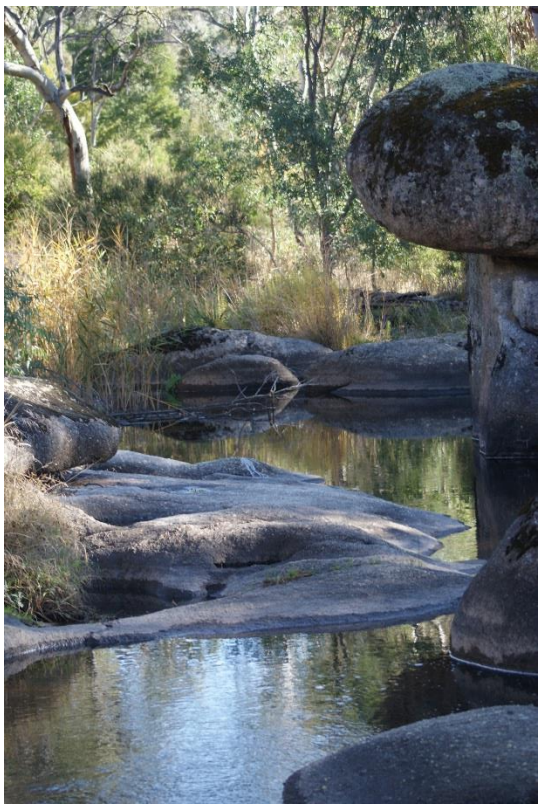
Goulburn Broken Catchment Research Forum



Water, Waterways,

Biodiversity, Land and Climate

21st May 2015

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GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY

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Preface

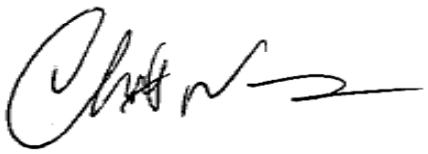
The Goulburn Broken Catchment Management Authority (CMA), in collaboration with our partners, is proud to host this workshop that presents the findings of land, water and biodiversity research in the catchment.

The Goulburn Broken CMA and our partners, have a long and proud history of investing in research that improves our understanding of natural resource management. Research has, and continues to, inform the actions of community, landholders, government and non-government agencies and organisations, in their efforts to maintain and enhance the economic, social and environmental resilience of the catchment.

Continuous learning through research is important as the Catchment faces a range of challenges, such as: risks associated with climate change, including increased frequency and severity of fire, flood and drought; changes in land use and values; water policy reforms; and the need to increase productivity of our land while ensuring that our natural resources are sustained and enhanced. Research plays a critical role in enabling us to identify, and increase our understanding of, how we can address challenges, and it informs policy and on-ground actions.

This workshop highlights a broad range of research projects undertaken in the Goulburn Broken catchment. We commit to continuing to share and discuss these and other research projects into the future.

I would like to thank all those who have assisted in bringing this day together, those who have shared their research findings, keynote speakers and session chairs. Most importantly, I would like to thank and acknowledge Wayne Tennant who showed foresight in recognising the value of research forums, such as this one, that results in the sharing of knowledge so that we can all participate in improving the health of our Catchment.



Chris Norman
Chief Executive Officer
Goulburn Broken CMA

Agenda

8.30-9.00am	Registration	
9.00 – 9.10 am	Opening Ceremonies **Neville Atkinson (Welcome to Country)** **Murray Chapman (Chair, Goulburn Broken CMA)**	
9.10 – 9.40am	Maintaining the resilience of the catchment – Implementing the Regional Catchment Strategy **– Chris Norman CEO, Goulburn Broken Catchment Management Authority**	
9.40 – 10.10am	**Keynote Address -** The role of Research in Management of our catchments **– Dr Andrew Bennett (Deakin University / ARI)**	
10.10am – 10.30am	Morning Tea	
Session Chairs	Tim Barlow	Gary Deayton
10.30-11.00am	Toward Eradication of Cabomba from the Broken River - **Tony Dugdale**	The 3C project - framework for evaluating scenarios in terms of biodiversity persistence; and for mapping the biodiversity benefits - **Michael Drielsma**
11.00-11.30am	The Shepparton Irrigation Region Salt Water Balance Project - **Terry Hunter**	Climate Change Planning within the Goulburn Broken - **Kate Brunt**
11.30 – 12.00pm	The Living Murray program in Barmah National Park: Research & Monitoring for adaptive water management **- Keith Ward**	Greater Murray Biodiversity Monitoring Program: Reptiles and Bird responses to changes in management. **Damian Michael**
12:00 pm – 12.45pm	Lunch Break	
Session Chairs	Lisa Duncan	Sally Mann
12.45- – 2.15pm	Movement, spawning, and recruitment of golden perch and responses to flows - **Wayne Koster** Restoration of native fish populations in Broken Creek - the story thus far **Matt Jones** Long-term monitoring of Macquarie perch within the Mid-Goulburn River and tributaries and identifying knowledge gaps and interventions for management **– Joanne Kearns** Demonstration Reaches and supporting Threatened Species - **Scott Raymond**	Monitoring and evaluating direct seeding across the Goulburn Broken Catchment to ensure adaptive management practices' **Elizabeth - Clare Pryde** Long term monitoring of a 360 ha revegetation site 'Wetlandia'. **Janet Hagen.** Does riparian condition and management influence breeding success in woodland birds in the Longwood-Violet Town Plains? - **Birgita Hansen**
2.15 pm – 2.30 pm	Afternoon Tea	
Session Chairs	Simon Casanelia	Carla Miles
2.30 – 2.50 pm	Wetlands response to fire and environmental water **– Jo Wood**	A study in Native Plant Genetics in the Goulburn Broken Catchment - **Dr Linda Broadhurst**
2.50 – 3.10 pm	Decommissioning of Lake Mokoan improved the ecological state of the Broken River - **Rick Stoffels**	Native vegetation quality: Are there indicators of bird species diversity? **Andrew Bennett/Greg Holland.**
3.10 – 3.30 pm	Exploring stream water temperatures in the Mid and Upper Goulburn catchments **– Pat Feehan**	Extracting Traditional Ecological Knowledge out of the Strathbogie archaeological record - Taungurung Clans Aboriginal Corporation & GBCMA - **Gaye Sutherland**
3.30 - 3.45	Closing Remarks	

Applying a resilience approach to managing transformation of natural resources in the Goulburn Broken Catchment, Victoria

Chris Norman Goulburn Broken CMA

The protection and conservation of natural resources is fundamental to the long-term viability of the Goulburn Broken Catchment and the well-being and prosperity of its people. The current Goulburn Broken Regional Catchment Strategy (RCS), completed in late 2012, provides an integrated planning framework or 'blueprint' for the management of land, water and biodiversity resources. It is the overarching strategy describing the relationship between people and nature, for directing action, and for implementing priorities of government and the community.

The approach to catchment management in the Goulburn Broken region has evolved from a focus on the single threat of salinity in the 1980s, to integrated catchment management (addressing salinity, water quality and biodiversity) in the mid-1990s, to a focus on valuing ecosystem services (such as maintaining clean water, air and productive soils) in the early 2000s. The current RCS is applying a resilience framework to maintain and improve the resilience of social-ecological systems (SESs), identified in the Catchment, to continue to deliver critical ecosystem services in an ever-changing world. This has been a truly adaptive approach underpinned by strong collaboration with researchers and continual learning from practice and experience.

But why use a resilience framework now? Major events in recent years from bushfires, droughts and floods to the global financial crisis, have severely tested the Catchment's communities and ecosystems. A series of a resilience assessments (2008 and 2013) has identified the major drivers of change for the Catchment and their impacts at SESs of different scales. A key to using the resilience framework in the Goulburn Broken Catchment has been the identification of SESs that acknowledge the role of social and economic dynamics in achieving natural resource management outcomes. Whilst SESs exist at a range of connected scales, from individual properties to the whole-of-Catchment, the scale considered most effective for decision-making following community conversations has been the sub-Catchment. This balances being small enough to understand the details and differences sufficiently, while being large enough to allocate resources efficiently. Integrated SES plans have now been developed that identify key thresholds, state-transition models, and enable the prioritization of actions and decisions at the local community (sub-Catchment SES) scale.

This presentation will describe the resilience journey being undertaken in the Goulburn Broken Catchment.

Biography: *Chris Norman has been the Chief Executive Officer of the Goulburn Broken Catchment Management Authority (CMA) in northern Victoria, Australia, since mid-December 2009. The Goulburn Broken CMA is one of the largest of 56 such regional Natural Resource Management bodies in Australia with an annual budget of over $60 million. Over the past few years the Goulburn Broken CMA and their partners have established one of the largest on-farm irrigation upgrade projects in Australia's history as well as delivering the biggest environmental flows seen down the Goulburn and Murray Rivers.*

In recent years, the Goulburn Broken CMA has been at the forefront of implementing a resilience approach to managing its natural resources. This resulted in Chris being invited to present this work at the 2014 International Resilience Conference in France as well as to the United Nations Environment Programme's Scientific & Technical Advisory Panel in Sydney in November 2014.

Prior to this role, Chris led the development and implementation of a new Statewide community relationships model for the Department of Primary Industries linking regional communities to policy development and Ministers. Chris has tertiary qualifications in science and rural resource management as well as Diplomas in frontline Management and Company Directors. He also completed the Goulburn Murray Fairley Leadership Program in 2001.

The role of research in catchment management

Andrew F Bennett Department of Ecology, Environment and Evolution, La Trobe University and Arthur Rylah Institute, Department of Environment, Land, Water & Planning

We all benefit every day from the outcomes of research, although often we may not recognise it. Mobile phones, new medicinal drugs, fuel-efficient cars, different varieties of fruits and vegetables, new fabrics, email communication, and weather-resistant house paint, are all products of research. So too with catchment management, much of the knowledge base regularly used in managing natural resources is a product of research: for example, maps of the distribution of plant and animal species, the composition and distribution of vegetation types, techniques for effective revegetation, the role of streamside vegetation in reducing erosion and pollutant run-off, and the GIS data layers that underpin planning of the catchment. Knowledge generated by research provides an essential foundation for planning management activities, and a means of determining whether the management actually worked, or how it could be improved. Three types of research (or knowledge generation) are particularly useful for catchment management: 1) surveys and associated modelling of the distribution and status of plants, animals and key resources (e.g. native vegetation, pest plants and animals, water levels and flows, soil condition); 2) management 'experiments' that rigorously test the outcomes of different management activities; and 3) ongoing assessment of changes in resources through time in response to environmental variation, land-use or specific management actions. Catchment Management Agencies benefit greatly from research undertaken by other groups and agencies; but there is also a role for CMAs to lead, commission or partner in research that has direct application to their local area. Important considerations to keep in mind include: 1) asking the 'right' question; 2) planning the research so that clear answers can be obtained; 3) ensuring data is collected systematically; 4) collating and storing information; 5) analysing and presenting the data and 6) communicating the outcomes. Given that there are 10 CMAs in Victoria, as well as other land and water managers, much could be gained by stronger partnerships for research where there are common issues of concern (rather than each attempting to 'reinvent the wheel'). In the 21st Century, knowledge is a key commodity. Generating and using new knowledge is something with which everyone can be involved: the insights we gain will help us sustain our catchments and make a better world for all.

