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ABSTRACTS

ORAL PRESENTATIONS

1

Climate Change 2016: The Challenge for Limnology

Will Steffen[1]

1. Australian National University, Acton, ACT, Australia

The talk begins with a general overview of observed changes to the climate system over the past century or so, and the evidence that these changes are primarily due to the human emission of greenhouse gases. We then focus on the changes to the global water cycle that are associated with climate change, including changes in atmospheric water vapour content, in precipitation patterns and in evapotranspiration. The focus then shifts to Australia, where we explore the observed changes to the hydrological cycle in Australia, examining the evidence for the influence of climate change on many of the observed changes. We then turn to the future and outline the range of projections for alternations to Australia's water cycle through the rest of this century, depending on the amount of additional greenhouse gases that are emitted into the atmosphere. The emphasis then turns more directly to the relationship between human societies and the water cycle; that is, the distribution of our population, agriculture, industries etc. is, in large part, determined by the nature of the water cycle. As the water cycle changes, this is already putting generic pressures on human societies, as clearly evident in several parts of the world. Finally, we conclude with a brief examination of climate change in a broader, long-term Earth System perspective.

2

Evolution of environmental flows in a changing world

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Climate change and other forms of hydrologic non-stationarity are creating new challenges for the science and effective practice of environmental flows. Foundational assumptions underlying standard e-flows approaches are based in the notion of a reference state, both hydrologically and ecologically. Shifting statistical baselines in hydro-ecosystems due to increasing water demand and climate change require a re-thinking of the methods and measures of success in e-flows. The prevailing paradigm of a restoration focus based on statistical averages of long-term hydrologic records and presumed equilibrial ecosystem states is giving way to a forward-looking adaptation approach, where hydrosystems are viewed as event-driven and ecologically dynamic. New concepts about managing for resilience or against failure are emerging to grapple with climatic non-stationarity. Emerging imperatives for e-flows are broadening of targets (to include states, rates and traits), embracing uncertainty in endpoints, and adopting a more process-based (as opposed to statistical) approach that utilizes monitoring to gauge success in terms of system trajectories in an adaptive fashion. Given the limited water typically available for e-flows, prioritization of e-flows interventions is increasingly needed and careful targeting of e-flows is necessary to support economically efficient yet ecologically effective management. Beyond these concerns, the traditional e-flows focus on at-a-site restoration needs to be expanded to a broader whole-basin water management perspective to address the scales of human alteration of river systems relevant to long-term freshwater conservation.

3

Managing freshwater values in a year of climate extremes

Carolyn Maxwell[1]

1. Hydro Tasmania, HOBART, TAS, Australia

Hydro Tasmania manages water from 35% of Tasmania's catchments across a range of multiple uses. In the past 10 years, two extreme weather events have resulted in very low water levels in our system. Extreme weather events have brought both record-breaking low and high rainfall events within the past twelve months. The challenges presented were most acute in yingina/Great Lake, which is home to two Federally-listed and nine State-listed threatened species. How did the low lake level events in yingina/Great Lake between 2007 and 2015 differ? What are the ecological questions that arose for water management? How did science and uncertainty interact and inform decision making? What challenges do climate change and climate variability pose for the future management of ecosystem values in this lake?

Results from qualitative, statistical and quantitative dynamical ecological modelling, research into the life history traits of resident species and data on population structure were used to inform assessments of ecological disturbance. Downscaled climate change modelling and dendrochronology research inform the context within which we will manage future challenges to this ecosystem.

4

Macroinvertebrate assemblage changes along a gradient of water temperature in a thermal-spring fed stream as an analogue for the impacts of climate change

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Thermal artesian springs are characterised as having a minimum discharge water temperature of 36.7^{0}C. However, the often high temperatures measured at the 'vent' decrease by convection as water flows outward. This natural gradient of water temperature from a thermal spring vent as it flows out into a spring-fed stream provides a unique opportunity to investigate the influence that temperature can have on aquatic biota. In such rare situations most other drivers of ecosystem patterns and processes (e.g. flow regime, riparian cover, substrate composition etc.) remain constant while temperature alone varies. Therefore, this represents a natural analogue for the effects of temperature increase from global warming and permits predictions to be made of the effects of this on stream ecosystems.

This study investigated the relationship between the aquatic macroinvertebrate communities and a gradient of water temperature associated with outflows from Talaroo spring complex in North Queensland. Over 170 m of stream length the water temperatures ranged from 47.9^{0}C near the vents to 26.0^{0}C downstream closer to

the confluence with the Einsleigh River. Sixteen macroinvertebrate samples were collected along the stream length. A total of 41 different taxa of macroinvertebrates were recorded. Taxa richness ranged between 1 and 21 at sampling locations along the gradient, with a generally progressive loss of taxa as temperature increased. The normal tolerable temperature limits for multicellular organisms is approximately 45^0C so it was surprising to collect specimens of ostracods, hemipterans and dragonflies at locations with higher water temperatures. Analyses of macroinvertebrate assemblage data showed a significant relationship with water temperature. The changes and general loss of taxa with increasing temperature are likely to be associated with their thermal tolerance limits

The results suggest increases in water temperature from climate change may cause a measurable reduction in taxonomic richness.

5

Predicting climate change effects on dormant aquatic invertebrates in intermittent rivers

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Understanding ecological consequences of climate change is critically important but difficult, because changes include environmental warming as well as alterations to hydrology and biogeochemistry and interactions with other stressors. In river systems dormant aquatic invertebrates remain viable in riverbed sediment during dry phases, forming a source for recolonisation during wet periods. The likely impacts of climate change on the viability of this recolonisation source remains poorly known, due to the complexity of effects. We used a microcosm experiment with a simple warming treatment to look at the interactive effects of warmer and drier conditions on river invertebrate diversity in isolation. Extended drying and increased temperatures had a negative effect on diversity and shifted assemblage composition, particularly for temperate rivers, despite rivers in semi-arid regions sampled having similar hydroperiods. There was no interactive effect of warming and extended drying on invertebrates, despite a negative effect on sediment moisture. Semi-arid rivers had higher potential for dry riverbeds to act as a source for recolonisation under climate change, given high resistance of invertebrate assemblages in sediment with low moisture levels and elevated temperatures. Regardless of the complexity of real world interactions and difficulties scaling microcosm experiments, regional differences in response to climate stressors allows prediction of differing limits to adaptation.

6

Freshwater invertebrate life history traits for surviving desiccation

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In many regions, climate change is prolonging dry periods in rivers and wetlands, exposing freshwater invertebrates to increased periods of desiccation. Invertebrates show a range of strategies for surviving desiccation, but the effects of the degree of exposure to desiccation on the expression of particular traits is unknown. We synthesized existing information on the desiccation-responses of freshwater invertebrates to examine the flexibility of these survival strategies and the relationship between strategies and the degree of desiccation to which individuals are exposed. We focused on desiccation at the small spatial scales experienced by individuals and clarified the terminology used to describe resting stages present during dry periods. We present a key to terminology used for different forms of dormancy to support the use of appropriate terms. All invertebrate taxa showed a range of strategies for surviving desiccation. Sometimes, different traits were expressed among different populations of a species however it is unclear how many species show multiple desiccation-response strategies. Many crustacean taxa showed physiological dormancy responses to desiccation that enabled survival for long periods (years). Insects often rely on emigration from drying waterbodies as flying adults, or on larvae occupying damp refuges on the benthos. Altered water regimes may alter the phenology of desiccation responses,. However, there is limited empirical evidence demonstrating the flexibility of, or limitations to, expression of these survival strategies and their potential fitness costs, limiting our ability to predict the effects of prolonged drying on invertebrate biodiversity.

7

Temporal shifts in littoral fish assemblages from shallow lakes following prolonged drought

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Global climate shifts are likely to increase the frequency and severity of drought events in semi-arid and arid regions. These extreme hydrological events act to significantly shift the functional groups present in a given ecosystem. Abundances of many aquatic fauna have significantly declined, some near the point of extinction, as a result of extended drought. For fish, it is assumed that drought favours tolerant generalist species over more specialist species but questions remain as to the mechanisms of persistence and timescales over which these changes occur. Despite flooding that broke the Millennium Drought in 2010/11 in the Lower Lakes, South Australia, the once-abundant and diverse assemblage of native small-bodied fish had not recovered in recent years. We compared the post-drought littoral fish assemblages in the two lakes, which differ in hydrology and habitat availability. Catch per unit effort from fyke nets showed that common small-bodied fish were more abundant in Lake Albert than Lake Alexandrina. For all years sampled, Lake Albert showed a higher catch per breeding season than Lake Alexandrina. The total small-bodied fish catch per site for both lakes showed a negative trend through time although the ratio of alien to native fish also decreased through time. This trend in ratio was reversed in recent sampling, largely driven by an increase in the number of juvenile and small redfin perch (*Perca fluviatilis*). There were differences in the species present, their abundances and the functional groups between lakes. This study documents an ongoing decline in native small-bodied fish assemblages despite the end of drought conditions and indicates that management for alien fish species may be required before recovery of that assemblage is likely.

8

Facilitating on-the-ground climate change adaptation for aquatic ecosystems: what role scientists?

Jane Chambers[1]

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At ASL over the years we have been lambasted at intervals about how scientists do not communicate our science well to the people that make it happen – politicians and managers. As a scientist that has recently focussed attention on attempting to facilitate climate change adaptation of our aquatic ecosystems, I have been engaged in a variety of modes of communication with different audiences including large forums, workshops, talks, development and delivery of tools and risk assessment frameworks, web modules and interpretative guides. In my experience, there is a disconnect in the topics, spatial and temporal scales of information that managers/community want and what (and what can) scientists do. As climate change is happening so fast, our ability as a society to adapt to a new regime is lagging and the capacity to research, synthesise and uptake new information is not well resourced, especially as regards the inland aquatic environment. The issue is not necessarily communication per se but the need for a frank discussion and resourcing to define workable adaption pathways at appropriate scales. Some key elements

are the adoption of a paradigm shift in natural resources policy and management, understanding the role of science in risk assessment, the impacts of multiple stressors and climate adaptation strategies from other sectors, an understanding of appropriate scale both for understanding and managing the issue, and the lack of a coordinated approach and appropriate foci for climate change adaptation. We all want to save our aquatic biodiversity and ecosystems. In this talk I suggest what are our strengths and weaknesses as scientists, and how we can use this knowledge to best effect, both individually and as a society.

9

Evaluating Basin-scale significance of area scale outcomes of environmental flows

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The Commonwealth Environmental Water Office (CEWO) Long Term Intervention Monitoring (LTIM) project seeks to evaluate the outcomes of the management of Commonwealth environmental water and its contribution to Basin Plan objectives. The evaluation process is one step in the adaptive management of Commonwealth environmental water designed to support both the CEWO reporting and adaptive management obligations. This LTIM program represents a collaboration between 6 Government Departments, researchers from 6 Universities, consultants and natural resource management agencies. Commonwealth environmental water is allocated to specific high value assets to achieve specified outcomes. A core component of the evaluation is to determine the significance of these short-term areas scale outcomes in terms of progress toward achieving Basin scale objectives and targets. This presentation will describe the framework that has been developed to support this component of the evaluation and the outcomes of the first year of the evaluation of monitoring undertaken in 2014-15. A key consideration within the evaluation is that area scale outcomes are only expected to become apparent over the medium to long term as environmental flows initiate changes that take time to manifest at the larger scale. An example of this would be fish breeding where subsequent recruitment and dispersal would be expected to take time. The framework described provides a basis for considering the significance of changes in condition at the Basin scale, however, further work will be required to inform judgements for the different indicators included in the LTIM project

10

Hydrological Outcomes of Commonwealth Environmental Watering actions across the Murray-Darling Basin

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Environmental flows are delivered by one or more discrete flow interventions (or watering actions) taking the form of releases from storages, restrictions on diversions, or diversion of water into alternate flow paths and off-stream habitats. Generally, hydrological and ecohydraulic responses are the first link in the causal chain leading to an ecological outcome. Like all ecological intervention monitoring, evaluating hydrological outcomes must address the methodological challenges of detection and attribution. Whilst these challenges may seem trivial for individual discrete watering actions such as pumping water into a wetland, there are serious challenges when hydrological targets are distant from the point of intervention and multiple actions are considered across a large river basin. This presentation discusses these challenges in the context of the Long Term Intervention Monitoring Program for the Commonwealth Environmental Water Office in the 2014-15 water year. We present the methods and outcomes of the commonwealth program including contributions to baseflows, flow freshes and wetland filling across the basin.

11

Vegetation outcomes of Commonwealth Environmental Watering actions across the Murray-Darling Basin: consideration of scale and level of organisation

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2. Australian Rivers Institute, Griffith University, Nathan, QLD, Australia

Vegetation responses to flow regimes are influenced by both the temporal and spatial scale at which responses are assessed as well as the level of ecological organisation. The distribution and abundance of plant species is influenced by hydrological conditions in the short-term (such as duration, depth and rates of change) as well as longer-term hydrological conditions such as flood frequency and time-since-inundation. Equally, the distribution and abundance of plant species in space and time, in turn, determine the composition and structure of vegetation communities and assemblages of communities, referred to here as 'vegscapes'.

The Long Term Intervention Monitoring (LTIM) Program aims to assess responses across a range of scales. The Vegetation Diversity component of the Basin evaluation uses data collected by Monitoring and Evaluation Providers at Selected Areas, in combination with data and analyses made available by other Basin Matter components, particularly Hydrology and Ecosystem Diversity. The aim is to evaluate the effects of Commonwealth environmental water on the diversity of plants and vegetation communities with respect to: plant species-level, vegetation community-level and vegscape-level responses.

Using the first year of data this presentation discusses the challenges and opportunities in assessing vegetation responses at a Basin-scale, including spatial variability in diversity responses, complexity in the range of watering regimes / events, heterogeneity responses at landscape scales and the ability to predict responses in unmonitored areas.

The LTIM Program is funded by the Commonwealth Environmental Water Office.

