcomes, build a greater understanding of issues facing native fish populations, create ownership of local and regional projects, and provide the government with a significant return on investment. Involving the community will also ensure that local stakeholders are engaged and prepared for long-term watering activities. This activity will require applying solutions for re-instating and improving in-channel habitat through processes including restoring local hydraulic variability, re-snagging, planting riparian vegetation and restoring aquatic habitats. Detailed costings for demonstration reach locations will be prepared and costed if endorsed to proceed to business case stage.

Alignment with Basin Watering Strategy outcomes

This activity directly addresses several planned outcomes of the Basin Watering Strategy (MDBA 2001), including:

- No loss of native species currently present in the Basin
- Improved distribution of key short and long-lived fish species across the Basin
- Improved breeding success of short-lived fish species (every 1-2 years) and long-lived species (at least 8/10 years at 80% of key sites)
- Improved populations of short-lived species (numbers at pre-2007 levels), and long lived species (with a spread of age classes representatives
- Improved populations of Murray cod and Golden perch (10-15% more mature fish at key sites)
- More native fish using fish passages

Addressing cold water pollution

The problem

Water delivered downstream from large dams, whether for environmental, irrigation, or consumptive purposes is often significantly colder in summer and warmer in winter when compared to natural flows. This occurs because water is released from deep within the dam. In summer, water temperatures can be up to 13 degrees lower than natural river flows at some structures. The impact is greatest immediately downstream of the dam, but can also persist for tens or even hundreds of kilometres. This provides another paradox: when environmental water is delivered from upstream dams, it may be too cold for fish to complete essential life history stages. So in essence, the quality of environmental water can be unsuitable for fish in cold-water pollution zones.

Cold-water pollution impacts the biology and life-cycles of fish in four ways:

- It changes the habitable range and distribution of species
- It reduces the opportunity for effective reproduction
- It reduces body growth rates and condition, and
- It reduces recruitment

Cold-water pollution therefore remains a significant problem hindering the recovery of native fish populations in the Murray-Darling Basin; affecting over 2,500 km of waterway basin-wide (Lugg and Copeland, 2015). On the basis of available scientific evidence, it is reasonable to conclude that cold-water pollution is one of the more serious degrading processes operating in the main rivers of the Murray-Darling Basin, and is probably one of the key factors behind the reduction in abundance and range of native freshwater fish species. Sustainable Rivers Audit data indicate that the reaches of the main western rivers downstream of large impoundments are generally missing 50 per cent or more of the expected number of native species (generally between 10 to 15 species missing).

The solution

Cold-water pollution is completely solvable using engineering measures. Multi-level off takes can be installed to ensure warm surface water is drawn for downstream delivery, reservoirs can be aerated to encourage mixing and break down temperature stratification, or thermal curtains can be installed (one was completed at Burrendong Dam for $3M). Mitigating thermal pollution will increase available habitat for native fish by 2,500 km if addressed at all sites. Existing prioritisation lists could be expanded to include costed proposals and a works program developed to fit within funding constraints. Addressing cold-water pollution will also maximise the benefits of environmental watering programs as delivered water will be of a sufficient temperature to assist native fish (and also other aquatic fauna that require warm water such as macrophytes, macroinvertebrates and plankton).The expected life of solutions could range between 10 and 80 years depending on the design and construction material.

Alignment with Basin Watering Strategy outcomes

This activity directly addresses several planned outcomes of the Basin Watering Strategy (MDBA 2001), including:

- No loss of native species currently present in the Basin
- Improved distribution of key short and long-lived fish species across the Basin
- Improved breeding success of short-lived fish species (every 1-2 years) and long-lived species (at least 8/10 years at 80% of key sites)
- Improved populations of short-lived species (numbers at pre-2007 levels), and long lived species (with a spread of age classes representatives

- Improved populations of Murray cod and Golden perch (10-15% more mature fish at key sites)

Re-establishing threatened species

The problem

Native fish in the Murray-Darling Basin are at 10% of pre-European levels and some species that were once abundant have not been seen for over 40 years. Species that inhabit wetland habitats have particularly suffered due to the impacts of river regulation and the proliferation of pest species such as carp and Gambusia. Surveys of fish populations in the years prior to the construction of Burrinjuck Dam (Murrumbidgee River) demonstrated an abundance of fish species, including wetland species such as Southern Purple-Spotted Gudgeon (*Mogurnda adspersa*), Southern Pygmy Perch (*Nannoperca australis*), and Olive Perchlet (*Ambassis agassizii*). None of these species have been recorded naturally in the catchment since 1975. Permanent extinctions of several species will occur within twenty years without on-ground action. Many of these species are unique to the Basin, form critical links in food webs and are key indicators of environmental health across the Murray-Darling.