Biography: *Andrew Bennett holds a dual position as Professor of Ecology at La Trobe University and Science Leadership and Capability at the Arthur Rylah Institute for Environmental Research (DELWP). His long-standing research interests are in landscape ecology and conservation biology, with a particular focus on understanding how human land-use and landscape change affect native wildlife and ecological processes. Together with students and colleagues, he has undertaken much research in agricultural environments, investigating the factors that assist native fauna to persist in these landscapes. More recently, with colleague Mike Clarke, he has been leading projects studying the effects of fire on wildlife in a range of vegetation types, from semi-arid mallee to box-ironbark and foothill forests.*

Toward eradication of Cabomba from the Broken River

Tony Dugdale, Biosciences Research Division; Department of Economic Development, Jobs, Resources and Transport (DEDJTR); and AgriBio Centre, 5 Ring Road, La Trobe University

Abstract: Cabomba (*Cabomba caroliniana* Gray) is a submersed aquatic weed which forms dense surface reaching stands displace native aquatic plant communities and impedes recreational and aesthetic activities. Drawdowns have been enacted in Lake Benalla, initially aiming to suppress cabomba. These drawdowns were coincident with the September 2010 floods, which together with the drawdowns provided periods of extreme water level fluctuation and turbidity, thus eliminating cabomba from the lake. Further activities were undertaken in associated wetlands to eradicate all cabomba from upstream of Benalla Weir. No cabomba has been recorded from the lake for 4.5 years and attention now moves to Casey's Weir, the only other known infestation of cabomba on the Broken River.

Key Words: Cabomba, Lake Benalla, Caseys Weir, aquatic weed, drawdown

Biography: *Tony Dugdale is an aquatic weed scientist from Department of Economic Development, Jobs, Resources and Transport (formerly Department of Environment and Primary Industries) Melbourne. He has been a professional in the field of aquatic vegetation ecology and management since 1999. He has worked as an aquatic plant ecologist in New Zealand, an environmental consultant in Australia and completed a PhD on biofouling algae at University of Melbourne. He is currently leads research projects on aquatic weeds to improve control techniques and outcomes. Today, he will be speaking about cabomba in the Broken River.*

Paper

Introduction: Cabomba (*Cabomba caroliniana* Gray) is a Weed of National Significance and was first identified in Lake Benalla in the 1990s. Its dense surface reaching habit poses an entanglement danger for swimmers and is unsightly. Further, this infestation represents a potential propagule source for downstream colonisation of the Broken, Goulburn and Murray Rivers, and associated wetlands (e.g. Barmah Forest Ramsar site).

Method: In 2009 a project was funded through Caring for our Country with the aims of controlling cabomba in the lake and reducing the likelihood of downstream spread. A Project Control Board (PCB) was established, consisting of representatives from Goulburn Broken Catchment Management Authority, Benalla Rural City, Goulburn-Murray Water, DEDJTR and Australian Government Department of Sustainability, Environment, Water, Population and Communities, to guide the control work and make decisions. Key activities were to map the locations where cabomba was present and develop a control matrix that described control options available for each habitat, along with their feasibility and likely success.

Results: Based on the control matrix, winter drawdowns of the lake were enacted in 2009 and 2010, along with pumping of areas where water did not drain and earthworks on the bed of the lake to allow depressions to drain. This resulted in collapse of cabomba stands in the lake, although a high proportion of the stems and crowns remained viable due to sediments remaining wet or saturated. These drawdowns were followed by floods from September 2010, which would have had at least two effects on the collapsed cabomba. Firstly, the high flows through the lake during the peak flood flow may have both dislodged and buried the collapsed cabomba, depending on their position relative to deposition and scouring zones of the lakebed. Secondly, the floods resulted in increased water level and turbidity for several weeks, both of which would have reduced the light reaching the bed of the lake and therefore reduced the subsequent regrowth of the collapsed cabomba. We cannot separate the effects of the floods and drawdowns, but together they dramatically reduced cabomba abundance (biomass reduced from 441 to 0 g / m^2) and distribution (percent of sampling sites with cabomba present reduced from 86 to 0%) in the lake and Broken River. Based on this success the PCB changed its aim from suppression of cabomba to eradication. A summer drawdown was conducted in the lake to kill any cabomba propagules remaining in the sediment, several billabongs with cabomba were pumped dry, Casey's Weir was lowered, and a stormwater wetland was scraped with a digger. Cabomba has not been recorded from Lake Benalla for more than four years. Attention now focuses on Caseys Weir.

Management Implications

Keys to the success of this program are:

- the co-ordinated effort provided by the PCB,
- fortuitous timing of natural floods, associated with high turbidity,
- detailed monitoring of cabomba abundance and viability before and after management activities,
- re-evaluating aims and activities according to progress, and
- continued support for the project.

Acknowledgements

Wayne Tennant, Jo Wood, Geoff Brennan, Tim Barlow (GBCMA), Larissa Montgomery (Benalla Rural City) Trevor Hunt, Daniel Clements (DEDJTR), Mark Finlay (Goulburn-Murray Water) Tim Allen (DELWP)are thanked for initiating and undertaking this project. The project was carried out with funding from the Caring for our County program (Australian Government Department of Sustainability, Environment, Water, Population and Communities).

Does riparian condition and management influence woodland bird breeding in riparian zones in northern Victoria

Birgita Hansen Federation University Australia, Ballarat

Abstract: Riparian zones are typically areas of higher avian diversity and abundance compared to surrounding landscapes. Where riparian zones are subject to livestock grazing and vegetation modified or clearance, woodland bird breeding success might be predicted to be lower than in more intact landscapes. This research project investigated the influence of riparian management and condition on woodland bird breeding in riparian zones in the Longwood-Violet Town Plains in northern Victoria. In spring 2013, breeding activity was measured at 17 riparian sites representing a gradient of impact from grazed and highly modified through to relatively intact. Over all sites, 36 woodland and 17 generalist species were observed attempting to breed. The proportion of woodland species successfully breeding (as evidenced by the presence of fledged young) was generally higher at more intact sites. There was a strong negative effect of grazing on woodland bird breeding activity and success. Generalist species did not exhibit the same response except where the grazing intensity was high (>15 DSE/ha). Breeding of woodland birds in restoration and intact sites was much higher compared to grazed sites, and compared to breeding of generalist species. Preliminary vegetation data analysis indicates that woodland bird breeding activity appears to be positively related to tree basal area, shrub cover and tussock grass cover, and negatively related to average Diameter at Breast Height (DBH) and percentage cover of grass and weeds. Whilst structural elements of riparian zones appear to positively influence woodland bird breeding in modified landscapes, grazing of riparian zones by livestock appears to have a negative overarching impact on both the frequency of breeding in different species and their success at nurturing young to fledging. This has implications for augmenting ecological functions like productivity through riparian restoration in highly modified agricultural landscapes.

Key Words: riparian management, bird breeding, grazing

Biography: *Birgita Hansen is a research fellow at Federation University in Ballarat. She has a strong interest in the management and restoration of riparian zones and wetlands, and is focusing on investigating the responses of birds to modification of these habitats in order to develop more targeted approaches to the management of interface zones. She is currently undertaking bird surveys at "Wetlandia" to collect baseline data for the purpose of measuring restoration success at the site in coming years.*

Evaluating the genetic quality of Seed Production Areas in the Goulburn Broken Catchment

Linda Broadhurst CSIRO National Research Collections Australia/Centre for Australian National Biodiversity Research
Tara Hopley DPaW WA
Lan Li CSIRO National Research Collections Australia/Centre for Australian National Biodiversity Research
Jim Begley Goulburn Broken CMA

Abstract: Vegetation clearing, as well as land use change and intensification, has depleted many natural communities and land managers are now faced with the task of restoring complex ecosystems. A major impediment to the success of rebuilding these communities is having regular access to sufficient quantities of high quality seed. Seed Production Areas (SPAs) can help generate this seed, but must be underpinned by a broad genetic base to maximise the evolutionary potential of restored populations. However, genetic bottlenecks can occur at the collection, establishment and production stages in SPAs, limiting their use as high quality seed sources. We will present the findings of genetic evaluations of SPAs for three key restoration species - *Acacia montana, Dodonaea viscosa* and *Eucalyptus melliodora* as well as chromosomal studies for SPAs of several grassland herbs.

Key Words: Restoration, seed, inbreeding, genetic diversity

Biography: *Linda began researching the genetic impacts of fragmentation on long term plant persistence more than 13 years ago to help improve the conservation and management of remnant vegetation. This research highlighted that genetic diversity plays an important role in the both quality and quantity of seed produced by fragmented plant populations. Given that seed produced by these populations is often used for restoration she began investigating whether this is likely to impact on the persistence of these restored populations. Her recent research has been directed at evaluating the genetic diversity of restored plant populations and their seed crops as well as the quality of seed generated in seed productions areas.*

Research Paper

Introduction: Having regular access to large volumes of high quality seed from a diverse array of plant species is necessary if we are to meet current and future restoration targets. But seed produced in fragmented landscapes can be affected by inbreeding which leads to a reduction in the amount of seed that is produced and/or to its quality. Seed production areas (SPAs) are one tool that land managers can use to provide the quantities of high quality seed they require. Since SPAs require significant investment it is important that they have a broad genetic base and are representative of the diversity present in natural populations.

Method: We sampled leaf material from remnant populations and SPAs of *Acacia montana*, *Dodonaea viscosa* subsp. *cuneata* and *Banksia marginata* located in the Goulburn Broken CMA to determine the quality of the seed that these are producing and whether we could improve this in any way. Three generations of plants were sampled: (1) the original remnant population plants from which the SPA seed was collected, (2) mature plants from seed production area plants, and (3) offspring (seed) from the SPAs and some of the original populations. We first compared levels of genetic diversity and inbreeding in the SPA plants to that in their source remnant populations followed by a similar comparison of genetic diversity in seed produced by the SPAs and remnant populations.

Results: Our results showed that genetic diversity was similar among the remnant plants, SPAs and seed but there was some concern associated with inbreeding in some of the SPAs. We also assessed how well the SPA plants represented the types of genetic diversity found in the remnant populations. Here we are interested in learning whether the SPAs contain an even mix of genotypes found in each remnant, or were some genotypes from some populations more common than others. This can be important as it means that the seed produced is essentially representative of one population only. The results for each SPA were variable with some being representative and some not.

Management Implications: 1. Tracking plant survival after planting an SPA is important is to ensure that plants from all remnant populations are represented.

2. The Goulburn Broken Seedbank should continue to mix appropriate wild collected seed with that produced in the SPAs to increase the genetic diversity of restored populations.

3. Additional plant material needs to be incorporated into the SPAs to increase genetic diversity, alleviate inbreeding and produce seed more representative of the original populations.

Knowledge Gaps: The survival, growth and genetic diversity of plants produced by the SPA needs to be evaluated to ensure that these are creating new populations capable of becoming self-sustaining in the future.

Acknowledgements: *Janet Hagen, Cathy Olive, Liz Evans, Kim Magnay, Andrew Sands, Andie Guerin, Woka walla NRM crew, Neil Morris, Martin Driver, Sue Logie, Andrew Saunders, RADCOM crew, Goulburn Broken CMA, Australian Government, Sarah Roberts, Murray Seedbank, Goulburn Broken Indigenous Seedbank, Euroa Arboretum, Murray Local Land Services.*

Climate Change Planning within the Goulburn Broken catchment

Kate Brunt Goulburn Broken CMA

Abstract: The Goulburn Broken CMA has been working on integrating climate change into regional Natural Resource Management (NRM) planning for the past 5 years, resulting in the development of the CMA's first 'Climate Change Integration Strategy'. In recent times there has been an influx of climate change information available to support regional NRM planning and while this has been invaluable in progressing climate change adaptation planning, it also provides a challenge for NRM organisations to keep on top of identifying new information appropriate to their needs, interpreting and then integrating this information into NRM planning.