12

LTIM – If it ain't wet, it doesn't help – Findings from Year 1 Stream Metabolism Measurements

Mike Grace[1]

1. Monash University, Clayton, Vic, Australia

This talk will present some of the major findings from the first year (2014-15) of stream metabolism measurements in five of the selected areas (catchments) in the Murray-Darling Basin. This work was performed as part of the Long Term Intervention Monitoring program funded through the Commonwealth Environmental Water

Office. With a few exceptions, 2014-15 was characterized by relatively low flows. This resulted in no broad, discernible relationships between flow and rates of gross primary production (GPP) or ecosystem respiration (ER). It is hypothesized that this lack of a significant relationship is primarily due to the additional water remaining within the confines of the main river channels rather than reconnecting backwaters and perhaps the floodplain. In this context, the relationships between flow, nutrients and light will also be briefly described. While there were some regional and seasonal differences, rates of GPP and ER were at the lower end of the 'normal range' when compared to international data. But perhaps this is simply standard behaviour for streams in the MDB.

13

Effects of the *Chrysosporum ovalisporum* bloom on water quality in the Edward-Wakool system- comparison with Long Term Intervention Monitoring data.

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3. Water Studies Centre, Monash University, Clayton, VIC, Australia

The Edward-Wakool river system is a major anabranch of the Murray River and has been intensively studied since 2010, including as a study site for the Long-Term Intervention Monitoring program. This site was impacted by a major bloom of the cyanobacteria *Chrysosporum ovalisporum* during February-June 2016. Water quality parameters including dissolved oxygen, temperature, pH, nutrients, dissolved organic carbon, carbon spectroscopic properties, chlorophyll-a and algal biovolumes were measured weekly and compared to baseline data from previous seasons. Water quality was strongly impacted by the bloom, including increases in total nitrogen and total phosphorus following the onset of the bloom and intermittent rises in NO_x and ammonia. Changes in dissolved organic carbon were not well correlated to the absorbance or fluorescence of the water samples and are not reliable predictors of bloom collapse.

14

Evaluating the population-dynamic consequences of fishes to flow within LTIM

Rick Stoffels[1]

1. CSIRO, Wodonga, VIC, Australia

An objective of the Commonwealth Environmental Water Office's Long-Term Intervention Monitoring Project is to develop models that link fish population dynamics to flow events and regimes. In this talk I will explain why this objective was deemed necessary, highlight the risks, and explain how we're managing those risks. Within LTIM the models will be used to project long-term population response to multi-year flow scenarios; project population response in areas where flows are delivered, but where fish data are not being collected; lift evaluation of flow response beyond that of the individual process (e.g. spawning); characterise uncertainty; and facilitate intervention analysis. While the approach we're taking follows best practice in adaptive management, it is untested within the Murray-Darling Basin and so may therefore be considered risky by stakeholders. LTIM has managed this risk by investing in a diverse fish monitoring portfolio and undertaking precision analysis to determine methods are fit for purpose. I will present some results of those precision analyses demonstrating how the LTIM methods have greatly improved our ability to estimate population structure.

15

Knowledge of past climatic and hydrological events for a better management of water resources

Patrick De Deckker[1]

1. Australian National University, Canberra, ACT, Australia

Climate is ever changing and we must acknowledge this fact. Hence, we need to better understand the range of climate variability as well extremes, and in order to better comprehend changes, we can look at the past. The Holocene, which spans the last 12,000 years, is a good reference point as this period witnessed significant and broad changes, going from very wet years to prolonged drought all occurring when humans were present in Australia. The arrival of Europeans also dramatically changes the environments and we must identify these changes so as to better understand how aquatic systems, including groundwater, responded to such modifications.

We have now been able to unravel the differences between human-related changes from natural ones on aquatic systems, and have been able to document the timing and rates of changes during the Holocene. These findings enable us to comprehend the scale of possible changes and these can be of great value to environmental managers. Nevertheless, there are new 'unknowns' which we are already facing, and these are related to significant landscape alterations, the increase of atmospheric CO2 which can modify water chemistry and introduction of exotic biota and chemicals in our aquatic systems.

I will document our current knowledge of selected lake records using geochemical signatures of biogenic carbonates (principally ostracods) that show the scope of past changes in eastern Australia. I will also use the geochemical records of riverine clays obtained from a core taken offshore the Murray mouth to document past river regimes in the Murray Darling Basin spanning also the Holocene. Finally, I will remind the audience that SE Australia has entered into a progressively arid phase that commenced some 6,000 years, with serious implications for aquatic systems and their biota.

16

A 7500 Year Rainfall Reconstruction for Drought-Prone South-East Queensland Indicates we haven't seen the worst of it

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South-east Queensland is a major population centre and experiences severe droughts. During the 'Millennium Drought' (2001-2009), rainfall deficit reached 1500 mm and water storages fell to c.20% capacity. Stochastic modelling suggested that while worse droughts could occur, likelihood is less than 1:10000 years.

To evaluate this expectation, we reconstructed regional rainfall over the past 7500 years. We used the carbon isotope composition of the leaves of the tree Melaleuca quinquenervia, collected monthly over eleven years, to accurately model rainfall from leaf isotope composition, and applied this to a long sequence of these leaves found preserved in lake sediments. Results accurately represented decadal-scale rainfall patterns when reconstructed and measured rainfall overlapped.

The Millennium Drought was the driest decade in 1500 years, although earlier, but less severe, dry periods lasted centuries. Thus, extended periods of rainfall deficit have occurred more frequently than 1:10000 years. Moreover, the c.120 year instrumental rainfall record is atypical of the past 1500 years. This information has great potential to inform water policy and climate change predictions in south-east Queensland.

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Salinity - An intermittent feature of the Holocene landscape inferred from lake/wetland sediments in South-west Western Australia

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A mosaic of vegetation types and numerous lakes/wetlands, which vary from freshwater to saline, exist within the highly biodiverse region of South-west Western Australia (SWWA). In many parts of this region dryland and stream salinity is a major concern to farmers, land management and conservation agencies. Numerous studies have investigated the causes, mechanisms, nature and extent of contemporary dryland and stream salinity in the region, as well as remedies to alleviate it. However, there is currently no palaeo (pre-historical) record of salinization for the SWWA.

This research investigated early to late Holocene (i.e. pre-historical) salinity, vegetation and fire history of a study area (40km NW of Mt Barker, SWWA) to gain insight to the complex processes that have driven palaeoenvironmental variation in the region. Stratigraphic sequences of lake/wetland sedimentary cores from the study area indicate environmental variation in the landscape through time but shed no light on the nature or drivers of this observed variation. Multi-proxy indicators, in particular, fossil diatoms, geochemical markers, fossil pollen and fossil charcoal extracted from the lake/wetland sediments have been used to generate stand-alone palaeoenvironmental records. These records provide information about past variation of the lake/wetland salinity and geochemistry, the vegetation and the fire regimes enabling an inferred palaeoenvironmental reconstruction for the landscape of study area, using analogies to present day conditions and processes.

It is anticipated that these prehistorical records will provide a useful baseline for land management and conservation agencies that will furnish insights into the nature and degree of palaeo salinization of the lakes/wetlands and landscape of the study area. Such insights are useful when determining present day targets for the rehabilitation of areas affected by dryland and stream salinity in SWWA as salinization has been an intermittent feature of many of the lakes/wetlands and landscape of SWWA.

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Size, shape, spatial position and sensitivity. Do billabong morphology and position in the landscape control resilience to the effects of land use and hydrological change?

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Billabongs are diverse and productive elements of riverine landscapes, and likely play an important functional role as refugia in these highly variable environments. There is strong historical evidence that billabongs have been negatively affected by a range of human activities, including catchment disturbance and river regulation. Improved catchment management and the delivery of environmental water have the potential to mitigate the negative effects of land use and hydrological changes, however, the effectiveness of these measures will require a good understanding of what the critical stressors are and of how and why their influence might vary within the diverse array of billabongs that exists across riverine landscapes. Many palaeo records from the Murray-Darling Basin show evidence of abrupt loss of submerged plants associated with the beginning of European occupation, however, this change is not consistent and there is evidence of a geographical pattern in response types: billabongs on the Upper Murray and smaller tributaries show persistence of submerged plant communities over this period; billabongs from the middle Murray show almost universal loss of macrophytes; while billabongs from the Lower Murray show mixture of macrophyte loss, persistence of macrophytes and an unstable condition where there is no evidence of submerged macrophytes persisting for long periods. It is unclear whether this pattern reflects spatial variation in stressor intensity or underlying variation in the resilience of individual billabongs due, for example, to morphology, hydrology or location with respect to the main channel. This study explores the relationships between the degree of change in billabong ecosystems associated with European occupation and a range of morphological and landscape measures in an effort to determine the critical factors controlling resilience to the effects of land use and hydrological change.

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Water quality changes in Murray River wetlands – a neglected driver of condition decline?

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Much of the focus of wetland restoration in the Murray floodplain has been underpinned by the focus on river flows as the cause of system degradation. A longer term view of ecosystem condition inferred from sediment cores identifies the flux of sediments, salts and nutrients as significant supplementary drivers of wetland change. There is clear evidence for increasing sedimentation rates and salinization from early after European settlement. The regulation of the river increased the extent of change with the fossil diatom assemblages in all of the 50+ sites examined reflecting a degraded state relative to the 'natural' baseline. Sedimentation rates often exceed 1 cm/yr and this high flux in fine sediments has increased the turbidity of the most sites. There is evidence for the widespread replacement of submerged macrophytes with phytoplankton consistent with stable state change models. A spatial analysis of paleolimnological records has enabled the identification of a wetland typology of vulnerability to this shift with middle reach wetlands most at risk. Investment in the mitigation of water quality decline would supplement the benefits that may accrue from the provision of environmental water.

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Extending memory - providing long-term environmental change from palaeo-records of estauries to inform more appropriate management.

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Throughout southeastern Australia, management authorities are often challenged by public memory regarding what the 'natural' or ideal state of coastal wetland environments are. This is particularly exacerbated when local residents recall the record high rainfall years of the mid 1950s-60s and consider this to be the optimal state. Another obstacle may be the listing of a wetland under the Ramsar Convention, aimed at preserving the ecological character of significant wetlands. However, the condition at the time of listing may be far from pristine and thus the management guidelines recommend conserving a degraded or modified state.

Although meteorological records have been collected from weather stations for up to the last 150 years, condition reporting on Australian estuaries has only been considered in the last 30-40 years, at best. In addition, all estuaries considered here have been heavily impacted by changes in land use practices and hydrological modification since European colonisation in the mid-19th century.

Here we apply a combination of palaeocological methods to determine primarily the salinity, but also turbidity, nutrient flux and trophic state changes within a suite of estuaries along the southeast Australian coast. We use both ostracod assemblage changes and shell chemistry ($\delta^{18}O$, $\delta^{13}C$), diatom assemblages, and sediment geochemistry (iTRAX – XRF, $\delta^{13}C$, $\delta^{15}N$, C/N). These combined methods act to determine the state of the estuaries, including their natural variability, prior to extensive catchment modification. The sediment records also preserve the rate and trajectory of change of each of these wetlands, both in terms of management practices and climatic variability.

In each of these cases, our results have been taken into consideration to modify modern wetland management. Although it may not be possible – or desirable – to return to pre-impact conditions, the use of combined palaeoecological methods allows informed decisions about estuarine management to be made.

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Understanding the effects of direct and indirect pathways of climate change on Tasmanian Cladocera

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The drivers of long-term (supra-centennial) dynamics in Southern Hemisphere aquatic ecosystem dynamics are poorly understood, particularly in relation to the influence of climatic change. Direct influences of climate on aquatic systems include temperature change and lake level fluctuations, but what of the response of aquatic systems to changes in the surrounding terrestrial environment? Long term drivers of landscape dynamics, such as vegetation change and soil/catchment dynamics, are often overlooked when considering long-term aquatic ecosystem dynamics, and ecosystem response to climate is typically the main focus. To fully understand how aquatic ecosystems are affected by climate we need a better understanding of the complex processes driving their dynamics through time, including both the direct (eg. climate) and indirect (eg. terrestrial vegetation shifts) pathways that cause change. Our aim is to better understand the pathway(s) in which climate influences aquatic ecosystem change. We present a Holocene multi-proxy palaeolimnological record from Paddy's Lake, northwest Tasmania, Australia, that comprises pollen, organic and inorganic geochemistry, charcoal and cladocera as a means of understanding the relationship between terrestrial and aquatic ecosystem processes and climate. The cladocera record is the first record of its kind in Tasmania. Our data demonstrates (1) that vegetation and fire activity surrounding Paddy's Lake closely track climatic variability, principally the El Niño Southern Oscillation; and (2) that changes in aquatic ecosystem dynamics (cladocera) are driven both directly and indirectly by climatic change during the Holocene.

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How unusual is the Big Dry? Evidence from the Victorian Lakeland

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Lakes respond to changing hydroclimate through changes in lake level which induces changes in water chemistry, habitat availability and so to biota. The fossilised evidence of different lake conditions are archived in the sediments which accumulate through time. The Victorian Lakeland is among the most intensively studied regions of the world in terms of paleoecology. Long term records from these lakes show great hydroclimatic variability, including multi-decadal droughts, in the past. Some records show drought to have been a major factor in switching lake condition before the arrival of Europeans. However, the Big Dry appears to be a significant event at centennial, and even millennial, timescales and most lakes are now at the margins, or outside, their long term range of variability. This is consistent with observations of the anomalous state of the Southern Annular Mode and suggests that the Lakeland is on a trajectory towards a drier future.