The solution

These species are completely flow dependent. However, no amount of environmental water will bring them back without first reintroducing them; there is no other way. Once re-established through stocking, environmental watering may then be used to support their essential life history requirements. The solution is very simple: construct a threatened fish hatchery, commence commercial scale production, reintroduce fish into key sites across the basin (ideally following removal of Carp to prevent competition), and then deliver environmental water in a manner that enables fish to reproduce, spawn and expand their distributions. Techniques to propagate species such as Murray Cod, Golden Perch, Silver Perch, Freshwater Catfish, Trout Cod, Southern Purple-Spotted Gudgeon, Southern Pygmy Perch and Macquarie Perch are well established. Olive Perchlet methods could be developed within three years. If environmental water supports reintroduced species to become self-sustaining, then the need for this intervention will only be short term. If future environmental watering events are performed in a manner that supports the establishment of these species, the solution would be permanent. The capital outlay for facilities, and operating costs until 2024, present value for money considering this will be a permanent solution that aligns closely with Basin Plan expected outcomes.

Alignment with Basin Watering Strategy outcomes

This activity pursues the Basin Watering Strategy outcome (MDBA 2001) of ensuring no loss of native species currently present in the Basin most effectively. Other watering strategy outcomes addressed include:

- Improved distribution of key short and long-lived fish species across the Basin
- Improved breeding success of short-lived fish species (every 1-2 years) and long-lived species (at least 8/10 years at 80% of key sites)
- Improved populations of short-lived species (numbers at pre-2007 levels), and long lived species (with a spread of age classes representatives
- Improved populations of Murray cod and Golden perch (10-15% more mature fish at key sites)

Enhancing fish passage

The problem

Barriers to migration are a major contributor to the decline of native fish species within the Murray-Darling Basin. Their listing as a key threatening process in state and Commonwealth threatened species legislation is evidence of their impact on aquatic biodiversity. Despite environmental water being delivered for fish migration outcomes, benefits will only be local (or may be lost altogether) if fish are obstructed by dams or weirs. There are over 10,000 dams and weirs in the Basin that block migration routes. Because fish are motivated to move in response to flow, these dams and weirs are presently limiting the ability for environmental water to provide connectivity outcomes.

The solution

In 2001 the Murray-Darling Basin Commission initiated the “Hume to the Sea” fish passage program, which aimed to restore fish migration along 2225 km of the River Murray through the construction of fishways at 15 weirs. The program was underpinned by research and development and had a strong ecological basis (Barrett and Mallen-Cooper 2006). This investment has attracted international recognition for its strategic approach to riverine restoration and its adaptive improvement in fishway design. Importantly, prior to the Sea to Hume program, the only way fish migration could be provided was during ‘drownout’ events that completely inundated weirs. It is impossible to deliver such events for fish over the migration season (generally Sept to March). Now, fish can move under any flow, from low-level base flows upwards.

Despite the improvements of fish passage along the Murray River, this investment has not been matched in the major catchments that share hydrological connectivity with the Murray. A strategic program to reconnect other systems to the mainstem of the Murray is needed in order to address the fish passage barriers across a greater portion of the Basin and enhance the benefits of the Hume to Sea fish passage project. If achieved, fish will be able to move across significant proportions of the Basin; accessing important spawning, feeding and nursery habitat. It also means that future environmental watering initiatives will be able to achieve more outcomes with less water. Concept diagrams for all Darling River fishways have been completed, as well as for several Victorian catchments.

Alignment with Basin Watering Strategy outcomes

This activity directly addresses several planned outcomes of the Basin Watering Strategy (MDBA 2001), including:

- No loss of native species currently present in the Basin
- Improved distribution of key short and long-lived fish species across the Basin
- Improved breeding success of short-lived fish species (every 1-2 years) and long-lived species (at least 8/10 years at 80% of key sites)
- Improved populations of short-lived species (numbers at pre-2007 levels), and long lived species (with a spread of age classes representatives
- Improved populations of Murray Cod and Golden Perch (10-15% more mature fish at key sites)

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