Over the past 2 years, NRM organisations across Australia have undertaken climate change planning projects with funding support from the Australian Government. Running simultaneously to this work has been several research activities which have resulted in the development of numerous climate change NRM planning tools, including new projections, planning resources and information hubs. The Goulburn Broken CMA has also developed its own spatial assessment tool to assess the Catchment's systems' vulnerability to climate change and is now developing a Climate Change Adaptation Planning Strategy to outline priorities for climate change adaptation to support the implementation of the Goulburn Broken Regional Catchment Strategy and provide information to partners within the Catchment to assist in regional planning for the impacts of climate change.

Biography: *Kate Brunt has been working in the NRM industry for 17 years in both Victoria and Western Australia and has had a number of roles including, Landcare Facilitator, Threatened Species Project Officer and Biodiversity Project Officer, however for the last 7 years Kate along with Melanie Haddow has been focused on integrating climate change into NRM planning and looking for opportunities that might arise as a result of Climate Change in the Goulburn Broken Catchment. Kate was been with the Goulburn Broken CMA for over 10 years and in that time has seen Climate Change called a multiple of things and State and Federal policies change a number of times, however the Goulburn Broken CMA have maintained a strong policy position on climate change throughout this time and through the RCS and the upcoming Goulburn Broken CMA Climate Change Planning Strategy hope to support key planners in the region adapt to climate change.*

Assessing the effectiveness of direct seeding as a revegetation method

Elizabeth Clare-Pryde University of Melbourne
Jenny Wilson Goulburn Broken CMA

Abstract: Direct seeding is considered to be a more efficient and economic alternative (or complement) to hand-planting for revegetation projects. However, we have relatively little data to assist our understanding of the trajectory of direct seeded sites through time and to identify the factors that have important influences on both their establishment and long-term success. We are contributing to these knowledge gaps through the strategic design and implementation of monitoring surveys of direct seeded revegetation sites across the Goulburn-Broken Catchment. We have completed phase one of the project: vegetation monitoring of the oldest direct seeded sites in the catchment and will present results of this study. These results will be analysed along with data collected from more recently seeded sites as well as baseline sites (vegetation condition prior to seeding) later in the year. This should allow us to not only evaluate the effectiveness of direct seeding in terms of their ecological value through time but also to identify management actions that should be explored to ensure their progress towards EVC targets. This project will provide important information for the adaptive management of current and future revegetation projects.

Key Words: direct seeding, monitoring, revegetation, evaluation.

Biography: *Liz is a conservation biologist interested in applying science to inform conservation decision-making. She has spent much of her research career in the tropics, collecting impressive numbers of insect bites and falling into a lot of mud. She completed her PhD in 2014 on the conservation management of a forestry production landscape in Papua New Guinea. Now a mum, Liz is carving out a niche, sitting in front of a computer playing with models designed to help make strategic decisions about monitoring and evaluating conservation actions and for managing landscapes to improve conservation and production outcomes.*

How effective are agri-environment schemes? Terrestrial fauna response to woodland management in the Greater Murray bioregion

Damian R. Michael Conservation and Landscape Ecology Group, Fenner School of Environment and Society, the Australian National University
Jeff T. Wood, Thea O'Loughlin, David B. Lindenmayer Conservation and Landscape Ecology Group, Fenner School of Environment and Society, The Australian National University

Abstract: Do sites managed under agri-environment schemes (AES) support greater biodiversity than sites managed for primary production? This question underpins financial incentive delivery programs that aim to modify livestock grazing regimes and improve the condition and extent of threatened woodland ecosystems. To address this question, we established two long-term monitoring programs; one in the North East and Goulburn Broken catchments of Victoria and the other in the NSW Riverina bioregion. We stratified monitoring sites according to four management classes: 1) agricultural production sites, 2) sites placed under a CMA management agreement in 2010 in Victoria or 2008 in NSW, 3) sites placed under a Trust for Nature covenant in Victoria or Greening Australia project in NSW, and 4) sites in Parks Victoria managed conservation reserves or travelling stock reserves (TSR) in NSW. We surveyed terrestrial woodland fauna and evaluated patterns of diversity among management classes and over time. We found study-region differences in the response of some taxa to woodland management. Herpetofauna species richness and abundance, and bird species richness did not differ significantly among management classes in Victoria, although CMA funded sites supported a greater diversity of woodland birds of conservation concern. By contrast, reptile species richness and bird species richness differed significantly among management classes in NSW, and bird community composition varied according to management, with small-bodied, insectivorous birds more common in TSR's. Across all taxa, we found large differences in diversity measures between years. In Victoria, species richness and abundance of reptiles, frogs and birds peaked in 2011. In NSW, bird richness peaked in 2010, frog diversity peaked in 2012 and reptile diversity increased over time. Our findings suggest that agri-environment schemes play an important role in protecting high levels of biodiversity, including birds of conservation concern. However, due to lag effects associated with changes in vegetation structure, improvements in biodiversity may not be evident in the short-term. Instead, climate conditions appear to drive short-term species response patterns.

Key Words: agri-environment schemes, woodland ecosystems

Biography: *Dr Damian Michael is a landscape ecologist and herpetologist with the conservation and landscape ecology group, Fenner School of Environment & Society, ANU. Damian joined Professor Lindenmayer's research group in 2001 and is the Senior Manager of several large-scale, long-term biodiversity monitoring programs in the Greater Murray catchment. His research interests include understanding the response of terrestrial fauna to woodland management interventions, exploring the ecological values and management of rocky outcrops in farming landscapes, and evaluating survey methods to detect and determine the status of reptiles in grassy woodland ecosystems. He has published over 70 scientific articles on conservation biology and woodland ecology, and has co-authored five books with Professor Lindenmayer. Damian is also the author of Reptiles of the NSW Murray catchment: a guide to their identification, ecology and conservation.*

Making monitoring meaningful

Janet Hagen Strathbogie Ranges Conservation Management Network

Abstract: Methods for collecting useful baseline data at the beginning of a large scale (100 ha) landscape restoration project will be discussed, as well as how that data will be used to adapt management decisions as the project advances.

The Wetlandia landscape restoration project has been going for over three years and over that time we have explored various methods of measuring how and if biodiversity returns as the site reverts from flood prone grazing and cropping paddocks back to grassy woodlands and wetlands. The need to use established and regionally recognised long term monitoring techniques is important if the data collected is to be shared with other researchers. Vegetation quality, bird life, mammals, reptiles and frogs are being monitored but we are expanding into insects, moths and maybe even ants and bats.

Biography: *Janet Hagen has lived and worked on a farm near Ruffy in the Strathbogie Ranges for 30 years. She carries out many roles within the Goulburn Broken Catchment. She is: a Landcare Facilitator for Hughes Creek Catchment Collaborative; a facilitator for Strathbogie Ranges Conservation Management Network, coordinating field days, and delivering revegetation projects for the Goulburn Broken CMA; a direct seeding contractor, a native seed collector and has been instrumental in increasing the sustainability of farming in the Strathbogie Ranges. Her latest project is revegetating all of a 100 ha property 'Wetlandia' in the Riverina Plains, and using monitoring to determine how a range of species respond to that revegetation.*

The Living Murray program in Barmah National Park: Research & Monitoring for adaptive water management

Keith A. Ward Goulburn Broken CMA

Abstract: In 2002, the Murray-Darling Basin Ministerial Council established The Living Murray initiative - a long-term program of collective actions aimed at returning the Murray River system to a healthy working river. Barmah-Millewa Forest (66,000ha) was recognized as one of six Murray River Icon Sites where funding has since been provided towards Environmental Water Delivery, Condition Monitoring and Intervention Monitoring that primarily focused on fish, birds and vegetation. Long-term Condition Monitoring projects include tree condition, understorey vegetation, fish spawning, waterbirds and bushbirds, while event-based Intervention Monitoring include water delivery compliance, water quality, and various aspects of fish, birds and vegetation response not otherwise covered.

This paper, and associated presentation, focuses on summarising Condition and Intervention monitoring project outcomes and how they relate to water management within Barmah-Millewa Forest, as well as highlighting the transferability of knowledge for potential adoption into broader wetland and waterway management. Details of projects reside in individual researcher reports and published papers, but also collated in annual synthesis reports for Barmah-Millewa Forest.

Key Words: Barmah-Millewa Forest, Condition Monitoring, water management.

Biography: *Keith was originally employed by the Department of Conservation & Environment in 1990 to research wetland flora and fauna flood requirements on the Murray River floodplain.*
His main areas of research have been the vegetation of Barmah-Millewa Forest near Echuca, and fish and waterbugs of the Hattah Lakes system near Mildura, plus various waterbird and frog monitoring programs throughout northern Victoria.

Keith has since been responsible for writing water management plans for a variety of wetlands, and also responsible for the implementation and construction of numerous on-ground works.

Mostly known for his association with Barmah-Millewa wetlands and the implementation of a wetland rehabilitation program on the Murray River floodplain, Keith is now with the GBCMA as an Environmental Water Reserve Officer where he project manages The Living Murray initiative in the Barmah Forest.

Research Paper

Introduction: The Barmah-Millewa Forest is the largest River Red Gum (*Eucalyptus camaldulensis*) forest in Australia, covering approximately 66,000 ha of floodplain straddling the Victorian and New South Wales boarders between the townships of Tocumwal, Deniliquin and Echuca (Figure 1). The forest floodplain vegetation communities includes a range of habitats, including swamps and marshes, rush beds, lakes and billabongs, open grassland plains, River Red Gum forests, River Red Gum woodlands and Black Box woodlands.

Figure 1: Location of the Barmah-Millewa icon site (modified from MDBA)

Flooding drives the Barmah-Millewa Forest wetland ecosystem, which respects no artificial state boarders. The site is very low in the landscape where river flows readily start to inundate the floodplain when flows exceed 10,500ML/d downstream of Yarrawonga (lower flows now being prevented from entering most of the forest by regulators that have been constructed on the distributary channels at their junction with the Murray River). River regulation, however, has altered the timing, frequency and duration of flooding. Winter and spring flows are captured in upstream storages and released for consumptive use to prolong steady-state higher flows through spring, summer and into autumn. The use of environmental water therefore plays a critical role in the management of the Barmah-Millewa Forest ecosystem. Environmental water is used primarily in spring to increase or prolong desired flows, and occasionally create inundation of part of the floodplain in-line with achieving a suite of ecological objectives for the forest.

Planning and management is undertaken across state boarders, and therefore includes a much broader range of stakeholders than a comparable ecosystem contained solely within the one state. The Murray Darling Basin Commission developed a water management strategy for the forest between 1990 and 1993 with community consultation. In 1993, the Murray Darling Basin Ministerial Council approved an annual allocation of 100 Gigalitres (GL) of water, provided in equal shares by NSW and Victoria, to meet the needs of the forest ecosystem, and in 1994 the Barmah-Millewa Forum was established under the Murray-Darling Basin Agreement. An additional 50GL per annum of lower security water has subsequently been added to the allocation, which was unique at the time in having the ability to be carried over between watering years if not used (up to 700GL total, storage airspace permitting).