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Rehabilitating wetlands and their carbon sequestration capacity

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The biological capture of carbon dioxide (CO_2) by biosequestration is a central mechanism for reducing atmospheric CO_2 concentrations. As Australia seeks to capitalise on biosequestration opportunities, interest is growing in restoring inland wetlands, which may be important carbon sinks, for offset purposes. Wetlands have often undergone widespread alteration via agricultural and urban development, and water extraction and degradation of wetland soils can trigger the release of ancient,

stored carbon into the atmosphere, turning them into carbon sources. We investigated whether rehabilitating wetlands can restore carbon stocks and sequestration capacity in the central Murray region, NSW. We applied a 'space-for-time' analysis, capitalising on the region's 20-year legacy of wetland rehabilitation. For 12 wetlands, soil core samples were analysed (n = 90) for elemental carbon to quantify carbon stocks, and ^{210}Pb age-dated to determine carbon accretion rates. Wetland carbon stocks increased linearly with time since rehabilitation. Importantly, this relationship existed despite carbon stocks also being influenced by other factors that could not be controlled, which had been expected to limit the detectability of carbon gains (e.g. land-use prior to rehabilitation, soil type, frequency of water inundation and elevation). Land-use prior to rehabilitation explained significant variation, with wetlands that were previously both cropped and grazed having higher carbon stocks than wetlands that were previously subject to grazing only. Carbon stocks in rehabilitated wetlands were similar (87 Mg C_{org} ha^{-1}) if not higher than those reported for other freshwater wetlands in Australia, suggesting that carbon sequestration capacity can be restored within reasonable (5 – 20 yr) time frames. Based upon preliminary data on soil accretion rates, estimated carbon sequestration rates at the sites studied are between 1.0 and 4.1 Mg CO_2e ha^{-1} yr^{-1}. Our study provides promising experimental evidence that wetland rehabilitation can help restore the carbon sequestration capacity of wetlands.

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Carbon sequestration by wetlands: vulnerability and opportunity

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Wetlands supply a range of values for ecosystem function and human well-being. Yet as climate change rapidly becomes a reality, wetlands are increasingly drawing attention for a different reason: they have vast potential for storing atmospheric carbon. So far, investigations of the carbon sequestration capacity of wetlands have concentrated on coastal or 'blue carbon' wetlands (i.e. seagrasses, saltmarshes, and mangroves). But in fact, estimates identify inland wetlands as the earth's largest store of terrestrial carbon; they contain 33% of the soil carbon pool, yet occupy a mere 6–8% of the land surface. Despite this potentially extreme worth, wetlands have historically been underappreciated; since European settlement, Victoria has seen widespread losses of wetlands through agricultural development, urban development, and water extraction. Crucially, wetland loss and degradation has two major consequences: the loss of carbon sequestration capacity; and the potential release of ancient carbon back into the atmosphere – an impact that effectively transforms wetlands from carbon sinks, into carbon sources. The purpose of this study was to survey the carbon stocks of Victoria's inland wetlands (n = 103). At least 10 wetlands were chosen within each of the ten Victorian Catchment Management Authority regions and from a range of wetland types. Sampling involving taking soil cores (to 1 m; n = 5 cores per wetland) and analysing the organic/inorganic carbon content (via MIR and a CHN analyser) at different depths (n = 6) in each core. Average sediment carbon stocks were highest in alpine peatlands, and were significantly lower in permanent open freshwater wetlands. Using this data, we have estimated significant carbon emissions that may have resulted from wetland loss since European settlement. From here, I will also highlight opportunities to avoid carbon emissions, and to make significant carbon offsets, through protection and rehabilitation of wetland habitats.

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The effects of climate change on cryptic biomass in temporary lakes

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Temporary lakes play a vital habitat role in the semi-arid zone of the Murray-Darling Basin. Aquatic microcrustacea and aquatic plants persist in dry lake beds by virtue of resting propagules: eggs and seeds. As lakes fill, microcrustacea and plants emerge, providing an important food source for larger animals including waterbirds, frogs and fish. As waters recede, resting propagules are deposited. The status of cryptic propagules across dry lakebeds in relation to inundation regimes, with implications for ecosystem foodwebs, is poorly understood. Under a drier future, spatial filling extent, duration and frequency may be reduced in Australia's semi-arid zone, leaving some propagules high and dry. We examined differences in microcrustacea and plant biomass emerging from sediments across a gradient from lake centres to shorelines to determine patterns in biomass, abundance and diversity. We used an ex-situ setup of microcosms from five temporary lakes in the Paroo Basin of north-western NSW. There were differences in microcrustacea and aquatic plants at different filling levels. The results have implications for the effects of climate change on aquatic organisms, and are also relevant for environmental flow management in the Murray Darling Basin. These results can inform flow duration and frequency in relation to a key component of the foodweb: aquatic microcrustacea and plants.

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Vegetation outcomes: what are we seeking and why?

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Maintaining or improving vegetation condition or diversity are objectives of environmental water management common to wetlands across the Murray-Darling Basin. But what do we mean by an improved condition or diversity outcome and why do we care? The way we measure and assess condition and diversity outcomes is dependent on scale and the desired vegetation function. Here we conceptualise the need to consider vegetation responses across multiple scales of organisation (i.e. individual plants, populations, communities, landscapes/vegscapes) and multiple types of vegetation traits (e.g. compositional, structural and process). We also discuss the way in which interacting drivers may constrain the expression of vegetation traits. We provide examples of the way the conceptual framework may be applied to aid in the planning and assessment of vegetation outcomes at a range of scales and for a variety of functional outcomes.

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The decline of *Pseudoraphis spinescens* (Moira Grass) grasslands at Barmah Forest, Victoria: current distribution and implications for floodplain conservation

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Floodplain grasslands are highly productive ecosystems that are becoming increasingly degraded and fragmented because of changes to natural flood regimes. In southern Australia, one of the largest floodplain grasslands occurs at Barmah Forest, Victoria. These grasslands are dominated by *Pseudoraphis spinescens* (Moira grass), an ecologically important mat-forming grass. Although *P. spinescens* was once widespread in treeless areas within the forest, there has been a dramatic decline in its extent, particularly since the Millennium Drought (2001–09) and subsequent unseasonal and prolonged La Niña-associated flooding from late 2010 to 2012. In this project we mapped and quantified the distribution of *P. spinescens* to determine its current extent, and to investigate the response of the grasslands to environmental flows. Our detailed on-ground surveys found only 182 hectares of *P. spinescens* grassland remaining in treeless areas of Barmah Forest, representing ~12% of the total area of treeless plains and lakes. Critically, just 51 hectares of the thick monospecific *P. spinescens* swards that were a historically important part of the floodplain were located and mapped. Although there was a small increase in the area of *P. spinescens* in some treeless areas following a favourable flood season in 2013–14, the boundaries of most grassland patches remained relatively stable. Potential drivers of the overall decline in *P. spinescens* across Barmah Forest include the direct and indirect impacts of altered flood regimes, drought, grazing pressure, and seedbank decline. We discuss strategies for managing these floodplain grasslands, including the use of environmental flows to provide more natural flood regimes, and the challenges of grassland restoration in a regulated and highly modified ecosystem.

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Watering requirements of iconic floodplain vegetation species of the Lower Balonne Floodplain.

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Floodplain vegetation is an important component of the ecology of the Lower Balonne Floodplain system in the northern Murray Darling Basin. Dominant vegetation species in the area (the trees Coolibah, River Red Gum, Black Box, and the shrub Lignum) are all known to depend on flooding to maintain plant condition, with species-specific tolerances for both the maximum period between floods and the duration of inundation during such events. However, most of the knowledge of these requirements is derived from research undertaken in the southern Murray Darling Basin in rivers with climatic and hydrological regimes far removed from those of the Lower Balonne Region. Previous investigations in the Northern Basin have suggested that flooding of a certain frequency to maintain the condition of a particular species to be over-simplifications of a much more variable dynamic.

A multi-year project being undertaken by the Queensland Government as part of the larger Environmental Watering Knowledge and Research (EWKR) project is aiming to better define the water requirements of floodplain vegetation in the Lower Balonne. The overall approach of the project is to combine analysis of long-term time series of vegetation condition, as measured from satellite images, with patterns of water availability from floods, rainfall and groundwater. Vegetation responses to water availability are then being interpreted in relation to mapped landscape characteristics. Results are being validated by detailed field measurements at selected field sites using techniques such as stable isotope analysis and measurement of sap flow to quantify vegetation water use and geophysics to characterise soils, identify shallow aquifers and explain recharge processes of soil water and groundwater.

Preliminary results presented here suggest that some portions of the floodplain landscape, where asset vegetation species dominate, are likely to be utilising shallow groundwater and that flood dependency is mediated by availability of other water sources.

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Does floodplain watering improve understorey vegetation response to natural flooding?

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Watering areas of floodplain has become a widely adopted management intervention during periods without flooding. The aims of these interventions are to improve overstorey condition, provide conditions suitable for recruitment of flood dependent species and maintain floodplain condition so that it will respond to flooding. There is considerable evidence that watering improves overstorey condition and provides conditions suitable for recruitment of flood dependent species; however, how watering influences the response of floodplain vegetation to flooding it is not well understood. We proposed that the response of the understorey vegetation to flooding would be more positive on a watered floodplain compared to an unwatered floodplain. To test this hypothesis we compared the understorey vegetation before and after the 2010-11 flood on two floodplains on the lower River Murray: the Chowilla Floodplain which received 27.5 Gl of environmental water between 2004 and 2010 and the Pike Floodplain which received no environmental water. Vegetation surveys were undertaken in February 2010 on both floodplains and the vegetation was dominated by terrestrial and salt tolerant species with large areas devoid of vegetation; however, two temporary wetlands on the Chowilla Floodplain were watered in spring 2009 and those areas were dominated by flood dependent species. Species richness for Chowilla and Pike was 42 and 17 respectively in February 2010. The same sites were surveyed after the 2010-11 flood and the vegetation in areas that were flooded was dominated by flood dependent species on both floodplains and the species richness at Chowilla and Pike was 66 and 68 respectively. Data collected in this study did not show that there was a more positive response of the understorey vegetation on the watered floodplain and there is no evidence that watering maintains areas of floodplain so that they respond to flooding.

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Understanding the mid-Goulburn River: are cold flows a problem?

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Surveys of fish in the mid-Goulburn River, between Lake Eildon to Lake Nagambie, have shown the native and freshwater fisheries in this reach are sub-optimal despite there being good habitat. Macroinvertebrates have also been shown to be in poor condition. A major contributing factor to poor fish and macroinvertebrate community health in the region may be from the water releases from Lake Eildon. The large volumes of water released from Lake Eildon have significantly altered the flow regime of the river, and provide unseasonably cold waters during spring and summer that impact the river as far downstream as Seymour. The study aimed to determine

whether the abundance of macroinvertebrates was low where there were low numbers of fish and to determine whether they were stressed from the modified flow regimes and associated water quality caused by Lake Eildon. Macroinvertebrate community was assessed at four sites within the mid-Goulburn and King Parrot Creek over multiple levels of organisation (community, population, individual and sub-lethal) in a multiple lines of evidence approach. Several methods were employed across three seasons (spring, summer and autumn) including replicated edge sweep samples (community structure, relative abundance of key taxa, biomass), artificial substrate samples (community structure, relative abundance of key taxa, biomass) and shrimp (*Paratya australiensis*) cage studies (survival, growth, biomarkers). Our results show that macroinvertebrate fauna in the Goulburn River are impaired and very different to those in King Parrot Creek. A lack of large bodied crustaceans (shrimp) is evident in the mid-Goulburn despite surrounding tributaries containing high abundances of them. It is likely that large water releases from Lake Eildon are impacting macroinvertebrates in the Goulburn River, with the greatest impacts occurring in spring and summer when water temperatures associated with the water releases were colder. The management implications of these findings will be discussed.

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Improving environmental water delivery to degraded wetlands

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Flow regulation and land use change has impacted on the condition of billabongs along the Yarra River. Following an initial review of the ecology and water requirements of numerous billabongs in the Yarra River catchment by Melbourne Water, a priority list has been developed. Jacobs has developed a framework for determining and implementing a preferred water regime, based on individual wetland management objectives. The framework is based on four stages; characterisation of the wetland and determination of management objectives, identification of a preferred watering regime, water regime delivery (through infrastructure design/modification), and monitoring, evaluation and adaptive management.

This paper presents an overview of the framework and a case study of its application to three sites of differing complexity; Yering backswamp, Spadoni's Billabong and Cockatoo Creek Swamp. The purpose of these projects has been to further develop a conceptual understanding of the site, establish management objectives, identify a preferred watering regime and determine a suitable environmental watering solution that could enable the preferred regime to be delivered.

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Upper Ovens River low flow planning: Increasing understanding of aquatic habitat under extreme low flows with the use of an interactive river depth map

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The upper Ovens River is one of the last major rivers in the Murray-Darling Basin which retains a near natural flow regime. Although largely unregulated, water is harvested by pumping to fill farm dams, to irrigate crops and for domestic, stock and town use. In dry years, consumptive demand has the potential to significantly reduce or stop flow. Low flows and cease-to-flow events can have negative impacts on aquatic fauna by reducing the quality or quantity of aquatic habitat and reducing water quality. One way to assess habitat under low flows is to use hydraulic models, however, this is problematic because the upper Ovens River has a porous riverbed, meaning that a portion of the flow passes through the riverbed, a type of flow not easily accounted for by hydraulic models.

To better understand the upper Ovens River under very low flows, the North East CMA and Jacobs Group Australia completed a bathymetric and aquatic habitat survey. Jacobs developed an innovative kayak mounted survey rig to complete a high accuracy depth and aquatic habitat survey of 40 km of the Ovens River between Bright and Myrtleford under extreme low flows. The output was an interactive, GIS based map of the river, incorporating the depth survey, spatially oriented photography of the river and quantitatively based conceptual models of the main riffles identified in the river. The interactive map and conceptual models provide the CMA with a powerful tool to understand the river and to determine how habitat availability and condition change as flows reduce.