The Living Murray Initiative was established in 2002 by the Murray-Darling Basin Ministerial Council as a long-term program of collective actions aimed at returning the River Murray system to a healthy working river. The First Step decision was made in 2003 to create a process of implementing the longer term goals of The Living Murray (TLM) program. This was followed by the signing of an intergovernmental agreement in 2004 by Victoria, New South Wales, South Australia, the Australian Capital Territory and the Australian Government to address water allocation in relation

to environmental objectives affecting six nominated Icon Sites, one of which is the Barmah-Millewa Forest. The Barmah-Millewa Forum was replaced in 2005 by a new TLM consultation and planning arrangement that remain to this day, although the Environmental Water Management Plan was updated in 2012 to reflect altered planning and refined objectives (MDBA 2012).

A considerable Works & Measures program has been central to TLM implementation to undertake a range of physical works, water management and monitoring at the Icon Sites. It is the monitoring component of the TLM program that is discussed in greater detail for Barmah-Millewa Forest as part of this presentation.

Method: TLM monitoring has been funded in Barmah-Millewa Forest on an annual basis since 2005 (although Millewa Forest program was suspended in 2014-15 following funding shortfall from NSW). Two main types of monitoring are being undertaken: Condition Monitoring (which includes Murray River system-scale monitoring) and Intervention Monitoring.

System-scale monitoring is designed to determine if the overall health of the system improves following implementation of The Living Murray Initiative, and includes floodplain tree condition assessments and annual aerial waterbird surveys. This type of monitoring is managed by MDBA.

Condition monitoring provides· information on the environmental condition of the icon sites including how the condition changes through time to determine progress toward the ecological objectives of each icon site. Condition monitoring is focused on fish, waterbirds and vegetation consistent with icon site ecological objectives. The methods for each project remain consistent each year, regardless of the degree of flooding or other activity, so that long term trends can be elucidated. This type of monitoring in Barmah-Millewa Forest is generally managed by state land managers (DELWP and/or OEH).

Intervention monitoring is designed to assess the ecological responses to TLM watering and management actions and hence understand how specific environmental management actions result in changes at icon sites. Intervention monitoring projects can vary each year according to annual water management aims and activities, but tend to focus on projects such as water diversion flow measurements, waterbird nest counts, Moira Grass response inventories, and some novel small-scale research or mapping activities as required. This type of monitoring in Barmah-Millewa Forest is managed by Goulburn-Broken CMA as Icon Site Water Manager.

Results: The Millennium Drought had understandably created adverse conditions for a wide range of flora, fauna and wetland ecosystem functioning. Significant system-wide declines in tree condition and waterbird diversity and abundance occurred, while floodplain fish numbers reduced in-line with the widespread loss of wetland habitat (although the main river channel and connected waterbodies was protected to some extent by flow regulation) (MDFRC 2013).

The return of prolonged wet conditions in winter 2010 until mid-2012, which included two significant floods, and more normal seasonal flooding until winter 2014, had been associated with some large improvements in tree condition and wetland vegetation diversity, although Moira Grass (*Pseudoraphis spinescens*) has not responded as well as expected (GB CMA 2012, 2013, 2014, 2015). The response of the fish community more ambiguous, with invasive species (primarily Carp and Gambusia) greatly increasing in number following the first flood while native species abundance significantly declined between 2010 and 2012, and Southern Pygmy Perch may have become locally extinct since 2007. An extensive and prolonged blackwater event following the first flood is thought to be implicated in this response. By contrast, waterbirds increased in diversity and abundance following the return to wetter conditions, with many species having a strong breeding response.

Small environmental water releases were made during the extreme drought years of 2006-2010; in 2008 to refresh remaining waterholes to support floodplain fish species and turtles (MDBA 2008), and in 2009 to a specific wetland to support vegetation and provide foraging habitat for waterbirds (MDBA 2010). These interventions provided some relief to some flora and fauna species from the worst effects of the drought in Barmah-Millewa Forest. However, the condition of River Red Gums declined on the remaining dry floodplain with the proportion of stressed trees increasing from 60% in 2003 to 72% in 2010 (Cunningham *et al*. 2009, 2013), while growth of understorey species was very poor

with much of the forest floor instead being covered by dry leaf-litter or becoming bare (MDBC 2008). The main exceptions for the understorey species were the wetlands that were allocated environmental flows such as Boals Deadwood and Reed Beds Swamp where Giant Rush (*Juncus ingens*) was reinvigorated for future waterbird nesting substrate (Ward 2007).

Another consequence of the drought was the encroachment of Giant Rush at Barmah Lake where approximately 70% of the previous bare lake bed had become covered by 2.5 m tall rush thickets. This encroachment had the effect of reducing the amount of open water habitat previously available to a diversity of low-growing wetland plant species and to open-water feeding waterbirds, as well as creating a highly- modified and unwelcome vista at a major visitor site (MDBC 2008).

This work has shown environmental water releases made during the drought years, despite their small size, were of great value in providing relief to some flora and fauna species from the worst effects of the drought in Barmah-Millewa Forest. Many hundreds of Long-necked Turtles were saved due to maintenance of drought refuge pools (which unfortunately was not the case where water could not be supplied). The Ibis and Spoonbill breeding event immediately following the breaking of the drought in 2010 was attributable solely to the reedbed habitat having been supplied with some environmental water in the previous year to make the reeds green and pliable for use as a nesting substrate.

Environmental water releases made during wetter years remain very important, as continually shown following releases to colonial waterbird breeding sites when nesting initiates, particularly ibis, spoonbill and cormorants. The releases have been responsible for achieving most of the breeding success whereas without the releases river regulation would usually have caused premature water recession to result in the abandonment of such nesting events prior to chick fledging (as has occurred in some years).

And clearly, anoxic blackwater is to be avoided where possible, as shown when extended drought was followed by large natural flood events occurring in late-November and early-December to cause widespread native fish and crayfish deaths in the Murray River downstream of Barmah Forest in 2010. Connectivity and flushing of accumulated organics from the floodplain in cooler months therefore remains of importance to floodplain and riverine ecosystem health.

Annual summaries of water management and monitoring outcomes are compiled into annual reports for the forest (e.g., GB CMA 2012-15), while annual synthesis is undertaken and available on the MDBA website (http://www.mdba.gov.au/media-pubs/research-reports/tlm-icon-sites-synthesis-monitoring-outcomes).

Monitoring reports produced as part of TLM are generally made available on the MDBA website (http://www.mdba.gov.au/kid/).

Management Implications

1. Environmental water releases remain critical to achieving a broad range of environmental objectives in the now regulated river environment. These can be used to:
   a) bridge successive natural flood events if they occur in winter-spring to replicate missing longer duration floods;
   b) amplify small natural flood peaks to replicate missing frequency of deeper floods;
   c) maintain flooding at waterbird breeding sites for maintaining nesting attempts to replicate the greater frequency of successful events that would have occurred without river regulation;
   d) provide refuge to nurse particular species through drought conditions, such as turtles and floodplain fish, as a result of increased impacts from anthropogenic-induced drought frequency and duration, and from created pressures of introduced species competition and fragmentation.
   e) create floodplain inundation after a sustained absence of natural flooding, particularly during cooler months, to reduce accumulated organic matter on the floodplain and hence reduce potential for anoxic blackwater events if a small flood event were to occur later in warmer months.
   f) freshen permanent waterbodies if water quality or depth is otherwise to exceed a known threshold of concern, especially where this has been manifest by an unnatural event or where threatened species dictate.

2. Ensuring some minor flow variability occurs in the Murray River channel in late-October and November, when water temperatures exceed 17^{o}C, to create improved spawning cues for Golden Perch and Silver Perch.

3. Encourage Moira Grass to achieve flowering by flooding for at least four months, >0.5m deep, in spring to early-summer, but attempt to manage grazing impacts from feral horses (which can even occur during flooding) and from kangaroos during drying. The removal of all feral horses from the forest would improve outcomes from environmental water investment.

4. Consideration may have to be given to potential re-introductions of probable locally-extinct species such as Southern Pygmy Perch and Growling Grass Frog.

5. Undertake active clearing of River Red Gum seedlings and Giant Rush tussocks from open wetland plains if such environments are to be maintained. The encroachment of these species is occurring as a result of reduced natural flood depth and increased frequency of rain-rejection events, and will generally persist once established in these previously un-inhabited regions of the floodplain for these species that are forcing the continued contraction of Moira Grass and hence a loss of part of the listed Ramsar ecological character. Environmental water allocations alone are unlikely to reverse the situation given restrictions on volume and delivery rates to emulate desired natural flood regimes that would otherwise reduce the incidence of tree and rush colonizing onto the open plains.

6. Construct a fishway on Gulf Regulator (located in northern Barmah Forest that feeds a major forest distributary channel) and a regulator on Kynmer Creek (located in the extreme east of Barmah Forest that is currently affected by an elevated sill at the mouth of the waterway). Both structures have been fully designed and have gained all initial approvals for construction, and hence only await funding.

Knowledge Gaps: Despite considerable research and monitoring effort having been undertaken in Barmah-Millewa Forest, and/or of similar wetland environments where gained knowledge can be transferred, there remains a number of knowledge gaps and management interests that remain unresolved or poorly understood. These include (in no particular order):

1. What are the long-term consequences of Blackwater events? Our understanding of blackwater has improved in recent decades, although thresholds of concern (or benefit) for species remains poorly known as does the duration that the impacts persist.

2. What is the most important reproductive mechanism for Moira Grass in Barmah-Millewa Forest and how is this best managed for? This requires an understanding of the seed production and viability, including seedbank lifespan, and of vegetative reproduction importance and requirements. Although a brief investigation last year found low abundance and viability of Moira Grass seed in that year, an extension to the program is required to repeat in a different year as well as undertake studies into other aspects of Moira Grass lifecycle.

3. Why is Growling Grass Frog (*Litoria raniformis*) not present in Barmah-Millewa Forest despite historic records indicating that they were once present until the 1970s but apparent suitable habitat remains present? Would re-introduction be viable?

4. Where and when do each of the local three freshwater turtle species breed in the forest, and how could water management and complimentary management activities best facilitate nesting success? This is currently subject to investigation from Katie Howard from ARI, but could be further expanded.

5. What is the micro-habitat preference for Australian White Ibis, Straw-necked Ibis and Royal Spoonbill in Barmah-Millewa Forest wetlands given continued decline of the species despite apparent suitable habitat being available? Is the over-abundance of Giant Rush or Common Reed in many of the traditional breeding wetlands causing a decline in nesting attempts? A research project is required to create some open mosaics within thick reedbeds compared to controls to determine relative nesting uptake rates.

6. What are the floodplain fish habitat and water requirements, particularly of uncommon native species such as Southern Pygmy Perch that may have become locally extinct from Barmah-Millewa Forest wetlands? Is re-

introduction of rare species required and would it be viable under current wetland and management conditions? Aspects of Pygmy Perch are currently subject to investigation from Rick Stoffles from MDFRC but could be expanded.

7. What cues do fish use for spawning, including the refinement of our current understanding of riverine fish species such as Golden Perch and Silver Perch response to flows. Aspects of this are currently being investigated by ARI but could be expanded.
8. What is the distribution and flood requirements of Swamp Yabby (*Cherax rotundus*) within Barmah-Millewa Forest?
9. Are there threatened insect species present in Barmah-Millewa Forest, and what are their management requirements?
10. Are there aquifer systems that can be recharged during times of drought to provide greatest benefit Red Gum trees in Barmah-Millewa Forest?
11. What issues of indigenous culture can best be improved through use of environmental flows and associated complimentary management actions?
12. Where are threatened species (flora and fauna) located and what are their flood and other management requirements?

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Relationships between riverine flow regimes and spawning, movement and recruitment of golden perch

Wayne Koster Arthur Rylah Institute for Environmental Research

Abstract: Understanding key life history processes and relationships with environmental conditions is needed to develop appropriate and defensible conservation initiatives (e.g. “environmental flow” programs) to restore disturbed or regulated river ecosystems and their biota. We used drift sampling, acoustic telemetry and electrofishing over five years (2009–2014) to investigate relationships between environmental conditions and movement patterns and reproduction of golden perch in the Goulburn River. The results of the study show that movement behaviour was spatially and temporally complex and included long-distance movements associated with elevated discharge and temperature during the spawning season. Spawning activity of golden perch was also associated with increased flows in spring. Population surveys revealed no strong relationships between increased flows and recruitment of juvenile fish, suggesting that increased golden perch spawning during high flow years may not necessarily translate into recruitment of juveniles into the local population. The study’s findings have the potential to contribute to the development of defensible conservation initiatives, particularly in relation to environmental flow recommendations

Key Words: spawning, movement, environmental flows

Biography*: Wayne Koster is a fish ecologist at the Arthur Rylah Institute with over 10 years’ experience in fisheries research and management. The focus of much of Wayne’s recent work directly relates to assessing the responses of native fish to environmental flows. Wayne is leading the native fish component of the Commonwealth Environmental Water Office Long-Term Intervention Monitoring 5-year program in the Goulburn River to evaluate the effectiveness of environmental water use in the Murray-Darling. Wayne is also currently undertaking a project which investigates the effects of environmental flows on native fish in Broken Creek for the Commonwealth Environmental Water Office, and another project which assess the responses of native fish to environmental flows in the Yarra and Bunyip rivers for Melbourne Water. Wayne has an extensive knowledge of the ecology and habitat requirements of freshwater fish species, and the sampling techniques employed in the assessment of freshwater fish populations including the use of acoustic telemetry, radio telemetry, electrofishing and netting.*

Restoration of native fish populations in Broken Creek - the story thus far

Matthew Jones Department of Environment, Land, Water and Planning

Abstract: Native fish in the Murray-Darling Basin are regarded as depleted. Construction of dams, weirs and regulators, and alterations to natural flow regimes for irrigation purposes, combined with habitat loss and the introduction of exotic species such as common carp, have all contributed to this decline. The Broken Creek, located in north central Victoria and earmarked for extensive agricultural development in the late 1800's, is no exception to this trend.

Our understanding of how to manage native fish in the modern environment has however, improved substantially in the last few decades. Research in the 1970's found that native fish move large distances, while research in the 1990's found that these movements were likely to be spawning and habitat related – both important for a stable native fish population. Central to these findings, was the impact of regulators and weirs preventing longitudinal migrations, and this initiated a fishway installation program aimed at mitigating the adverse impacts of instream barriers on fish movement, and it still continues today. Further to these developments, research has also shown that habitat and natural flow patterns can be restored in riverine environments to the benefit of native fish.

The story of native fish restoration in Broken Creek, is one that showcases the aforementioned trends and impacts, and it is one of scientific research, fishway construction, habitat restoration, environmental flow development, collaboration and adaptive management.

Key Words: Fishways, re-snagging and environmental flows.

Biography: *Matthew Jones is a freshwater fish ecologist at the Arthur Rylah Institute for Environmental Research. Matthew has approximately 16 years of experience working is freshwater ecosystems throughout Victoria, New South Wales and South Australia. Matthew has published a number of articles in international journals and has a PhD. Matthew's work has focused on fish movements and river-floodplain connectivity, exotic species, environmental flows and fishways. Matthew is currently investigating the effectiveness of newly constructed fishways for passing native fish in the Murray and Yarra Rivers, and regularly provides advice on various fish passage issues. Matthew has been involved in a number of projects along Broken Creek including the installation of PIT reader systems, development of environmental flows, and restoration of instream woody habitat.*

Long-term monitoring of Macquarie perch within the Mid-Goulburn River and tributaries

Joanne Kearns Arthur Rylah Institute
Co-authors **Renae Ayres**, **Justin O'Mahony**, **Graeme Hackett**, **Scott Raymond**, **Zeb Tonkin** and **Jarod Lyon**

Abstract: Macquarie Perch have been exposed to significant variations in environmental conditions over the past 50 years which has resulted in highly fragmented populations within sub-optimal tributaries of the Mid-Goulburn River. In 2006, the Goulburn Broken Catchment commenced a threatened species monitoring program where ecological surveys were conducted by the Arthur Rylah Institute to determine the status and trajectories of key Macquarie perch populations throughout the catchment. Population surveys recurrently continued to the present year at many of these sites including the King Parrot Creek, Hughes Creek, Seven Creeks, Broken River, Yea River, Hollands Creek, Yea River and the Goulburn River. Importantly, this monitoring encompassed periods of extreme environmental conditions (e.g. drought, floods and bushfires) and various intervention actions (translocation and habitat works).

As such, these long term monitoring programs have not only enabled managers to keep a close eye on populations, but are starting to shed some light on the key factors governing the Goulburn Broken's Macquarie Perch populations. This enables us to identify the key resource/s to firstly protect these fragmented populations, expand their range and population size, and ideally reconnect them to assist safeguarding the species into the future. In December 2014, a workshop was partaken by researchers, management and community members to identify and discuss knowledge gaps and interventions for Macquarie Perch within the Goulburn Broken Catchment. This presentation reports the key trends of the monitoring programs and the major outcomes from the workshop.

Biography: *Joanne is a scientist in the applied aquatic ecology section at the Arthur Rylah Institute. She has a special interest in threatened species ecology, monitoring and conservation. Joanne currently manages several projects for the threatened species program which monitors Macquarie perch and trout cod populations throughout the Goulburn-Broken Catchment, working closely with the staff in the GBCMA's river health team. Joanne has also been an integral member of several fish habitat restoration projects including the Murray River Restoration Project and the Melbourne Water Instream Habitat Restoration Project.*

Hollands Creek Demonstration Reach 2007-2015

Dr. Scott Raymond Arthur Rylah Institute
Joanne Kearns Arthur Rylah Institute
Wayne Tennant Goulburn Broken CMA

Abstract: Native fish within the Murray-Darling Basin (MDB) are estimated to have declined by approximately 90% in the last two centuries. In an attempt to halt and reverse this trend, the Native Fish Strategy (NFS) was initiated with the aim of increasing native fish populations to 60% of pre-European settlement levels. A core component of the NFS was the establishment of the Demonstration Reach concept. Demonstration reaches consist of a section of river where multiple river rehabilitation interventions are undertaken to show the community the cumulative benefits of river restoration on native fish populations.

A section of the Hollands Creek in North-Central Victoria (upstream from the township of Tatong) satisfied a number of criteria used to determine the location of potential demonstration reaches. Criteria included; a partly degraded but fixable stretch of river, a high value asset (Macquarie perch), amenability for works, community support and good accessibility. The Hollands Creek Demonstration Reach (HCDR) is a partnership program between the Murray-Darling Basin Authority (MDBA), Department of Environment, Land, Water and Planning (DELWP), the Goulburn Broken Catchment Management Authority (GBCMA), local landholders and community groups.

This document collates eight years of monitoring data to investigate reach-scale population responses of three iconic large-bodied native fish species; Macquarie perch, Macquaria australasica, Two-spined blackfish Gadopsis bispinosis, and River blackfish Gadopsis marmoratus to the multiple rehabilitation techniques undertaken within Hollands Creek.

Lack of structural woody habitat, degraded riparian vegetation, barriers to fish migration, presence of introduced fish species, low flows and the potential occurrence of avulsions are major threats facing the Hollands Creek native fish community (GBCMA 2008). These threats reduce in-stream habitat availability for native fish, interfere with natural thermal regimes, inhibit migration, reduce access to better habitat, increase competition and predation and impact negatively on native fish population structure and function.

Actions to ameliorate these threats to the Hollands Creek native fish fauna included re-snagging, riparian vegetation planting and protection, fencing, removing barriers to migration and control of alien species.

Key Words: river rehabilitation, Macquarie perch, Two-spined Blackfish, translocation

Biography: *Dr Scott Raymond is a senior research scientist at the Arthur Rylah Institute. He is part of the freshwater ecology team and is currently researching topics on;*

- *the impacts of river rehabilitation and flows on native fish,*
- *system productivity, and*
- *the relationship between fish population structure with changes in connectivity, migration and river regulation.*

Research Paper

Introduction: The Hollands Creek Demonstration Reach (HCDR) project aims to improve native fish populations within Hollands Creek using a variety of river rehabilitation strategies. In isolation, these interventions have led to negligible improvement or the continued decline in fish populations. However, the cumulative benefit of multiple interventions is believed to have the maximum impact on restoring native fish populations. Temporal, spatial and structural changes to fish populations are used to highlight the benefits of multiple interventions.

Method

- The HCDR was monitored annually for fish and water quality in January/February of each study year.
- Both active and passive fish collection techniques were used to monitor the HCDR fish assemblage. Backpack electrofishing (active) was undertaken using a NIWA ® model 12 backpack electro-fisher (settings: 250 volts, 60 Hz, pulse DC [Figure 4]) following the Sustainable Rivers Audit (SRA) protocol which includes eight, 150 second shots at each site (Murray Darling Basin Commission 2004b). The electrofishing operator fished in an upstream direction, fishing all accessible habitats.
- Two single-winged fyke-nets (passive) were placed within each monitoring site in the late afternoon and early evening and collected early the following day. Nets were set in pairs at the head and/or the tail-end of pools: each net was set to face downstream on a 45 degree angle from the bank with a float attached to the cod end (top) to ensure survival of any trapped mammals. All fish were identified to species level and their total length measured to the nearest millimetre before being returned to the water.
- Water quality parameters were recorded using a portable TPS water quality meter (Conductivity, Temperature, Dissolved Oxygen, pH, and Turbidity). Spot measurements were taken at a single location for each of the treatment and control sites. The aim of the water quality testing was to document significant changes in water quality in the event of short-term environmental disturbances such as the presence of blackwater and to provide contextual data used to determine electrofishing settings.

Project design included eight survey sites on Hollands Creek (intervention reach) and four sites on Ryan's Creek (control reach) to determine the impact of intervention works on the native fish assemblage.

Results: Implementation of multiple river rehabilitation works was followed by changes in fish;

Abundance

- a six-fold increase in the Macquarie perch population (from 11 to 72 individuals),
- an order of magnitude increase in the Two-spined blackfish population (from 6 to 106 individuals),
- a two-fold increase in the River blackfish population (from 82 to 180 individuals) over the life of the program (Figure 1.).

Distribution

- distribution of Macquarie perch increased from a single site in 2008 and 2009 to as many as five sites in 2014
- the distribution of Two-spined blackfish (absent in 2008-2010, first captured from two sites in 2011 and three sites in 2015).

Population structure

- Young- Of-Year (YOY) Macquarie perch were sampled from the treatment reach (2013, 2014 and 2015) indicating that the Hollands Creek Macquarie perch population is being strengthened through recruitment.

- Population size of Two-spined blackfish varied from adults only in 2011 (first record of the species in the reach) to populations containing YOY in 2012 to 2015.

Management Implications

- River rehabilitation strategies contribute positively to fish population structure at the reach scale
- Fish translocations are an important and effective strategy to facilitate species resilience
- The need to implement similar strategies on a broader scale, particularly downstream
- Continue to implement strategies within the reach (still lots to do eg. Exotic fish removals, riparian planting, fencing, blackberry removal etc.)
- Flow management may be a useful strategy to promote fish movement and spawning

Knowledge Gaps

The current monitoring program has highlighted a number of criteria that require further investigation. These criteria include specific information of the ecology of fish species within the system to broader system-scale questions.