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Evaluation of *Moira Grass* seed bank from Barmah Forest floodplain

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Use of environmental water allocations to conserve floodplain and wetland plants is becoming an increasingly common management tool. In south-eastern Australia, Moira grass (*Pseudoraphis spinescens* (R.Br.) Vickery) historically covered extensive areas within Barmah Forest where it is deemed to be ecologically significant and of high conservation value. The areal extent of Moira grass significantly declined throughout the forest during the Millennium drought (1996 – 2010). Natural flooding (2010 – 2012) failed to elicit an expected increase in the extent of Moira grass suggesting that this species may not have a viable long-lived seed bank. We investigated the existence and viability of the seed bank of Moira grass by (i) germination trials, (ii) identification of seeds within the sediment and (iii) estimates of seed viability. No plants were identified as Moira grass during the germination trial, however seeds of Moira grass were identified as being present in the sediment but the majority (98%) were not viable. In comparison, 16% of seeds collected from mature seed heads were found to be viable. Results from this study demonstrates an absence of a persistent long-lived seed bank of Moira grass at Barmah Forest. This suggests that to maintain Moira grass successive flood regimes may be need to encourage seed germination and that there is a need to manage existing stem fragments and rootstock.

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Depositional zones for seeds within river channels

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Seed banks are an important component of the ecology of aquatic and riparian plant communities. Seed banks provide a reserve from which plants can regenerate when germination cues are met and provide a measure of resilience against adverse environmental conditions. While there has been a significant amount of research focused on seed banks within wetlands, there is a lack of research on the role, formation and function of seed banks associated with river channels and of key deposition sites within a riverine system. The aim of this study is to assess the distribution and abundance of seeds within a river channel. We collected sediment containing seeds

from within the river channel, slackwater zones associated with the river channel, in-channel benches, the floodplain and floodplain wetlands. Results suggests more seeds are found on the floodplain and in floodplain wetlands compared to riverine habitats. Within the riverine habitats more seeds were found in slackwater zones compared to benches or the main channel. This data suggests that managing flows to maximise the distribution and persistence of slackwater zones will assisting promoting plant communities.

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Long-term inundation regimes drive floodplain wetland persistence at the landscape scale: informing environmental water management

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Inland floodplain wetlands in the Murray-Darling Basin depend on highly variable river flows and flooding regimes characterised by unique variations in magnitude, timing, duration and frequency. Vegetation responses are dependent on relationships among the flow pulse (annual), the previous sequence of flows (five years) and the long-term flow regime (decades). Understanding these relationships at the landscape scale is critical for effective environmental flow management. We use novel methods to map flooding regime extents (duration, frequency and time since last flood) in the Macquarie Marshes at three different ecologically relevant timescales: flow pulse, five year intervals and decadal long-term inundation regimes. We measure floodplain wetland persistence within two time periods: 1991-2008 and 2008-2013, corresponding to vegetation type mapping (1991, 2008 and 2013). At the shortest time scale, we identify flow pulses using river flow data and then for each flow pulse, we spatially aggregate inundation maps derived from Landsat observations calculating cumulative area (ha) of floodplain inundated and its inundation duration (days). For five yearly intervals before 2008 and 2013, we calculate inundation pulse frequency and duration metrics (mean, standard deviation, median, minimum and maximum). For long-term inundation, we focus on the 20 year interval before 2008 and 2013, calculating time since last flood observation, inundation pulse frequency and duration metrics. We use the random forests algorithm for classification to identify the variable importance of inundation co-variates in explaining vegetation persistence over short (5 year) and long (20 year) time periods. Long-term inundation covariates: time since last flood observation, 20 year average and standard deviation duration (days) and 20 year inundation pulse frequency are the most useful co-variates explaining vegetation persistence between 1991 and 2008 and between 2008 and 2013, compared to five year inundation co-variates. Long-term water management is critical for ensuring the persistence of a floodplain wetland vegetation mosaic.

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Optimising flows in Gunbower Creek to enhance survival of juvenile Murray cod (*Maccullochella peelii*).

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The ongoing challenge for environmental water managers is to apply the best available science to achieve demonstrable ecological outcomes, often within highly modified systems that are primarily operated to meet the needs of irrigated agriculture.

Despite the highly regulated nature of Gunbower Creek a population of Murray Cod has managed to survive. However, a decade of annual fish monitoring has tracked the decline in the population, with distinct and persistent fragmentation indicating the lack of successful recruitment.

A new approach to managing environmental flows within the highly regulated Gunbower Creek was needed. We designed a full year environmental flow hydrograph to accommodate specific life history processes for Murray cod, without impacting on consumptive water users.

Two aspects of the regulated flow regime were identified as critically impacting on Murray cod; extreme daily flow variability throughout spring, and cease-to-flow conditions throughout winter.

Working closely with irrigation operator's, environmental flow releases were augmented into irrigation releases, ensuring demands of irrigators and the Murray Cod were met. We termed this experimental flow regime for Gunbower Creek the 'Murray cod hydrograph'.

During the first year of implementation, monitoring confirmed strong Murray cod spawning, and for the first time in more than a decade, a strong cohort of young-of-year Murray cod was detected in the following year. Three years on, monitoring has indicated an improved population structure and an increase in overall abundance of Murray cod in Gunbower Creek. The initial achievement of implementing this hydrograph represents a success story in cooperation and knowledge sharing between ecologists, catchment managers and irrigation operators.

We present new initiatives in flow management that are being applied in regulated rivers to restore fish populations.

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Avoiding the "Hunger Games" risks of freshwater fish monitoring in northern Australia

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Environmental monitoring has always been rife with challenges. The most common include site accessibility, appropriate equipment, determining the right sampling design and amount of data required. However, some regions such as the wet-dry tropics of northern Australia, face additional challenges associated with the 'wildness' of the region. One of the primary challenges in monitoring freshwater ecosystems in this region is the ever present and very real threat of crocodile attack. Traditional monitoring methods for fish involve capture and count techniques, which require someone to be in or near the water, but this is not feasible in crocodile infested waters. We trialled the use of unbaited underwater video cameras (UVC) in wetlands of Kakadu National Park to determine if this technique can be readily applied in freshwater billabongs where the use of other sampling techniques are limited by the presence of crocodiles and extreme environmental conditions. The trial examined the utility of UVCs in shallow and channel billabongs with dense and sparse vegetation using both stationary and moving UVC deployments. UVCs were a feasible option for monitoring fish and with the appropriate design have the capacity and potential to capture more representative data than previously used traditional methods. We will discuss the design of the trial, the representativeness of the data collected, and comparisons with historical fish data for the sampled billabongs.

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A conceptual synthesis of flow-recruitment relationships for riverine fishes

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The Environmental Water Knowledge and Research Program aims to help inform flow management through understanding flow-ecology relationships. For the fish research theme, recruitment has been seen by both managers and scientists as a priority area. Three broad classes of theory have contributed to our understanding of riverine fish recruitment: life history theory, river ecosystem concepts and fish recruitment hypotheses. This paper will explore these, with the aim of developing an integrated model describing the recruitment of riverine fishes and its relationship with flow. Specifically, the synthesis investigates how physiological, behavioural and life-history traits are correlated, how these three components interact with the key features of river ecosystems – and flow in particular – to contribute to fish recruitment; explores the relevance of river ecosystem concepts for explaining patterns and processes in fish recruitment and population dynamics; relates current ideas and hypotheses about fish recruitment from all aquatic environments to rivers and riverine fishes; and explores how the resulting model can be used to identify knowledge gaps and future research areas, and to develop ecological guidelines for use in river management.

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Return of the Lignum dead: resilience of an arid floodplain shrub to drought

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In semi-arid regions, woody floodplain plants have developed methods of tolerance to both flooding and drought. Understanding the limits of tolerance to drought is critical to the efforts of restoring these communities. In Australia, Tangled Lignum (*Duma florulenta* (Meisn.) T. M. Schust; formerly known as *Muehlenbeckia florulenta* Meisn.), hereafter referred to as Lignum, is an ecologically significant floodplain shrub that dominates large areas of the Murray–Darling and Lake Eyre Basins. This study investigates the resilience of Lignum plants to dry periods by examining the capacity of plants to regenerate from dormancy. In particular, this study sought to determine if the capacity of Lignum to regenerate declined with increasing duration of dormancy. Lignum plants were surveyed at 12 sites on the Murray River floodplain in north-western Victoria. Sites were monitored annually between 2006–07 and 2012–13. This study found that although Lignum can regenerate from dormancy, regeneration is not guaranteed and the likelihood of successful regeneration varies among locations and diminishes with increasing length of dormancy. Lignum communities should be managed to maintain condition and resilience to drought in order to give Lignum plants the greatest chance of regeneration success.

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The effect of temperature on germination and viability of four semi-aquatic plant species

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Seed banks of terrestrial and aquatic plants allow the survival of populations when faced with adverse conditions. While there is a substantial amount of research on the effect of temperature on seeds of terrestrial plants, there are few studies that have examined the effects of temperature on seeds of aquatic and semi-aquatic plants. Given that floodplain sediment temperatures in south-eastern Australia have been reported as exceeding 40°C and as high as 70°C it could be predicted that seeds should be capable of persisting under these conditions for periods of time. This project investigates the impact of increasing sediment temperature on the germination of seeds of 4 common wetland associated plants. Seeds were collected from four common plants found associated with rivers and wetlands (*Alternanthera denticulate, Juncus usitatus; Persicaria lapathifolia; Persicaria prostrata*) and exposed to 6 temperatures between 25°C and 100°C for durations between 1 and 14 days. Seeds were then germinated on agar in a constant temperature cabinet. Results indicate that seeds can withstand heating up to 60°C with no loss of viability. However, future climate change scenarios predict an increase in air temperature of up to 4°C by 2070. This prediction has the potential to increase sediment temperatures by up to 10°C. The projected sediment temperatures may exceed the threshold of many aquatic and semi-aquatic plant species. Previous experiments have indicated that seeds of aquatic plants are sensitive to high temperatures with germination ceasing once temperatures exceed 50°C.

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Habitat modelling of key submergent macrophytes within the Lower Lakes, South Australia

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The Murray-Darling Basin in south-eastern Australia is subject to the compounding effects of river regulation and drought. The recent decade-long Millennium Drought saw large-scale changes in environmental conditions, degrading ecological communities and reducing species occurrence. With limited recovery of many communities post-drought, predictive habitat models were developed and field-validated to investigate the relationship between two key submergent macrophytes (*Myriophyllum salsugineum* and *Vallisneria australis*) and the environmental variables influencing their occurrence, using the Lower Lakes in South Australia as a case study. Telemetered records of logged environmental variables were paired with vegetation monitoring data to develop non-parametric multiplicative regression models. The influence of the intra-seasonal variation in conductivity and water temperature from the telemetered records, in conjunction with water pH from field surveys, were found to define the habitat envelope for those species. Therefore, these variables are potentially limiting species occurrence post-drought. These findings provide managers with regional predictions of species responses that can be incorporated into management decisions to ensure submergent macrophyte assemblages remain viable into the future, while providing a proof-of-concept for a modelling approach that can be undertaken to describe similar relationships for other key taxa within the Murray-Darling Basin and elsewhere.

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Allochthonous carbon utilisation by zooplankton of coastal rivers during a high flow period

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Freshwater flow events are important for transporting allochthonous resources to aquatic systems. These inflows may have a role in supporting secondary productivity in rivers. We examined the change in carbon stable isotope signatures of dominant zooplankton taxa in over 9 months during a period of high rainfall in five coastal rivers. Flow was positively correlated to DOC as well as total nitrogen, filtered nitrogen and total phosphorus in some rivers. The δ13C stable isotope signatures of zooplankton showed evidence of allochthonous support for all rivers after flow events. Evidence of this support was still evident in zooplankton δ13C signatures up to 6 months after large flow events on each river. This work contributes new insights to the importance allochthonous sources of carbon in coastal flowing rivers.

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The roles of Murray cod (*Maccullochella peelii peelii*) and Gambusia (*Gambusia holbrooki*) in structuring the community composition of emerging zooplankton

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Zooplankton are a valuable food source for both native and exotic freshwater fish species and play a key role in the survival of species during larval and juvenile phases. Predatory fish can alter the abundance of different taxonomic groups and change community composition. This study describes the impact of Murray cod (Maccullochella peelii peelii) larvae and Gambusia (Gambusia holbrooki) juveniles on the composition of emerging zooplankton communities. Using replicated mesocosms we quantified the impact of Murray cod and Gambusia larvae at three different densities, high (100 zooplankton per fish), medium (250 zooplankton per fish) and low (400 zooplankton per fish).

Cladocerans were consumed by both Murray Cod and Gambusia. Gambusia addition significantly reduced the abundance of all microinvertebrate taxa. Murray cod significantly reduced densities of cladocerans but not other taxa. In the Murray cod treatments, rotifers began to increase in abundance by the end of the experiment, but this effect was limited to the low density treatment. All densities of Gambusia caused decreases in zooplankton abundance and this effect continued for 21 days whereas the higher densities of Murray cod larvae led to an initial decrease in zooplankton abundance but this was not sustained over time.

Our findings show that high densities of Gambusia affect both the density and composition of zooplankton communities, potentially disrupting food webs and reducing food availability for native fish.

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Individual trait effects in aquatic food webs: a case study of behavioural traits in an arid-adapted fish

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Advances in food web modelling are revealing the characteristics of ecological communities that are related to stability and underpin their biodiversity. A key future research topic is the incorporation of intraspecific trait variability into our understanding of food webs. We explore the conceptual linkages between food web modelling and intraspecific differences in behavioural traits (e.g. animal personality). Specifically we describe the potential for intraspecific behavioural variation to be a stabilizing force in food webs, both as a source of within-species variability in food web interactions and by facilitating adaptive responses to changes in the trophic environment. We empirically investigated these conceptual links between food webs and behavioural traits, by studying the aquatic communities in Australia's arid-zone and populations of Australian desert gobies (*Chlamydogobius eremius*). This included community-level food web analysis conducted alongside individual-level analysis of goby's trophic position and behavioural traits. Our food web analysis revealed the importance of resource segregation and between-individual differences in trophic position to the stability of desert goby populations. Furthermore, behavioural traits (e.g. boldness, activity and exploration) varied within and between goby populations. Variance in these behavioural traits was closely linked the local trophic environment of goby populations. These results show that incorporating individual-level behavioural traits represents a promising area for food web research, and further highlights the importance of aquatic food web studies to the development of community ecology.