While the current study has answered a range of questions posed early in the program a number of research questions have arisen, including;

- What is the distribution of Macquarie perch within the system?
- Where are Macquarie perch breeding? (need to protect these areas or the potential exists to replicate spawning areas such as riffles for Macquarie perch)
- Are Macquarie perch moving past the rock-ramp fishway installed below the monitoring sites? And if so, at what flows is the fishway operating?
- Are Macquarie perch naturally recruiting (likely) and when will translocates successfully contribute to recruitment?
- Will the range of blackfish species overlap (likely)? and
- What will be the impact of species (blackfish) overlap?
- What is the relationship between individual fish species with flows?

Detailed information on system productivity may provide insight into questions relating to preferred conditions for growth, spawning and population structure of native fish species. This information may then be used to

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Wetlands Response to Fire and Environmental Water

Jo Wood Goulburn Broken Catchment Management Authority
Simon Casanelia Goulburn Broken Catchment Management Authority

Abstract: The Wunghnu complex fire destroyed 10,000 hectares of both public and private property in February 2014. Two wetlands, Black Swamp situated north east of Wunghnu and Kinnaird Wetland north of Numurkah were burnt out by the fire. Environmental water was proposed to be delivered to these wetlands in April 2014 to promote the growth of EPBC listed flora species specific to these sites. After the fire, the water had a new purpose to regenerate the wetlands.

Monitoring of these two sites occurred after the fire, before environmental water delivery and during delivery until the wetlands dried. Monitoring activities included time lapse photography, photopoint monitoring, water quality, water depth and extent, macroinvertebrate monitoring, waterbird species presence and breeding activity and acoustic monitoring.

A carp screen was installed at Black Swamp upon delivery of environmental water but not at Kinnaird Wetland due to construction works taking place and the size of the delivery system. The comparison of the effect of carp on these wetlands was also noted.

The wetlands were monitored as part of the Victorian Northern Wetlands Monitoring project funded by the Victorian Environmental Water Holder.

Key Words: Fire, Wetland, Environmental Water

Biography: *Jo Wood is an Environmental Water Project Officer with the GB CMA. She has worked in environmental water and wetlands for the past 5 years with the CMA and 5 years before that with successor bodies of the Department of Environment Land Water and Planning (DELP).*

Part of Jo's current role is to monitor wetlands within the Goulburn Broken Catchment using different monitoring techniques such as acoustic monitoring. Jo is also currently co-writing the Goulburn River Environmental Water Management plan and Seasonal Watering Proposal for wetlands.

Decommissioning of Lake Mokoan improved the ecological state of the Broken River

Rick Stoffels, CSIRO Land and Water, Murray-Darling Freshwater Research Centre

Abstract: The objective of the present study was to determine how the decommissioning of Lake Mokoan affected the water quality and fish community of the Broken River. Five years of annual monitoring showed that the decommissioning had significant and strong beneficial impact on water quality within the Broken River. Furthermore, the cessation of water diversions that were associated with Lake Mokoan operation is likely to improve the viability of the Murray cod population within the Broken River, particularly upstream of Casey's Weir. Overall, decommissioning of Lake Mokoan has improved the socio-ecological status of the Broken River.

Biography: *Rick is an animal ecologist with a decade of experience researching how animals respond to changing environments. His work has focused on many levels of biological organisation (from the individual, to the community), as well as across multiple spatial and temporal scales. He has published scientific papers on a broad range of topics, from the dynamics of human genes over evolutionary time, to the physiology of invertebrates. His most recent appointment at the CSIRO has seen him focus his attention on the ecology of riverine fishes. He holds two international credit cards and is the director of his own household when his wife, 3-year-old daughter, 1-year-old son, and border collie Sam aren't around.*

Exploring stream water temperatures in the Mid and Upper Goulburn catchments

Pat Feehan Feehan Consulting
Mark Turner, Goulburn Broken CMA

Abstract: The temperature of water released from Lake Eildon into the mid Goulburn River is assumed to form a barrier to the movement of Macquarie perch along the Goulburn River; this barrier is also assumed to block movement of Macquarie perch between Goulburn River tributaries such as King Parrot Creek, Yea River and Hughes Creek. It may also affect Macquarie perch spawning opportunities in the mid Goulburn

A scoping review of stream temperature data from sites in the mid and upper Goulburn catchment was undertaken. The Goulburn River Eildon to Trawool is impacted by cold water releases from Lake Eildon and the stream temperature climate is substantially different to unregulated streams in the same region – this may have an impact on Macquarie Perch spawning or migration. The impact of Eildon releases is reduced by the time flow reaches Trawool.

Even though the mid Goulburn River stream temperature climate is different to other streams, based on percentage of temperature observations greater than 17°C there should be no reason Macquarie Perch aren't breeding (based on temperature alone)at all sites analyzed except the Murrindindi River which is probably too cool for breeding.

A very brief initial analysis of stream flow and velocity data was undertaken and indicates that the flow climate of the Jamieson River and King Parrot Creek is quite different to the Goulburn River and may also be a factor affecting Macquarie Perch habitat.

It is possible that the temperature and flow barrier is not "solid"; there may well be windows where temperature and flow may not impede either breeding or movement of Macquarie perch.

Key Words: Stream water temperature, Macquarie perch, Goulburn River, Velocity

Biography: *Pat has 40 years' experience in land, water and catchment management. Much of this time has been spent working on a wide variety of issues in the Goulburn Broken catchment. After a long career with Government agencies including Goulburn-Murray Water and the Department of Conservation and Environment (and its predecessors) he set up his own small consulting business, based in Shepparton, working with clients in the catchment. He continues to have the good fortune of working on interesting issues.*

Research Paper

Introduction: Macquarie Perch (*Macquaria australasica*) were once widespread and abundant in the Goulburn river catchment. Following European settlement native fish populations have declined as a result of altered flows and temperature regimes, habitat loss, instream barriers, overfishing and the introduction of exotic fish species. Macquarie perch are now restricted to a few sites and are considered a nationally endangered species, (Kearns *et al.* 2014)

The temperature of water released from Lake Eildon into the mid Goulburn River is assumed to form a barrier to the movement of Macquarie perch along the Goulburn River; this barrier is also assumed to block movement of Macquarie perch between Goulburn River tributaries such as King Parrot Creek, Yea River and Hughes Creek. It may also affect Macquarie perch spawning opportunities in the mid Goulburn.

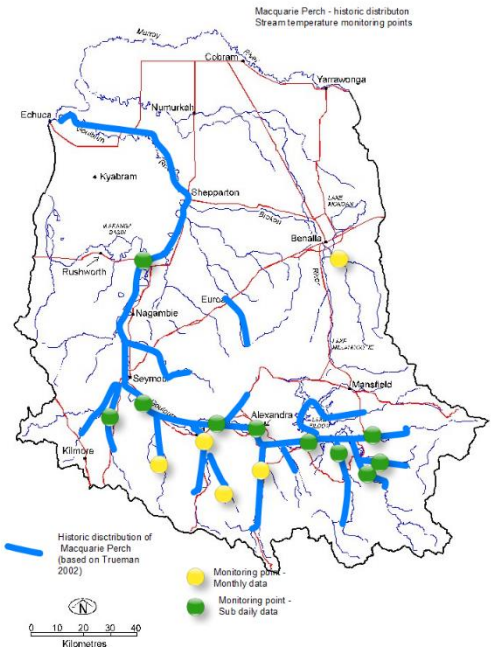
Stream water temperature data in the mid/upper Goulburn catchment is available from a number of sources. A first pass review of this data and an assessment of potential impacts on habitat requirements of Macquarie perch has been undertaken (Feehan Consulting 2014). A very preliminary analysis of flow data was also undertaken.

Method: Relevant stream temperature data are available from a number of sources, including:

- Victorian Cold Water Monitoring (hourly) – data supplied by G-MW
- Victorian Water Quality Monitoring Program (data from Victorian Water Data Measurement System)
- Monthly
- Salinity (hourly/15 minutes). Temperature data is collected along with EC data to standardize EC data.
- Goulburn Valley Water – water treatment plant data
- Flow data – data from Victorian Water Data Measurement System.

Data was available from sites above and below Lake Eildon and from unregulated tributaries of the mid Goulburn River (Figure 1). Data was analysed using readily available Excel spreadsheet tools.

Figure 1: Goulburn broken catchment - Macquarie perch historic distribution and stream temperature monitoring points



Comments about data availability: There are a number of sites high frequency data (sub daily) with a very large number of temperature data points (~160,000). These sites have relatively short periods of record (most from 2003). The data has been collected for salinity (monthly). These sites have the longest period of records (some from 1990).

Spatial location of sites with high frequency data is sub optimal for this report. No streams with current Macquarie perch populations in the mid Goulburn catchment have high frequency data. A couple of locations in the upper Goulburn have high frequency data.

Data availability spans "normal" and drought periods.

There are substantial gaps in the data which makes it difficult to properly compare sites.

Data collected at sub hourly intervals was of most use for this analysis however comparison of frequency between sites with monthly and sub daily data collection indicated that the less frequent data could still tell part of the story.

Critical temperatures: Macquarie Perch can tolerate temperatures below 9°C, but require temperatures of at least 16.5°C for spawning to occur. Hatching of Macquarie Perch usually occurs at water temperature of 11-18°C, with hatching occurring faster in warmer waters. For this initial analysis 17°C was selected as a biologically significant temperature. ARI staff suggest that 20°C is a more optimum temperature for spawning.

Data analysis: Frequency analysis: Histograms which show the relative frequency of classes of data (in this case 2°C classes) were prepared using both monthly and continuous data. Relative frequency is used as there are great differences in the amount of data between monthly and continuous sites.

This analysis shows that regulated streams (Figure 2) have a bi- modal temperature distribution with modes at ~ 10 and 20°C. The Goulburn River at Trawool shows some bimodal temperature frequencies but the temperature frequency does not vary all that much between about 9 and 23°C. Stream water temperatures become warmer downstream.

Unregulated streams temperature frequencies (Figure 3) are generally unimodal with the most frequent temperature in the range 9-11°C. Higher temperatures are less frequent. The Murrindindi River is much cooler than any other unregulated stream.

Figure 2: Histogram stream temperature Goulburn River Regulated sites.