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The Emergence of River Science: lessons from the driest continent

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Interdisciplinary river science evolved from two roots founded in quantitative and empirical studies during the 1970s. One advanced reductionist approaches to lotic research dominated by work on small streams in temperate environments, which were amenable to monitoring and experimental manipulation. The other advanced research on the fisheries ecology of large tropical floodplain rivers characterized by a predictable flood regime. Concepts emerged to underpin the new river science, including the River Continuum Concept, the Flood Pulse Concept, and the concept of Riparian Ecotones. From the late 1970s the two strands were integrated and applied to regulated rivers. Research on the ecological responses to changes in flow, temperature and sediment regimes below dams, weirs and abstractions challenged and developed the emerging concepts. These concepts were also applied to rivers in different geographical settings including dry-land rivers having highly variable flows and unpredictable flow regimes. This paper provides a perspective on how research on dry-land rivers has contributed to the development of river science by tracking the international contributions of Keith Walker's research on the regulated River Murray, Australia.

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River-floodplain connectivity and food web subsidies in tropical rivers

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The connection of rivers to their floodplains is known to facilitate a significant food subsidy to aquatic consumers - the flood pulse advantage. Although rivers in northern Australia are largely unimpacted by water resource development, there is considerable natural variation in the pattern of hydrological connectivity with their floodplains - in both space and time. This has been shown to influence the strength of subsidies to river food webs. Large mobile consumers in particular show a high level of dependence on subsidies from outside of the river channels they inhabit for much of the time. Our recent work, using conservative isotope tracers, in the Alligator Rivers Region suggests that mobile consumers derive much of their somatic growth from feeding in specific locations within inundated floodplains. These tend to be deeper areas that retain open water with submerged macrophytes throughout the wet season. Submerged macrophytes support a high level of epiphytic algae production, an important basal food resource for aquatic consumers, compared with other structural types. Changes to flow regimes that diminish the depth or duration of inundation of these 'hotspots' of high quality food resources, or the presence of barriers that restrict access of mobile consumers to them, are likely to have a significant impact on this important subsidy to river food webs and fisheries.

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Can further regulation of the River Murray be used to promote ecosystem health? A fish ecology perspective.

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Despite the pervasive ecological impacts of river regulation, further regulation, in the form of weirs, levees and pumping, is being used to artificially inundate floodplains of the River Murray with an aim to improve floodplain health. In the lower River Murray, a 3 m high, 79 m wide regulator on Chowilla Creek has been constructed with the primary objective of maintaining or improving the condition of floodplain overstorey vegetation. The Chowilla Anabranch system comprises permanent lotic habitats that are now rare in the main channel of the lower Murray, and supports a regionally significant Murray cod (Maccullochella peelii) population. Operation of the Chowilla Regulator may alter the hydrodynamics of lotic habitats, interrupt connectivity, and decouple riverine and floodplain hydrographs. This presents risks for native fish whilst potentially facilitating recruitment of non-native fishes. During spring 2014, the Chowilla regulator was used to inundate ~3,000 hectares of floodplain during relatively low river flows (≤10,000 ML/d). We quantified the hydraulic characteristics of perennial creeks, investigated the movement of Murray cod using radio-telemetry, and compared fish assemblages in ephemeral floodplain habitats between engineered and natural overbank flooding (discharge = 90,000ML/d). During regulator operation, mean water velocities and hydraulic complexity (strength and frequency of water circulation), were ~50% of those measured when the regulator was not in place. The regulator also obstructed the spawning movements of Murray cod. In floodplain habitats, native fishes were rare and young-of-the-year carp comprised 97% of the catch. During natural flooding, native fishes were numerically abundant, and carp represented 1% of the catch. Our results support the notion that engineered floodplain inundation simplifies and fragments aquatic habitats, and may benefit carp over native fishes. River regulation to promote ecosystem health represents an unparalleled experiment in lowland river restoration, requiring rigorous evaluation to provide feedback loops for adaptive management.

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Variable plasticity in shell morphology of some Australian freshwater mussels (Unionioda, Hyriidae)

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Shell shape varies markedly in freshwater mussels in the order Unionoida, with shells of the Australian unionid family Hyriidae varying in size and shape, beak and surface sculpture, hinge dentition, growth lines, erosion of the periostracum and the colour and thickness of the nacre. Freshwater mussels belonging to the genus *Velesunio* (Family Hyriidae) are distributed widely in the rivers and wetlands of Australia. Molecular evidence suggests there are at least three more species within the genus *Velesunio* than previously described using shell morphologically. Morphological differences in shell shape between the species are difficult to detect and differences appear to differ between drainage basins. This study explored differences in shell morphology between and within two major drainage basins within Australia, the Murray-Darling Basin and the Lake Eyre Basin. For all species there were significant differences between basins and rivers within basins, however for shells from the Lake Eyre Basin differences in shell morphology between sites was low. In comparison greater species level differences in shell morphology were observed at the site scale in the Murray-Darling Basin. Although both drainages are essentially 'dryland' systems with highly variable flows, the extreme flow variability of Lake Eyre Basin rivers means they spend considerable time as lentic waterholes. In contrast the rivers of the Murray-Darling Basin, while still highly variable, spend a far greater time under flowing water conditions. Thus, the level of difference in shell morphology between sites may reflect local hydraulic variability rather than large scale flow variability

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Frogs, flows and rainfall: monitoring frog response to wetland flows in the northern Murray Darling Basin

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Considerable investment in managing water for the environment in the Murray Darling Basin relies on systematic monitoring at relevant spatial and temporal scale to assess the outcomes of environmental flows for wetland-dependent fauna, including frogs. Here we report on results of frog monitoring in the Northern Basin where we assess the ecological relevance of two key environmental water considerations: flow timing and flow magnitude.

We undertook systematic surveys during natural floods and during periods of low flows, when small environmental flows were delivered, in two large semi-arid floodplain wetland systems in northern MDB (the Macquarie Marshes and the Gwydir Wetlands). Both systems have wetlands that are Ramsar-listed and therefore considered wetlands of international significance. Survey sites were spatially stratified by vegetation type and flooding frequency. We identified all species, breeding behaviour, recorded habitat variables and local weather conditions. Inundation extent across the floodplain and individual wetland sites was calculated from Landsat imagery and matched with survey dates to determine flooding metrics.

We identified three ecohydrological groups based on adult frog activity during floods, which broadly reflected morphological and physiological characteristics: flow-responsive, flow-ambivalent and flow-oblivious. Flow-responsive species were observed calling in all survey months, but calling intensity was higher at the start of flow event. The density of individuals (individuals ha^{-1}) remained relatively constant with flow event magnitude. Increases in calling activity and density of species in the other two groups corresponded primarily with changes in local rainfall. Managed flow events that commence in spring appeared to provide optimal breeding conditions for flow-responsive frogs in the northern MDB, with larger floods contributing to higher overall abundance and breeding activity necessary for population persistence. These findings demonstrate how long-term monitoring is critical for understanding responses of flow-dependent fauna in large variable systems and informing the planning and management of environmental water.

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Linking riverine flows and food webs: EWKR food web theme

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The Basin Plan seeks to protect and restore biodiversity in the Murray-Darling Basin's aquatic ecosystems. Food webs are a critical ecosystem function believed to be important in sustaining ecological assets such as bird and fish populations, and modifying flow regimes is one of the main tools that river managers have for the active management of such functions. Flow has three major functions in riverine systems**;** providing water as a resource or habitat, a disturbance regime that triggers major life-history events and influences community composition and dynamics, and as a vector for connectivity and lateral, longitudinal and vertical exchange of material, energy and organisms. In the Basin, the role of flow in disturbance dynamics and as a trigger of life history events (such as breeding or dispersal) is reasonably well known. What is less clear is the role that the hydrological regime can play in determining the flux of energy through food webs – particularly to top order predators including native fish and water birds. In this presentation, we will explore the current state-of-knowledge on the influences of hydrology on food web dynamics, particularly in the Murray-Darling Basin and identify the critical knowledge gaps that need to be addressed to better manage flow regimes for better environmental outcomes.

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Waterbird recruitment in the Murray-Darling Basin: Responses to flooding, stressors and threats

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Environmental watering events in Australia are frequently targeted at supporting waterbird breeding. Whilst knowledge exists regarding key breeding locations in the Basin and the flows required to trigger and complete nesting events, there is limited knowledge about recruitment rates and drivers – particularly in terms of the relative influence of flow variables, habitat variables, pressures and threats. Consequently it is difficult to model or predict population or management outcomes. The Waterbird Theme of the Murray-Darling Basin Environmental Water Knowledge and Research Project will begin to address these knowledge gaps through investigation of two main sets of questions:

1. Where and what are the critical foraging habitats during and after breeding events that support recruitment? How might these be affected by water management and threats such as habitat change?
2. What are critical nesting habitat characteristics we need to maintain and how do these affect recruitment? How might environmental flows, vegetation management and threats such as predation interact with nesting habitat characteristics to affect recruitment?

Here we describe our research rationale, methods and preliminary results stemming from a literature review and a pilot study conducted in 2015-16. We then outline our plans for the full research program.

This research will fill critical scientific knowledge gaps and will also produce information that will allow managers to better target water, vegetation and predator management actions to: maximise waterbird chick survival during flooding events; maximise 'event readiness' at nesting sites; and maximise juvenile and adult survival between flooding events.

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Improving our capacity to predict ecosystem responses to environmental flows

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Currently environmental water managers have limited capacity to consider ecosystem water requirements, and rely instead on the water requirements of key indicator species whose water requirements are both better understood and are believed to act as a reliable surrogate for ecosystem water requirements. The MDB EWKR project, by examining key ecosystem components (vegetation, fish, waterbirds and food webs) and the interdependencies among them, seeks to improve our capacity to predict ecosystem responses to environmental flows. Historically, researchers have focused on the development of detailed models that in some instances have been converted into Decision Support Tools. Adoption of these models has been relatively limited due to a number of issues; leaving managers without transparent of defensible means of either making trade-offs among watering priorities or ensuring that ecosystems are capable of sustaining their priority values (e.g. waterbirds, large native fish). Rather than develop a large complex model, the Murray-Darling Basin Knowledge and Research (MDB EWKR) Project is seeking to develop frameworks that will guide the application of both existing and new models to the task of predicting ecosystem responses to environmental flows. The MDB EWKR project will seek to develop one framework for consideration of landscape scale responses to flow regimes and a second to consider ecosystem responses to individual flows. It is hoped that this approach will increase the utility of existing knowledge in supporting decision making by providing a framework by which relevant information can be identified, adapted and applied to a greater variety of systems and situations.

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The comparison of four environmental water delivery methods to improve the hydrological metrics in the Snowy River, 2002-2016.

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In 1967, the construction of the Snowy Mountains Scheme (Scheme) resulted in significant alteration of the hydrology of the Snowy River, with 99% of the mean annual natural flow diverted to the Murray-Darling Basin. The post Scheme hydrology resulted in no pre-regulation hydrological metrics being achieved in the reaches below Jindabyne, NSW, and a significant decline in the condition of the river. In 2002, the Australian, Victorian and NSW Governments agreed to release up to 21% of the mean annual flow (i.e. 212 GL/year) in a staged release program to improve river condition. The key challenge was how to restore the hydrology of the montane river, knowing none of the pre-scheme hydrological metrics could be achieved.

Since 2002, four methods have been used to deliver environmental water in the Snowy River. These methods included: (i) a tributary release (i.e. 2002-2006), (ii) a default settings based on monthly average targets (i.e. 2006-2009), (ii) a building blocks approach based on perceived ecological water requirements (i.e. 2009-2013), and (iv) a surrogate unregulated montane river approach (i.e. 2013-16). A complimentary strategy was also adopted in the fourth stage to increase basal resources (i.e. Dissolved Organic Carbon (DOC), dissolved silica and macro nutrients) and manage a-seasonal warm water via tributary autumn release.

An evaluation of the hydrological changes associated with the four environmental water strategies implemented between 2002-03 and 2015-16 is presented. The tributary release provided a minor hydrological signal reflective of a small unregulated montane river, the default monthly settings provided a muted seasonal signal and provided limited flow variability. The building blocks method provided higher flow events while using over 50% of the annual volume in a single event, and thus limited daily flow variability. The flow scaling method reflected the hydrology of a montane river while still achieving high instantaneous discharge rates.

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Developing tools to assess the impact of development on the lower Mekong River

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After several decades of hiatus, plans are being actively implemented to construct a series of hydropower dams on the mainstream of the lower Mekong River. Concerns have been raised, particularly about the impact of the dams on the fishery (particularly migratory species), sediment transport and salinity incursion in the delta. Four riparian countries, with different economic and development goals, different social and environmental concerns, and different political systems, share the lower Mekong. The Mekong River Commission is utilizing DRIFT (Downstream Response to Imposed Flow Transformations), and interactive holistic flow modelling system to allow the lower Mekong countries to assess potential development scenarios and their environmental, economic and social impacts as a basis for negotiating trade-offs which can lead to agreements on the future management of the river. DRIFT is a system developed for evaluating environmental flow scenarios, which has been widely used in Africa.

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Streambed characteristics affect the vertical connectivity and movement of benthic invertebrates during water level reduction in streams

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Vertical connectivity between the surface channel and subsurface sediments may become increasingly important as climate change predictions forecast increased frequency of streambed drying in temporary streams in many regions. Streambed sediments can be a refuge for benthic macroinvertebrates during hydrological disturbances including streambed drying. A range of sedimentary characteristics may impede vertical connectivity and limit the potential of the subsurface to act as a refuge for aquatic macroinvertebrates during drying events. We directly observed the subsurface vertical movements of five lotic taxa, *Nemoura cambrica* (Plecoptera: Nemouridae); *Hydropsyche siltalai* (Trichoptera: Hydropsychidae); *Heptagenia sulphurea* (Ephemeroptera: Heptageniidae); *Asellus aquaticus* (Isopoda: Asellidae) and *Gammarus pulex* (Amphipoda: Gammaridae) in response to water level reduction using a variety transparent artificial microcosms containing different sediment sizes and interstitial pore space volumes. In addition, we examined the effect of varying fine sediment loads and reducing water level on the vertical movement of *G. pulex* in transparent mesocosms. The results from these novel experiments illustrate the importance of vertical connectivity and interstitial pathways to enhance faunal resistance and resilience in temporary streams and the need for their consideration in future restoration activities.