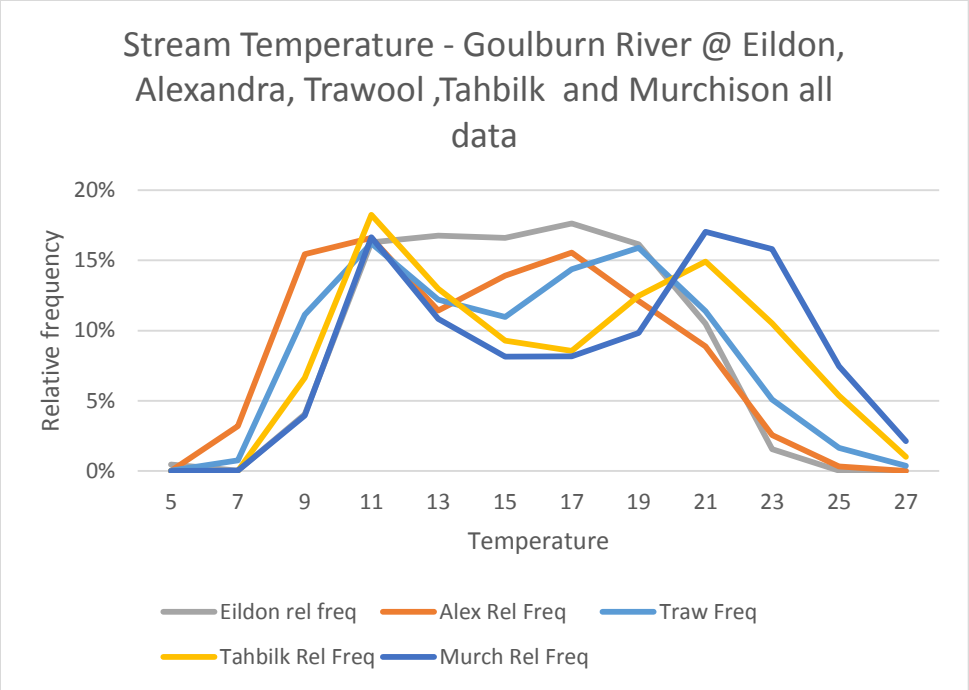
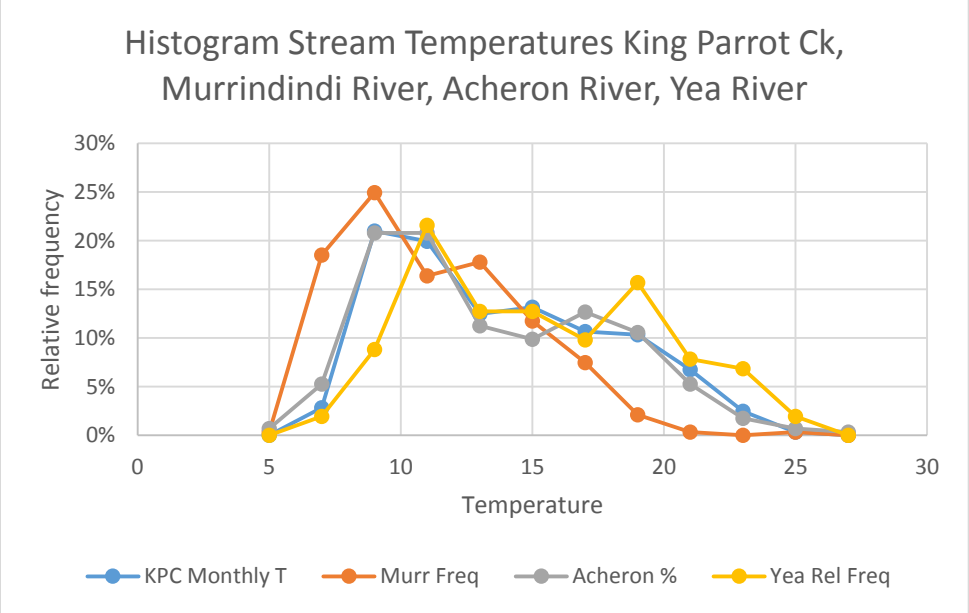


Figure 3: Histogram stream temperatures King Parrot Creek, Murrindindi River, Acheron River and Yea River (all unregulated)



Duration of stream temperatures > 17.0 C

- 17.0C was adopted as an important ecological threshold. Data from three sites Goulburn at Dohertys, Goulburn at Eildon (and Alexandra) and Goulburn at Trawool has been examined to determine:
- Data of first average daily temperature above 17.0 C
- The number of days during the next 100 days the temperature stays above 17.0 C.
- All sites except Murrindindi River have some monthly average temperatures greater than about 17C

In regulated streams:

- Stream temperatures greater than about 17°C can be expected from October/November to March/April each year.
- Eildon monthly average stream temperature is distinctly cooler in summer than other sites (except Murrindindi River) and warmer in winter than all other sites.
- Some years at Eildon have periods with stream temperatures above 17°C indicating possible suitable temperature for Macquarie Perch spawning
- At Trawool there are significant periods with temperature greater than 17°C (although with substantial variability (spread of temperatures)).

In unregulated streams:

- Stream temperatures greater than about 17°C can be expected from October/November to March/April each year.
- Once temp gets above 17°C it stays there for some time (with some dips below 17°C)
- There are significant periods with stream temperatures above 17°C,
- Winter monthly average stream temperatures can be quite cool (<10°C) for 3-4 months.
- The date of first daily temperature > 17. 0°C at Dohertys is about one month earlier than Trawool (you would expect this to be the other way round given Dohertys' highland location)
- The number of > 17.0°C days at Dohertys and Trawool is roughly comparable (under natural conditions you would expect more > 17.0°C days at Trawool than Dohertys because of Trawool's location lower in the catchment)
- Low number of days > 17.0°C at Eildon/Alexandra
- The number of days > 17.0°C at Trawool suggests good spawning conditions for Macquarie Perch
- The number of days > 17.0°C at Dohertys suggests good spawning conditions for Macquarie Perch
- Some years at Eildon/Alexandra have a comparable number of > 17.0°C days to other sites
- Unregulated streams generally have more days with changes of > 1.5° C, 0.99° C and 0.5°C , than regulated streams, (3-4% compared with 0-1%)
- Stream temperature falls of >0.5°C are more frequent than rises of the same magnitude.
- Some years have relatively low number of > 17.0°C days (e.g. 2004).

Flow velocities: Stream flow velocity is another factor that might affect habitat requirements for Macquarie Perch. A very brief analysis of stream flow and velocity data was undertaken.

Flow velocity (km/day) were computed from gauging information supplied by Thiess for three sites:

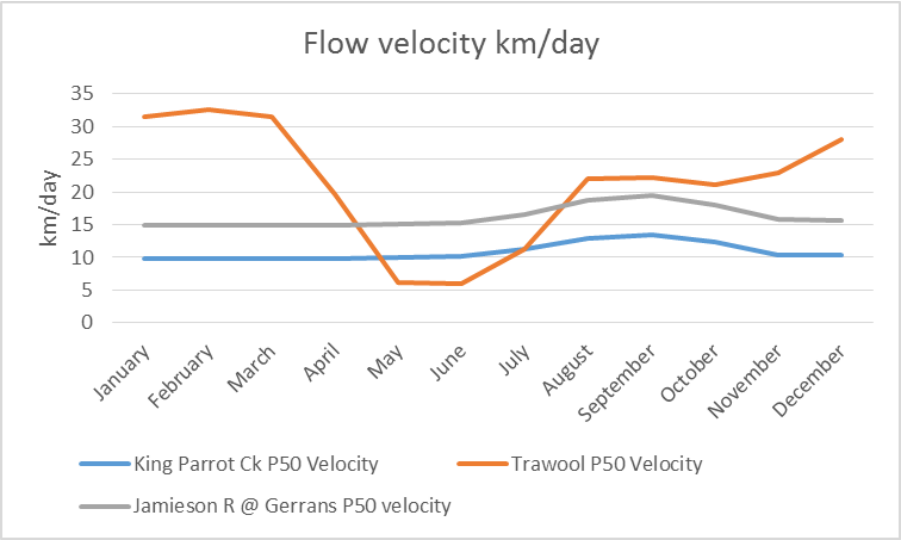
- 405218 Jamieson river @ Gerrans
- 405201 Goulburn River @ Trawool
- 405231 King Parrot Creek.

Relationships between flow (ML/day) and flow velocity (km/day) were determined using functions within Excel. These relationships should be treated with some caution but R2 values for 405218 and 405231 were 0.94 and 0.84 respectively. For 405201 the R2 was 0.34.

The relationships were applied to monthly P25, P50 and P75 values (determined using TimeTrends) with the results shown in Figure 3. This suggests that the flow climate of the Jamieson River and King Parrot Creek are quite different to

the Goulburn River and may be a habitat factor affecting Macquarie Perch habitat. Further analysis (in progress) using a different method to calculate flow velocity median suggests this relationship does not hold.

Figure 4: Monthly median stream velocity(km/day) King Parrot ck, Goulburn River at Trawool and Jamieson River at Gerrans bridge



Management Implications: The Goulburn River Eildon to Trawool is impacted by cold water releases from Lake Eildon and the stream temperature climate is substantially different to unregulated streams in the same region. The stream temperature climate of unregulated streams flowing into the mid Goulburn is also substantially different to regulated mid Goulburn between Eildon and Trawool – this may have an impact on Macquarie Perch spawning or migration. The impact of Eildon releases is reduced by the time flow reaches Trawool.

Even though the mid Goulburn River steam temperature climate is different to other streams, based on percentage of temperature observations greater than 17°C there should be no reason Macquarie Perch aren't breeding at all sites except the Murrindindi River which is probably too cool for breeding

A very brief initial analysis of stream flow and velocity data was undertaken and indicates that the flow climate of the Jamieson River and King Parrot Creek are quite different to the Goulburn River and may be a factor affecting Macquarie Perch habitat, although further analysis suggests this conclusion may not be valid.

On the basis of the conclusions above the assumption that temperature and flow of water released from Lake Eildon into the mid Goulburn River often forms a barrier to the movement of Macquarie perch along the Goulburn River and that this barrier also blocks movement of Macquarie perch between Goulburn River tributaries such as King Parrot Creek, Yea River and Hughes Creek is plausible. The nature of the barrier and its impact on movement and breeding should be investigated in more detail. It is possible that the barrier is not "solid"; there may well be windows where temperature and flow requirements may not impede either breeding or movement of Macquarie perch.

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The 3C Project – framework for evaluating scenarios in terms of biodiversity persistence; and for mapping the biodiversity benefits

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Glenn Manion Office of environment and heritage NSW; University of New England, Armidale
Jamie Love Office of environment and heritage NSW; University of New England, Armidale
Kristen J. Williams CSIRO Land and Water National Research Flagship, Canberra ACT
Tom Harwood CSIRO Land and Water National Research Flagship, Canberra ACT

Abstract: The 3C project integrates climate impacts with other key considerations – representation of distinct bioclimatic classes, past clearing and disturbance and the spatial configuration of habitat – in order to evaluate the impact of future climate on biodiversity persistence; and to map biodiversity benefits of undertaking conservation and revegetation across the 3C region.

The 3C region includes the East Coast, Central Slopes and Murray-Basin NRM Cluster regions and all of NSW, totalling approximately a third of the Australian continent (5.5M ha).

3C confirmed significant additional risks to biodiversity due to climate change and identified geographic shifts in conservation and regeneration focus if we are to maximise biodiversity persistence.

Visualisation products arising from the work are designed to engage people in creatively thinking and learning in relation to a changing and uncertain climate, and to provide a big-picture perspective to people who are well-placed to make decisions at a local scale.

Key Words: climate change, biodiversity assessment, conservation planning, engagement and learning

Biography: *Michael Drielsma, Glenn Manion and Jamie Love have worked together in the Office of Environment and Heritage in NSW for many years undertaking biodiversity assessment across a range of scales to inform conservation action using novel spatial modelling developed in-house. In particular they have developed innovative techniques in modelling vegetation condition and biological turnover. They have developed novel ways to use these basic inputs to model landscape processes and ultimately to assist conservation planning and decision-making. They have an on-going fruitful collaboration with modellers Kristen Williams and Tom Harwood from CSIRO, who have been key contributors to 'adaptNRM'. This collaboration has made the innovations within 3C possible.*

Research Paper

Introduction: NRM is currently faced with the daunting task of formulating strategies and initiating actions to manage remaining biodiversity in the face of complex and uncertain climate. We know that climate is a key factor in determining the spatial distribution of species and ecosystems, and climate change will drive significant changes. Unlike with past episodes of climate change, adaptation by the biota is now confounded by human disturbance – land clearing and alterations to natural ecosystem – which has weakened in situ resilience, depleted the availability of migration destinations and constricted movement pathways that allow biodiversity to move to emerging suitable habitats where they exist.