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Do pools impede stream insect drift dispersal?

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The dispersal of biota between populations is a key factor influencing the persistence of populations. In rivers, identifying constraints to drift dispersal between habitat patches is critical for greater understanding of the spatial extent of populations, recolonisation and river restoration. We determined whether stream insects drifting between riffle habitats (i.e. patches of suitable habitat) were impeded by pools (i.e. unsuitable habitat), limiting dispersal to the next downstream riffle. We measured invertebrate drift entering and exiting each of 13 pools, focusing on 13 species. We found that for 10 species, drift dispersal between riffles was significantly reduced by the intervening pool habitat, with the baetid, Offadens hickmani, showing the greatest reduction in drift numbers (60% reduction). The dispersal between riffle habitats for 9 species was related to one or more aspects of pool morphology. These relationships were consistent with the prediction that dispersal was increasingly impeded with greater areas of low or zero velocity within pools. Our results demonstrate that the drift of stream insects between habitat patches is limited by the intervening pool hydraulic conditions and individual species drift behaviours.

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(Another) truce with neutral theory – local conditions, species traits and spatial factors interact to drive community assembly

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Understanding the interplay between local conditions, species traits and spatial factors is critical foundation knowledge for effective management of biodiversity. We sampled aquatic communities in three chain-of-pools stream systems in central Victoria over three years. We sampled at the scale of the pool, the reach and the sub-catchment. We assessed a range of local habitat factors at each scale, and calculated simple Euclidean, stream network and resistance-weighted stream network measures of connectivity between all pools. Species were attributed dispersal traits from existing databases. Community composition was strongly structured by spatial factors in interaction with dispersal traits. A set of common taxa were present at all scales and were characterised by good dispersal ability and/or factors that made them resistant to reduced flows. Other taxa showed evidence of being dispersal limited, with a strong spatial signature in their occurrence. Local conditions were important for a small group of taxa, particularly shredders, but the communities were generally characterised by habitat and trophic generalists. These results show the importance of a whole-of-network perspective in managing local conditions for biodiversity.

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Building mussels: Understanding rarity in Hyridella narracanensis in southeastern Australia

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Freshwater mussels are in decline worldwide, including in Australia, although not all species are equally affected. To better understand the low levels of abundance in a rare Australian species, *Hyridella narracanensis,* we compared the factors responsible for its distribution with a co-distributed common species, *H. drapeta.* Environmental and habitat specific factors demonstrated no difference between the two species suggesting that abiotic factors are not restricting the distribution of *H. narracanensis,* which should therefore be able to find suitable habitat across coastal Victoria. Population genetic analysis for both species using mitochondrial DNA (mtDNA) showed similar patterns of isolation between river catchments, which suggest that dispersal is somewhat limited in both species, although this does not explain the differences between the two. Glochidial (larval) release strategies differ substantially between the two species and suggest that *H. drapeta* is a host generalist while *H. narracanensis* is host-specific. Therefore it appears that biotic factors (namely host availability) resulting from host specificity appear to be key in explaining the narrow distribution of *H. narracanensis*distribution, particularly in the Yarra River catchment where many native fish species are in decline. Interestingly, in the course of this study, the genetic analysis provided very strong evidence that another mussel species, the critically endangered *H. glenelgensis* is likely to be a translocated population of *H. narracanensis*. Broader surveying of Victorian streams is required to accurately determine patterns of distribution in *H. narracanensis*, and in particular, the identification and conservation of the fish host(s) used by *H. narracanensis* is critical to protect the species from decline, extirpation, or extinction

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The influence of groundwater contributions to stream food-webs in intermittent systems

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Flow intermittency can have a destabilising effect on stream food-webs by reducing algal abundance, changing the breakdown rates of particulate organic matter, and through the elimination of top predators. Contributions to surface runoff from groundwater can play an important role in maintaining baseflows in intermittent streams, thus providing a potentially stabilising influence on food-webs. Using stable isotopes (δ13C and δ15N), we investigated the role that baseflow has in shaping the food web structure in surface and hyporheic habitats of intermittent streams in two catchments in eastern Australia. Preliminary results indicate that non-filamentous algae and/or diatoms colonising benthic cobbles and rocks, and not particulate organic matter, are the primary basal food resource for higher trophic levels (macroinvertebrates and fish) in both stream systems. Furthermore, isotopic signatures of both basal resources and higher order consumers indicate groundwater contributions play an important role in sustaining basal production in these systems. The implications of current and potential future groundwater drawdown due to human activities in these systems is highlighted.

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Food webs and intermittent rivers: research to meet future challenges

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In a hydrologically modified, warming and increasingly uncertain world, predicting and mitigating impacts of food web changes on ecosystem functioning and biodiversity is challenging. Understanding and accounting for time lags, legacies, extremes and shifting baselines is paramount. To this end, rivers that cyclically flood, cease flow and dry present multiple research opportunities as model ecosystems. Yet a review of the literature reveals such endeavours are rare. The majority (>65%) of food web research on intermittent rivers is conducted while they flow, with <25% of studies spanning multiple hydrological phases. Few consider antecedent conditions, from either lag or legacy perspectives. Less than 20% incorporate experimental methods necessary to provide hard evidence of causal relationships. There is also bias regarding the source of our understanding, with most studies conducted in dryland regions. Surprisingly, <30% of studies aim to investigate effects of flow intermittency on food webs, with <10% investigating drying effects specifically. Recent work shows that drying reduces aquatic food chain length and trophic diversity,

often culminating in collapse of aquatic food webs, but also triggers switches in energy pathways and likely expands terrestrial food web dimensions. Global changes which exacerbate or produce unnatural drying may have deleterious and wide-ranging effects. Research on intermittent rivers, including the use of mesocosms and drying experiments, is key to develop and test hypotheses on and monitor and predict impacts of climate and hydrological changes on the food webs of dynamic ecosystems. We present several recommendations for how this can be achieved.

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Macroinvertebrate food webs in intermittent stream pools utilise general carbon sources despite variations in hydrology

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The primary source of C and N for macroinvertebrate food webs can be highly variable within intermittent streams. We hypothesised that differences within and among streams are related to increasing competition for autochthonous resources as surface water dries while macroinvertebrate density increases. We measured $\delta^{13}C$ and $\delta^{15}N$ values of macroinvertebrates and their possible food sources from pools of varying hydrology along an intermittent dryland stream in the Pilbara, northwest Australia. We compared differences in community composition and food web structure between two time periods (the late dry season and then later, after floods resulting from cyclonic rainfall, in the early-mid dry season) of a range of pools varying in connectivity to shallow alluvial groundwater (AW). While community composition was largely unchanged, differences in overall macroinvertebrate abundance between sampling periods were highly related to the degree to which pools had become disconnected from AW in the dry season and subsequently evaporated. While $\delta^{13}C$ and $\delta^{15}N$ values for primary producers did not differ across pools or sampling periods, several macroinvertebrate orders (Ephemeroptera, Hemiptera and Diptera) had lower (more depleted) $\delta^{13}C$ and $\delta^{15}N$ values in the early-mid dry season. Layman metrics of food webs structure indicated that food webs were larger and more diverse in the early-mid dry season. However, Bayesian mixing models of C and N source contributions to macroinvertebrate production showed no preferred food source at any time, for any order. In addition, low $\delta^{13}C$ values (≤40 ‰) for Ephemeroptera indicated that an unmeasured carbon source, perhaps derived from methane-oxidising bacteria, was contributing to macroinvertebrate food webs at times. We suggest that macroinvertebrates within intermittent streams consistently exhibit generalist feeding strategies due to the influence of high, long-term hydrological variation on community composition and available species pools.

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Nutrient limitations to production in Pilbara intermittent stream pools

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Persistent pools in intermittent streams of the semi-arid Pilbara region of northwest Australia are important biogeochemical hotspots and refugia for aquatic biota during dry periods. Allochthonous nutrient inputs are significant in short periods of connected flow, although processes of nutrient recycling, hyporheic interactions and evapoconcentration within disconnected pools are of increasing importance in maintaining primary production during no-flow periods. While it has been widely assumed that productivity of Pilbara streams is strongly phosphorus (P) limited, low amounts of dissolved inorganic nitrogen (DIN) in streams across the region suggest that nitrogen (N) is also potentially limiting. Here, we investigated the importance of N and P limitations on pools with and without alluvial groundwater connectivity in a Pilbara stream. We used in-situ bottle incubations and a ^{13}C-enriched $NaHCO_3$ isotopic tracer to measure production changes in response to nutrient amendments. Charophyte production was 2 mg C g^{-1} DW h^{-1} while water column production was orders of magnitude less (~0.01 mg C g^{-1} DW h^{-1}). Although charophytes showed no clear respiration response to short-term nutrient addition, productivity was positively correlated to both charophyte N and P content (R^2 = 0.65, p < 0.001 and R^2 = 0.41, p < 0.001 respectively). This relationship was stronger in pools which were disconnected from alluvial groundwater (N: R^2 = 0.92, p < 0.001 and P: R^2 = 0.77, p < 0.001). Short-term water column production was N limited in some pools (F > 7.6, p < 0.009) but this was not linked to alluvial inputs. Clearly both N and P, along with alluvial groundwater connectivity, have significant and complex roles in regulating production in these pools and build on our understanding of semi-arid intermittent streams.

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The cultural value of water to Australia's First Peoples' (Aboriginal People) and the evidence that will influence modern day water planning and management including quantity and quality.

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Australia is the driest inhabited continent on earth, yet is has been the traditional lands of its original inhabitants for thousands of generations because of their knowledge of water in the landscape. Australia's First Peoples its Aboriginal people rely on surface water and groundwater, this has been the case for generations primarily to ensure their survival in a dry landscape. Aboriginal people place protecting water landscapes as a high priority as it is a cultural obligation to do so. The challenge ahead for Australia's First Peoples is to ensure their value and relationship with water is not diminished by modern day water planning. Aboriginal people acquire the right wisdom and traditional knowledge from their Elders and many indicate that the Aboriginal worldview is seeing water connected to the land and to the sky and all are viewed as inseparable, bound by traditional lore and customs for its protection. As without these there is no culture or survival. For a people in a dry landscape, traditional knowledge of finding, re-finding and protecting water sites has been integral to their survival for so long. Aboriginal water dependent cultural values include tangible and non-tangible aspects, these are being reviewed to include cultural and Spiritual values for water quality and the NSW Governments Aboriginal Water Initiative (AWI) the only Aboriginal water unit in Australia is also changing the landscape on ways Aboriginal water values and uses are being considered and protected.

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Aboriginal Water Resource Management in WA

David Collard[1]

1. 2016, Como, WA, Australia

Many things can be said about the "Wild West" aka the state of Western Australia but I provide a small insight into the attempts to increase Aboriginal participation in Water Resource Management as part of the Nyoongar Nation. The need to assist Departmental staff to comply with Native Title and Aboriginal Heritage legislation with their on-ground works. The cultural obligations of the Traditional Owners to their responsibilities for their inherent right as the owners of the water resources upon their lands by developing new engagement frameworks and pathways. This talk will identify opportunities and strategies to assist the Aboriginal community to manage the water resources upon their lands BUT can it happen?.

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The Environmental Water Trust – using markets and innovative financing to restore wetlands and floodplains in the Murray-Darling Basin for financial, social and environmental outcomes.

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Water reform within the Murray-Darling Basin has given rise to opportunities for private environmental water trusts to be established using corporate and private investment. In late 2015, The Nature Conservancy and Murray Darling Wetlands Working Group began a 10 year partnership through joint ownership of the Environmental Water Trust, which aims to deliver water to stressed wetlands and rivers within the Murray-Darling Basin. This unique model is funded through the Murray-Darling Basin Balanced Fund, the first water fund in Australia with the objectives of generating financial, social and environmental returns. Traditional capital markets investors can support large-scale, long-term conservation works while diversifying their portfolio and earning income through investment in the water market. Annual allocations from water entitlements will be traded on a 'counter-cyclical' basis such that in the dry years when water is scarce and demand is higher, more water is made available to agriculture. In the wet years when water is abundant and agricultural demand is lower, more water is made available to wetlands. The Environmental Water Trust provides opportunities for public / private sector complementarity and watering will complement and integrate with government supported and run programs being undertaken by CEWO, MDBA and regional NRM organisations. Watering objectives include aboriginal social and cultural benefits and a range of conservation benefits are expected at both a landscape scale (flows to 'harder to water' wetlands on private land or floodplain forests) and local scale (improved health of key assets including tree canopy and frog, fish and waterbird habitat).

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Aboriginal Waterways Assessment: realising shared benefits through collaborative planning

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1. Murray Lower Darling Rivers Indigenous Nations, Brunswick North, VIC, Australia

Aboriginal people have rights and aspirations to see their values and objectives reflected in waterway management, likewise, water planners have partnerships and requirements which mean that they must work to deliver shared benefits. However, there are many challenges to delivering on these commitments. The Aboriginal Waterway Assessment tool (AWA) is a methodology for assessing the cultural health of waterways and prioritising sites for environmental water delivery, developed by the Murray Darling Basin Authority (MDBA) in partnership with the Murray Lower Darling Rivers Indigenous Nations (MLDRIN) and the Northern Basin Aboriginal Nations (NBAN). The AWA offers one approach to realising shared benefits and cultural outcomes in environmental watering. This presentation will outline a collaborative approach to planning, based on use of the AWA tool as a catalyst for relationship building, inter-cultural and inter-generational learning and practical assessment of waterway health.

MLDRIN has taken an active role in the application of the AWA and, in 2016-17, will coordinate a number of AWA projects in Victoria. This presentation will outline various stages in the planning and application of AWA projects. The authors will outline: factors for the successful and culturally safe use of the AWA tool, primary outputs (including quantitative data and community reports), secondary outcomes (including re-connection to Country and relationship building) and opportunities for integration of the tool into waterway management regimes.

The authors will consider the AWA as an important new tool in an evolving 'toolkit' of approaches to realising shared benefits and cultural outcomes in environmental watering. Succesfull, culturally appropriate use of the tool can support positive engagement in water resource planning and build capacity within Traditional Owner organisations to influence water management.

1. Australian Government, 2015. Module to the National Water Initiative (NWI) Policy Guidelines for Water Planning and Management. Engaging Indigenous Peoples in Water Planning and Management. P. 6
2. Murray Darling Basin Authority (2015) Aboriginal Waterways Assessment Program http://www.mdba.gov.au/sites/default/files/pubs/aboriginal-waterways-assessment-program.pdf

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Towards Cultural Flows - Glenelg River Aboriginal Water Values Scoping Project

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3. Barengi Gadjin Land Council, Horsham, Victoria, Australia

4. Beit Holmes and Associates, Iluka, NSW, Australia

Aboriginal water policy is in its infancy in Victoria. Victorian Traditional Owners have not been able to participate in water management at a level that appropriately reflects their rights and interests. In south west Victoria, Gunditj Mirring Traditional Owners Aboriginal Corporation (TOAC), Barengi Gadjin Land Council (BGLC) and Glenelg Hopkins Catchment Management Authority (GHCMA) are partnering on the '*Towards Cultural Flows - Glenelg River Aboriginal Water Values scoping project*'.

This project investigates Traditional Owner values and uses for the Glenelg River system, and the effective participation of Traditional Owners in regional water management.

Through cultural mapping and semi-structured interviews, community consultations have revealed 19 broad Traditional Owner values for the Glenelg River. The most commonly discussed values include river health, community access and cultural continuity, plant and animal use, and cultural heritage. River health for example was considered in terms of flow, impacts on river health, understandings of what a healthy river looks like, and understandings of current management decisions. Implicit in the value of river health is the interconnectivity between healthy ecosystems and healthy people: "*The spiritual connection is about bringing it [the river] back to life. It's all connected, if something is thriving, that is healthy country and that makes healthy people (TL-M, Gunditjmara Traditional Owner)*".

Continued discussions with community, on country, through improved access to the river will further the understanding of Aboriginal water values and interests for the Glenelg River. Other expected outcomes from this project include improved knowledge of Traditional Owners about river health and management; the development and furthering of relationships between Traditional Owners and other land managers and Agencies; and improved capacity to incorporate Traditional Owner rights and interests into both CMA and Victorian Government water resource management practices and policy frameworks.

[1] DSE (2011) Western Region Sustainable Water Strategy.

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National Cultural Flows and the restoration of Lake Condah

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Securing water entitlements is critical for the spiritual, cultural, social, environmental and economic benefit of Indigenous nations. A number of projects are currently underway to build the evidence base. The National Cultural Flows Research Project is a groundbreaking piece of research that is driven by Aboriginal people, for Aboriginal people. Through a combination of modelling and watering trials at two case study sites in the Murray-Darling Basin, the project will develop transparent and replicable ways to identify and quantify Aboriginal water requirements, and build a rigorous evidence base to enable Aboriginal water allocations to be embedded into Australia's water planning and management regimes. One example of restoration of culturally significant water management is Lake Condah & the Budj Bim Cultural Landscape.

Lake Condah is at the heart of Gunditjmara country along the Budj Bim Cultural Landscape. The lake and its water has been managed by Gunditjmara clans and people for the past 8,000 years to support traditional aquaculture systems along the Budj Bim (Mt Eccles & Tyrendarra) lava flows and wetlands. The lake was drained in 1954 as part of the state drainage program along with the Condah and Louth swamplands.

Following installation of Kerrup Jmara Weir in 2010, lake now has more permanent water through seasons to support natural, cultural, social and economic aspirations of Gunditjmara and broader communities in far southwest of Victoria. A world heritage nomination for Lake Condah and Budj Bim Cultural Landscape has been made by Victorian Government to Australia Government for consideration towards a formal UNESCO World Heritage nomination.

The Gunditjmara are drawing on their 8,000 year history of drought mitigation, traditional engineering, dispossession, colonisation and restoration along with broader community to face challenge of climate change in 21st century and how water will be managed at Lake Condah and Budj Bim Cultural Landscape.

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Recognising and managing for Aboriginal values in Victoria

Catheryn Lewis[1], Troy McDonald[1]

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Aboriginal communities have cultural, spiritual and economic connections to lands, waters and resources through their associations and relationship with Country. They have managed land and water sustainably over thousands of generations. Connectedness to lands, waters and resources on Country is an important determinant of Aboriginal health and wellbeing.

Past injustices and continuing inequalities experienced by Aboriginal people are still having an impact. Improving access to water for Aboriginal people will advance economic prosperity. This is part of the Victorian Government's commitment to close the gap between Victorian Aboriginal and non-Aboriginal people.

Over the next four years the Victoria government will develop and implement the Victorian Aboriginal Water Program. This will support Aboriginal Victorians' continued access to Country contributing to cultural wellbeing and economic prosperity, and improve water resource management by bringing deep knowledge of Country to the management of land and water. This talk will discuss what the initiative hopes to achieve, strategic directions and asks how will we know we have succeeded?

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Barapa Barapa Cultural connection to waterways

Robyn McKay[1], Sharnie Hamilton, Neville Whyman, Dixie Patten, Esther Kirby

1. North Central Catchment Management Authority, Hu, VIC, Australia

Barapa Barapa people have been custodians of waterways for thousands of years. We're one of many Aboriginal Nations who are Traditional Owners of Murray River Country. The health of our Country's waterways and wetlands is intrinsically linked to our cultural and spiritual identity.

European occupation has impacted dramatically on our culture and society, supressing its flow as dramatically as regulation has to rivers and wetlands. It is our inherent responsibility to look after Country -to heal the damage of the past and protect it for the future generations.

We want to share the message of our connection as it's important for you to understand the value of water from a cultural perspective, in order to work in genuine partnership with Traditional Owners to ensure the best possible cultural and environmental outcomes.

By learning the cultural landscape from us, water managers can listen to what our old people are saying. Scar trees, earth mounds and middens show tangible evidence of their presence. We feel their spiritual presence too and know these places were rich in resources now degraded or gone. Our connection through song, dance, storytelling, places and totems is our cultural science. These things also provide a lens that shows what our waterways were like before European occupation.

It is only through the willingness of people like you that we may drive reforms to policy, legal instruments and management frameworks and overcome the societal barriers that inhibit greater Aboriginal participation. You are our challenge and our strongest hope for change.

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Seeing the Land from an Aboriginal Canoe

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2. Faculty of Education and Arts, Federation University Australia, Ballarat, VIC, Australia

A remarkable project about bark canoes has brought to light a forgotten history of encounters between Aboriginal people and settlers on the waterways of colonial Victoria.

On the rivers of remote Victoria, the Aboriginal bark canoe was a technology in demand. In the 1800s European settlers depended on Aboriginal navigators and canoe builders to transport goods, stock and people.

Explorers and drovers, gold miners and settlers used Aboriginal ferrying services and boat building services to conduct trade and transport. Stories abound of trade, canoeing, and heroic rescues on rivers such as the Murray, Goulburn, Campaspe, Ovens and Loddon, shedding light on the generosity, resourcefulness and ingenuity of the Indigenous inhabitants and of the trading relationships formed between Aboriginal people and European colonists. Indeed it could be argued that the waterways skills of Aboriginal Australians were integral to the early economic viability of Victoria.

During this presentation an introduction and background to the project will be provided followed by a screening of the award-winning short documentary film 'Seeing the Land from an Aboriginal Canoe'.

http://www.cv.vic.gov.au/stories/aboriginal-culture/seeing-the-land-from-an-aboriginal-canoe/

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The imperative need for nationally coordinated bioassessment of rivers and streams: modernizing freshwater bioassessment and re-establishing a broad-scale focus.

Susan Nichols[1]

1. University of Canberra, CANBERRA, ACT, Australia

Declining water quality and ecological condition is a typical trend for rivers and streams worldwide as human demands for water resources increase. Managing these natural resources sustainably is a key responsibility of governments. Effective water management policies require information derived from long-term monitoring and evaluation. Biological monitoring and assessment are critical for management because bioassessment integrates the biological, physical and chemical features of a waterbody to provide an indication of ecological condition. Investment in nationally coordinated riverine bioassessment in Australia has almost ceased and management questions are focussed on more localised assessments. However, river systems often span political and administrative boundaries, and their condition may be best protected and managed under national policies, supported by a coordinated national bioassessment framework. A nationally coordinated program for the bioassessment of riverine health is an essential element of sustainable management of a nation's water resources. From examining the international experience in riverine bioassessment, a series of attributes of successful broad-scale programs emerge. A range of emerging technologies and approaches, such as molecular techniques and trait-based diagnostics, could help improve the efficiency of bioassessment and its suitability to meet the challenges of current bioassessment and future broad-scale programs. A reinvigoration and modernization strategy is needed to avoid the risk of bioassessment losing relevance and currency, and to address the longer-term needs of riverine ecosystems.

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Refuges from climate change in freshwaters

Belinda Robson[1]

1. Murdoch University, Murdoch, WA, Australia

The protection of refuges has been proposed to offer means by which we can assist species and ecosystems to adapt to climate change. Refuges are places secure from one or more disturbances, from which individuals emerge to recolonise landscapes after disturbance has ceased. Refuge function relies on two ecological processes: disturbance and recolonization. Recolonization depends on species' capacity for dispersal and reproduction to repopulate landscapes. Australian freshwater ecosystems are often disturbed by droughts, floods and wildfire, so freshwater species are expected to possess strategies for resisting or being resilient to disturbance. However, by altering basic environmental variables or increasing the frequency or intensity of disturbance, climate change presents new challenges to populations. Recent research shows that temperature and drought refuges exist across spatial scales in streams and wetlands. These refuges function to sustain biodiversity during single disturbance events, prolonged disturbance (e.g. millennium drought) and the onset of climatic drying (> 20 y of rainfall decline). In this keynote I explore a variety of refuges across spatial scales to demonstrate refuge function, which often relies on habitat features at the small scales relevant to individuals. Many species rely on microhabitat-scale refuges or on fringing vegetation for persistence and dispersal. Survival in refuges often involves specialized traits. Experiments that challenge species to respond can reveal previously undiscovered traits and unsuspected resistance capacity, potentially explaining unexpected biodiversity patterns, given climatic drying. Where humans alter freshwater ecosystems, such as through flow regulation and damage to fringing vegetation, connectivity and dispersal are reduced, compromising refuge function. Local extinction may occur and food webs may be modified, limiting adaptive capacity. Refuges will be key to the future viability of populations in fresh waters; but we need a much greater understanding of ecological processes across all life stages of species, especially those dependent upon, and vulnerable in, refuges.

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Smart rocks and sand slugs: innovative methods for modelling sediment transport in rivers

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Sediment erosion and transport are essential processes for structuring physical habitats in fluvial systems, but developing techniques to predict how and when sediment moves, and where that material will end up has proved difficult. That poses problems for engineers and communities trying to protect bridges, dams, levees and pumps from shifting sediment, and for ecologists trying to plan river successful restoration projects or understand patterns in biodiversity. We have developed two new techniques for better understanding processes that regulate the erosion, transport and deposition of fine sediments (<2mm) and cobbles (>128mm) in rivers. A digital elevation model, radiometric map and multiple geochemical tracers including physical characteristics, major and trace elements, and stable isotopes combined in a mixing model were successfully used to identify the sources of fine sediments dominating a large sediment slug in the lowland reaches of the Pages River. For large sediment, we have developed and validated 'Smart Rocks', artificial cobbles fitted with a GPS, triaxial accelerometer and radiotracker that allow the mapping of the conditions triggering cobble transport, as well as the specific path travelled by individual rocks during high flow events. When combined, these methods represent a

significant advancement in fine- and large-scale sediment modelling in river systems, and substantially improve our current conceptual basis of sediment dynamics in rivers.

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How old is your streambed?

Michael J Stewardson[1]

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The recirculation of streamflow through streambed sediments contributes to a variety of ecosystem functions including retention of nutrient and contaminants and the provision of permanent or temporary aquatic habitats. Whilst these functions have received a lot of attention in the literature and river management practice, the bio-physical nature of the sediment matrix, including both its spatial variability and its evolution with time is often neglected. This paper makes the case that river managers should pay attention to the evolving condition of the river sediments. A conceptual model is presented for the evolution of streambed sediment including: resetting with bed mobilisation; subsequent physical and biological clogging; and interactions with bioturbation by animals and plants. The conceptual model is tested in an empirical analysis of streambed surveys in over 100 river reaches. The conceptual model has important implications for management of flow regimes and river channels.

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Functional indicators of decomposition for monitoring ecosystem health in temperate wetlands

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Past assessments of ecosystem health have often neglected the overall functioning of a system by focusing only on structural components (e.g. species identity and abundance). Assessing ecological function, such as decomposition, provides a more accurate indication of the health of the entire water body than species composition alone. However, there are few rapid monitoring tools for assessing ecosystem function, despite their utility for natural resource managers. This research aimed to identify plausible rapid methods to quickly and efficiently monitor decomposition in wetlands and to test their consistency in two temperate regions. The initial research correlated water quality and sediment variables with four widely-established but resource-intensive measures of assessing decomposition over a 35-day period to identify potential rapid methods to monitor the ecological function of a wetland. Across six wetlands, we found positive correlations between the various rates of decomposition and water pH, electrical conductivity, total nitrogen concentrations and the proportion of sediment fines, and negative correlations with sediment pH, suggesting that these variables were potential indicators of decomposition rates. Microbial functional diversity was a general exception, tending to show opposite correlations with water quality and sediment variables compared with the wood, leaf litter and macroinvertebrate measures. The potential indicators were then tested for consistency in a second temperate region where they broadly consistent with the first region. The consistency in identified indicators suggests that these are likely to be useful rapid indicators of decomposition in wetlands. Thus, these rapid indicators will allow managers to quickly assess ecological health of wetlands and can be incorporated into a holistic functional assessment of wetland ecosystems.