3C models the climatic envelopes of the present distribution and a range of future distributions of 100 bioclimatic classes and integrates this information with process models that also consider the condition and spatial configuration of the contemporary landscape. The assessment provides insights into the ability of biodiversity to adapt and enables NRM to integrate this knowledge into planning.

Method: In order to represent the complexity and uncertainty that is inherent to climate change and biodiversity, the 3C employed a range of possible climate futures based of 4.5 and 8.5 RCP versions of the: Canadian Earth System Global Climate Model (CAN-ESM2;, the MIROC5 Climate Simulation Global Climate Model; and the Max-Plank-Institute Earth System Global Climate Model (MPI-ESM) climate models. Six sets of envelopes were derived for 100 bioclimatic classes (BCCs) using Generalised Dissimilarity Modelling undertaken as part of AdaptNRM (incorporating a mix of static substrate variables; and climatic variables, subject to each of the six climate scenarios) (Williams 2012; Dunlop & Brown

2008). Climate variables were topographically (statistically) downscaled to a spatial resolution of 250 m, which became the resolution of all subsequent analysis. Vegetation condition (the result of past clearing, landuse and degradation) of the 3C region was developed at 250 m resolution based on remote sensing and inferences arising from landuse and tenure information (Drielsma et al. 2010).

These two key sources of information were used as inputs to a range of process-based biodiversity assessment methods:

1. *The Biodiversity Forecaster (BFT)* (Drielsma et al. 2013; Drielsma et al. 2014) adapted to consider climate change by evaluating future distributions of BCCs against original, pre-European extents. The BFT provided an evaluation of expected biodiversity persistence for the current scenario and for each of the six climate future; and mapped the relative biodiversity benefits of undertaking conservation and revegetation across the 3C based on the evaluations. The separate benefit surfaces were also combined to identify areas of agreement across the scenarios.
2. *The 3Clinks*, based on the Spatial links tool (Drielsma et al. 2007). A combination of the existing cross-scale habitat links methodology extended across the 3C, and a novel approach that maps connections between existing habitat type and future similar habitats (based on modelled climate change).
3. The 3CMP. An adaptation of existing REMP metapopulation persistence methodology (Drielsma and Ferrier 2009) that dynamically links metapopulation dynamics across 5 year times steps of climate change.

Results across the six climate futures and the three methodologies were combined into a climate change impacts evaluation and a range of biodiversity benefits spatial products, maps and interactive visualization and learning tools.

The 3C has been described in a draft peer-reviewed report (Drielsma et al. in prep.)

Data and products were uploaded to the terranova portal where they can be freely accessed. The 3C team currently are assisting NRMs to apply the 3C to their planning.

Results: The 3C evaluation found potential for significant biodiversity loss across the range of climate futures and methodologies with more severe impacts arising from 8.5 emission scenarios. The most severe impacts resulted from the MPI 8.5 future with predicted losses by 2050 of similar magnitude to those due to all past habitat clearing and degradation since European settlement.

Biodiversity benefits of conservation and regeneration when climate change is considered, leads to shifting focus, including shifts to higher elevations, and south-easterly shifts towards the western escarpment of the Great Dividing Range.

Despite the high degree of complexity and uncertainty surrounding the study, strong agreement was found across the range of climate futures and methodologies, providing some confidence to NRM in terms of the risks to biodiversity and the implications for management. There are also likely to be other local refugia and islands of resilience that are not identified by 3C and should also be considered by NRM.

Management Implications

- Biodiversity in the 3C region is under increased risk due to shifting habitat conditions arising from climate change
- The relative benefits of undertaking conservation action and revegetation across the 3C region is shifting due to climate change. 3C provides guidance to refining NRM priorities.
- Good examples of existing priority vegetation should continue to be managed, augmented by native vegetation that will become the destination of shifting biodiversity.
- For revegetation NRM should carefully consider the species and providence used and target locations that will support priority habitat when the revegetation matures.
- 3C should be used alongside other sources of information and knowledge, including local, fine-scale spatial information and local knowledge.

Knowledge Gaps: Actual future climates remain uncertain, not least due to uncertainty over future emissions. Even with some certainty over trends, the actual sequence of climatic events (such as heat-waves, storms and droughts) and resulting secondary effects, such as fire, will drive actual patterns of biodiversity. There is still considerable uncertainty how populations of individual species will respond to future climate. We were unable to incorporate any projected changes in landuse, including possible carbon forestry and geographic shifts to agriculture, which are also likely to significantly impact on biodiversity persistence and the priorities for conservation action.

Acknowledgements: *Thanks to the cluster teams and NRMs for constructive feedback on the project, to reviewers, to Hanieh Saremi for help with map production; John Young for help with XL macro development.*

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Woodland Birds in the GBCMA: Indicators of Habitat Quality at Different Scales

Greg J. Holland La Trobe University
Andrew F. Bennett La Trobe University
Rowan Mott Monash University

Abstract: Extensive clearing of native vegetation results in biodiversity decline. Identifying factors important for the persistence of species in highly modified production landscapes is of critical conservation importance, but is also a great challenge. Not only is the extent and continuity of remnant vegetation altered, but local habitat characteristics can also vary markedly. Thus, various processes may be important for species persistence, and different processes may operate at different scales. Here we identify important aspects of habitat quality for woodland birds at both the landscape- and local site-scale. Twenty 'landscapes' (each 10 x 10 km) were selected for study in the Longwood-Violet Town Plains region of the GBCMA. Birds were surveyed at 10 survey sites per landscape, with survey sites being located in different types of remnant vegetation (e.g. riparian zones, roadsides, scattered paddock trees). A total of 97 species of landbirds were encountered during the study, with 55 of these considered to be dependent on woodland vegetation for survival. The number of species detected per landscape (i.e. combined across all 10 survey sites in a landscape) was positively influenced by the extent of tree cover per landscape. The diversity of vegetation types in a landscape, and the distance to a large (>10,000 ha) forest block were also influential. When data were analysed at the site-scale, more species were encountered at sites containing a mixed woodland community (i.e. Grey Box with Red Stringybark and/or Red Box) and in River Red Gum woodland than in pure Grey Box sites. Fewer species were found at sites where Noisy Miners were frequently encountered. Only two measures of local habitat attributes were influential. In this study, broad-scale factors (e.g. amount/type of tree cover, abundance of Noisy Miners) were a greater influence on woodland bird numbers than measures of local site quality. However, measures of local site quality are likely to be more important when broader environmental gradients are controlled. Results from this work are being used to guide both the management of remnant vegetation and the nature of restoration activities within the GBCMA.

Biography: *Greg Holland is a Research Fellow at La Trobe University whose work is largely focused on the fields of conservation biology and wildlife ecology. Greg's research seeks to address practical, management-relevant questions typically related to biodiversity conservation in human modified landscapes. The processes of habitat loss and fragmentation are of particular interest, including understanding the ways that native species are able to persist in the face of such change. Greg also works on a number of projects seeking to understand the effects of fire on plants, animals and ecosystem processes.*

Extracting Traditional Ecological knowledge out of the Strathbogie archaeological record – Taungurung Clans Aboriginal Corporation & Goulburn Broken Catchment Management Authority

Gaye Sutherland Goulburn Broken Catchment Management Authority
Shane Monk Taungurung Clans Aboriginal Corporation

Abstract: Taungurung Clans Aboriginal Corporation and Goulburn Broken Catchment Management Authority over the last three years have been engaged via the National Landcare Programme in the protection of various aquatic habitats in highland areas of Taungurung Country in north central Victoria. Whilst a key driver of the project has been an improvement in the ecological condition of sites, the project has also made a significant contribution to cultural mapping and collation of Traditional Ecological Knowledge for Taungurung people. The increasing awareness of the Strathbogie Tableland as an important area for Taungurung people has directed further research, in an attempt to derive Traditional Ecological Knowledge from the archaeological record for the Taungurung community. This paper will detail the project, the associated scientific research and the resulting knowledge and benefits that have been derived for the Taungurung people.

To date this research has focused on a large collection of artefacts held on a private property at Highlands on the southern end of the Strathbogie tablelands. These artefacts were found in association with a permanent stream, fed by springs from ground-water aquifer. With the assistance and participation of Taungurung community and the support of the GBCMA, a residue and use-wear analysis study was undertaken by Birgitta Stephenson of In the Groove Analysis Pty Ltd on a sample of the grindstone component of this collection.

This paper explores the Traditional Ecological Knowledge that can be extracted from the archaeological record, including through use of modern scientific methods, to assist Taungurung community in developing a greater knowledge of the significance of the Strathbogie tablelands to their ancestors; including potential patterns of movement through the landscape, responses to climatic change, and resource availability and use in a past environment.

Biography: *Gaye works as Indigenous Natural Resource Management Co-ordinator (cultural heritage) with the Goulburn Broken Catchment Management Authority (CMA) in Victoria. Gaye acts as cultural heritage advisor for the CMA, and is qualified as an archaeologist. In her position Gaye addresses cultural heritage management on waterways and wetlands in the catchment for the authority. Gaye also manages projects that build capacity for Traditional Owners to care for Country, and that facilitate the collation and exchange of Traditional Ecological Knowledge through partner projects with Traditional Owners within the Goulburn Broken Catchment.*

Shane Monk is a Taungurung man born in Healesville in the early 70's. He grew up in Healesville and enjoyed a happy childhood with his family. He was fortunate enough to have his mothers guidance from an early age to teach him his culture, as she was passionate about their heritage, and worked tirelessly for the rights of aboriginal people.

Shane started a plumbing apprenticeship at 15 and went on to work in that trade for the next 22 years. It was not until his mid 30's that Shane embraced his heritage and began working with Taungurung as a field officer and later doing his Certificate 4 in Cultural Heritage. This led Shane into his current position with GBCMA, where he has the ability to continue with his love of culture and country. The knowledge and training Shane has received has helped him to understand the Alpine High country, both ecologically and culturally. The GBCMA has been pivotal to Shane's life in learning and becoming the man he is today.

The Shepparton Irrigation Region Salt Water Balance Project – Revisiting Shallow Water Table Threats in a More Variable Climate

Terry Hunter Goulburn Murray Water

Abstract: With over 30 years of living with and managing salinity in the Shepparton Irrigation Region (SIR) we are still learning about what the risks are to the region and how they should be managed into the future. Research into the salt and water balance of the SIR has used observed data to better understand the hydrogeology of the catchment. This research has confirmed that salinity will always be a threat to the productive capacity and environment within the SIR regardless of how much is invested into upgrading irrigation infrastructure and improving water use efficiency. The research results are informing development of an adaptive management approach to help protect the significant investment in modernised irrigation, as well as the SIR's environmental features, from the potential impacts from salinity.

Biography: *Terry is the Strategic Drainage Programs Advisor with the Drainage Systems Team within Goulburn-Murray Water. He has over 35 years' experience with GMW and its predecessors working on groundwater and salinity investigations and implementation programs.*

You could say that his previous biggest claim to fame is; as the man who hand drew the very first Shepparton Irrigation Region Water Table map back in 1982. That was until now! Here to present his "Magnum Opus" (The Salt & Water Balance project) is Terry Hunter. Sit back and be astounded!