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The effects of urbanisation on trophic relationships in constructed wetlands

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Constructed stormwater wetlands are one strategy to mitigate the impact of urbanisation on aquatic ecosystems. However, the biotic community is generally dominated by organisms that are able to tolerate poor water quality. The reduced macroinvertebrate diversity and abundance in comparison to natural wetlands, and prevalence of invasive species such as *Gambusia,* can influence the flow of energy through food webs. We used stable isotope analysis ($\delta^{13}C$ and $\delta^{15}N$) of food webs to determine whether the amount of catchment urbanisation (measured as total imperviousness, the percentage of a catchment covered in impervious surfaces) influenced basal resources and trophic relationships in constructed wetlands, in Melbourne, Australia. We found that as total imperviousness (TI) increased there was a significant decrease in the abundance and diversity of macroinvertebrates and a significant increase in the values of $\delta^{13}C$ and $\delta^{15}N$ recorded for fishes and macroinvertebrates. An increase in TI was associated with a decrease in the mean trophic position of fishes and an increase in the mean trophic position of macroinvertebrates. Our results suggest that sources of carbon differed between sites of low and high imperviousness and that nitrogen sources increased with increasing TI. This study provides an understanding of the likely consequences of disturbance associated with urbanisation on the food-web structure of constructed wetlands.

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Natural abundance stable isotopes of nitrogen as a qualitative indicator of wetland function.

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Constructed wetlands are designed to treat nitrogen inputs in storm- and wastewater runoff generated in urban and industrial catchments. These systems utilise a number of natural processes; such as assimilation and denitrification, that store and remove nitrogen, respectively, preventing further transport downstream. Several studies have assessed the effectiveness of nitrogen removal in constructed wetlands in the initial design phase and shortly after construction. However, aside from monitoring inlet and outlet concentrations of nitrogen there is very little information gathered on the ongoing function of the system. We propose that natural abundance stable isotopes of NO_3^-, NH_4^+, plant-N, periphyton-N and sediment-N can provide useful qualitative information on wetland nitrogen pathways, allowing for more informed management of these systems. Nitrogen fractionates in a predictable fashion when it is processed, as such, we can use these levels of fractionation ($^{15}\varepsilon$) to identify the key processes, such as denitrification ($^{15}\varepsilon$ = ~2 ‰ $\delta^{15}N\text{-}NO_3^-$) and assimilation ($^{15}\varepsilon$ = 5-15 ‰ $\delta^{15}N\text{-}NO_3^-$), occurring in the system. These methods were employed in three constructed urban wetlands in Melbourne and Perth, Australia using transect sampling before and after a rainfall event. Initial results indicate that $\delta^{15}N\text{-}NO_3^-$ could be a useful tool in assessing wetland function. The results of more detailed studies will also be discussed.

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SSRIs (antidepressants) affect stream ecosystem function + drugs in bugs

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Pharmaceuticals are important contaminants of concern in aquatic environments. One class of anti-depressant drugs, SSRIs are now detected in surface waters worldwide; however, the ecological impacts of SSRIs are not well understood. Using a laboratory and field based approach we were able to test the impact of SSRIs on ecosystem processes in artificial streams and detect and quantify pharmaceutical concentrations within stream insects in an urban creek influenced by waste water. Leaf packs and uncolonized rocks were added to artificial streams amended with environmentally realistic concentrations of SSRIs (20ng/L - 20ug/L). Biofilm colonization on rocks was affected by SSRIs; GPP was 60% lower on rocks in SSRI streams compared to controls. The low concentration of SSRI (20ng/L of fluoxetine) led to earlier dipteran emergence compared to the control and 20ug/L treatments. To further our understanding we detected and quantified amounts of pharmaceuticals within aquatic insects found downstream of a waste water treatment plant. These findings suggest that exposure to low concentrations of fluoxetine appears to affect aquatic biota and accumulation of pharmaceuticals in invertebrates has implications for higher trophic consumers. Indicating that these compounds are not necessarily toxic, but may have the capacity to alter ecosystem processes.

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Assessing the effect of four PPCPs on denitrification rates using the *nosZ* gene in constructed wetlands

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Pharmaceuticals and personal care products ("PPCPs") have been detected in freshwater systems world-wide. Intrinsically biologically active, PPCPs have the potential to act on non-target organisms at sub-toxic concentrations including microbes involved in base food web processes. Denitrification is a microbe mediated process in which nitrate is reduced to di-nitrogen gas (N_2), effectively removing nitrogen from aquatic systems. The ultimate step in the denitrification process is the conversion of nitrous oxide (N_2O) to N_2 mediated by the nitrous oxide reductase enzyme, encoded by the *nosZ* gene. Chemical inactivation or mutation of *nosZ* will result in failure to complete this last reduction step; thus increasing the production of N_2O, a strong greenhouse gas. To date, few studies have examined the effect of PPCPs on denitrification in the environment and to our knowledge no studies have applied *nosZ* gene quantification to define the effects of PPCPs on denitrification. This study will explore the relationship between denitrification rate, N_2O production and *nosZ* gene abundance in the presence of four PPCPs: acesulfame (30-200 ng/L), amoxicillin (30-200 ng/L), diphenhydramine (20-100 ng/L) and triclosan (5-80 ng/L). The effects of these PPCPs on denitrification will be examined in sediments across a land use gradient from three constructed wetlands. Denitrification rates will be measured using ^{15}N-labelled NO_3^- and *nosZ* will be quantified by targeted PCR in the presence of environmentally relevant PPCPs concentrations.

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Impact of pharmaceuticals on light and dark aquatic environments

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Pharmaceuticals and personal care products (PPCPs) are contaminants of increasing concern in aquatic ecosystems. PPCPs reach aquatic systems via human waste-water following excretion and incorrect disposal, as well as manufacturing waste and agricultural runoff. Current waste water treatment plants are not equipped to fully remove large organic compounds such as PPCPs, leading to \ frequent detection of PPCPs in surface waters globally. PPCPs pose a considerable risk as an aquatic contaminant as they are biologically active by design, can be taken up by aquatic biota, and have largely unknown effects on non-target organisms including aquatic microbes. Early research indicates that select pharmaceuticals can inhibit functioning of aquatic organisms at low, environmentally relevant concentrations. However, the effects of PPCPs on whole-ecosystem structure and function is largely unknown.
This research examines the effects of a realistic pharmaceutical mixture of eight separate compounds on selected whole-ecosystem endpoints, including primary production, community respiration, microbial biomass and community composition and nitrogen cycling. In addition, we tested whether these effects differed between light and dark (shaded) streams, to test whether differences in energy dynamics driven by light availability alter stream ecosystem responses to pharmaceuticals. . Artificial streams colonised with rocks, leaf packs and sediment balls which were pre-incubated in a natural stream for one year, one month and one week respectively were divided into both light (unshaded) and dark (shaded) treatments using shade cloth. Within these two groups, half of the streams were dosed every other day with a mixture of pharmaceuticals mirroring those found in an urban North American stream receiving waste water inputs. Effects on biogeochemical processes including primary production, respiration and denitrification were quantified over the entire three week experiment.

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Gnammas Ad Infinitum: Why are Victorian rock holes so pathetic?

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Gnammas in central Victoria occur in scattered groups hidden away at Kooyoora, Terrick Terrick, Mt Pilot and Bald Rock. Compared to those in WA and SA, most pan and pit gnammas are small and shallow and occur in relatively young granites (450 MYBP), but some pits at Terrick Terrick are large. Waters are fresher than in those elsewhere and fill just as reliably, but hydroperiods are shorter. The study involved 50 sites visited 5-8 times over 3 years.

Momentary species richness varies from 2.7 species in the very shallow, windswept pans of Bald Rock, to 6.5 in the more benign Kooyoora pans, to 9.3 in the larger pans of Terrick Terrick which has a further advantage of being in a field of artificial pools which readily provide dispersants. Kooyoora pits average 7.6 MSR but the unusually large Terrick Terrick pits average 15.3 MSR. These figures are mostly significantly fewer than the figures of ca. 30 for pans and 12 for pits in the WA Wheatbelt

and ca.10 and 9 respectively for pans and pits of Eyre Peninsula, SA. Furthermore, central Victorian gnammas have no endemics compared to many in WA and a few in EP. In addition, only a few species appear to have special adaptations for life in the Victorian gnammas, compared to many in WA.

Factors thought to be influencing these differences include habitat size (a function of site age), number of gnammas per rock exposure (provides habitat variability and availability), and past climatic fluctuations (promotes speciation). All these factors enhance diversity in WA, but mostly inhibit it in central Victoria, with EP in between and closer to central Victoria geographially and biologically.

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Waterwatch and EstuaryWatch portals: a collaborative research partnership to develop online tools to enhance citizen science, data collection and provision, and information sharing

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Citizen science has an increasingly recognised role in contributing monitoring data, facilitating societal education and improving understanding about the environment (and other issues). Citizen science has been contributing data for more than a century and the value from these longitudinal environmental monitoring data sets is only just being realised, particularly at the research and policy level. EstuaryWatch and Waterwatch are two long-term citizen science programs, supported by Corangamite Catchment Management Authority and the Victorian Department of Environment, Land, Water and Planning. Waterwatch is an Australia-wide program that monitors water quality in waterways. Since its establishment in 1993, over 3300 volunteers have collected data at over 6500 sites on Victoria's waterways. The strategic direction and activities of the program include increasing the knowledge of the community and waterway managers to inform waterway management decisions and encourage waterway stewardship. The EstuaryWatch program was established in 2006 with the aim of raising awareness and providing educational opportunities to community in estuarine environments, and enabling communities and stakeholders to better inform decision making on estuarine health. It has nearly 100 active and trained members operating over 17 estuaries. Future objectives and approaches for both programs overlap considerably with each aiming to establish, maintain and review monitoring sites and plans, and to increase engagement with community in monitoring waterway and estuary health. Centre for eResearch and Digital Innovation at Federation University is collaborating with EstuaryWatch and Waterwatch to develop improved information management systems using web-based interoperable data portals and visualisation tools. Existing program databases were re-developed and integrated, and new "sister" websites developed for both programs. EstuaryWatch and Waterwatch websites and data management portals were developed in consultation with key members of each program and refined to increase useability, data accessibility and visualisation, and interoperability between both data systems and with other relevant agency data.

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The value of novel riparian ecosystems for native birds

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The riparian zone is a biological hotspot, serving important functions that determine aquatic health and support a wide variety of flora and fauna, many of which are uniquely adapted to the aquatic-terrestrial nature of the ecosystem. Birds are an important component of riparian ecosystems. Riparian bird communities are diverse and unique, and are involved in both aquatic and terrestrial processes. Riparian zones, however, are vulnerable – both through clearing and grazing of native vegetation as well as invasion by exotic flora. While the influence of exotic riparian plants on aquatic macroinvertebrate community assemblages has been widely studied an understanding of vertebrate responses to invasive plants is still widely incomplete. This study compares avian diversity and the representation of feeding and riparian dependence guilds across a number of small order streams within Bremer River Catchment, South-east Queensland. The chosen streams cover a gradient that ranges from native vegetation dominated ecosystems to non-native dominated ecosystems. Within this gradient are sites that consist of either mostly native vegetation, a mixture of native and non-native vegetation (novel), or mostly non-native vegetation. The non-native plant that dominates many sections of the Bremer Catchment is *Celtis sinensis* (Chinese Elm*)*. In this Honours project riparian bird community composition has been across sites using extensive bird surveys, to understand how the physical and biological structure of the vegetation drives avian communities. The representation of avian guilds within each location was identified, in order to understand how vegetation influences the presence or absence of birds that have specific roles or needs in riparian ecosystems. Chinese elm, *C. sinensis,* is fulfilling a structural role within these degraded stream ecosystems, and is providing habitat for riparian birds. Initial data suggests novel sites contain more generalist species while riparian dependent species are restricted to sites where native vegetation dominates.

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Routine identification of macroinvertebrates using high-throughput DNA sequencing: What it can do for biological monitoring of freshwater ecosystems?

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Macroinvertebrate families identified based on morphological examination have traditionally been used in routine assessment of freshwater ecosystems. However, high throughput DNA sequencing (HTS) promises to improve routine assessment by providing rapid and cost-effective identification of macroinvertebrate species. We compare the results of HTS with morphological identification across macroinvertebrate families by considering 12 sites in an urban river system. We found some taxa detected morphologically were not detected by HTS and additional taxa not detected through morphological sorting were found with HTS. However, this had only a small impact on computed family-level metrics of ecological condition. Species detection with HTS showed some dominant macroinvertebrate groups had high species diversity. These groups also varied their environmental responses, which could be used in developing metrics for diagnostic monitoring of freshwater ecosystems. We discuss the potential of HTS and how this technology could be further developed and used for species identification in rapid bioassessment protocols and other approaches where species identification is required.

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Assessing Phylogenetic Diversity of the Mitta Mitta River through retrofitting genetic data to long-term biomonitoring

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The uptake of DNA based identification of freshwater macroinvertebrates in routine monitoring programs offers opportunities to investigate new metrics for assessing river health. Phylogenetic Diversity (PD), a measure of shared evolutionary history within communities, is one such metric and is expected to act as a surrogate for measuring multiple functional traits.

We retrofitted DNA barcoding data to 16 years of routine biological monitoring data of the Mitta Mitta River. Phylogenetic Diversity values were calculated for each sampling event using species level data from just two taxonomic orders, caddisflies and mayflies. These values were then compared to Family Taxa Richness and SIGNAL2 scores, calculated from family level data and including multiple orders. Our results showed that Phylogenetic Diversity was strongly correlated with both Family Taxa Richness and SIGNAL2. Family Taxa Richness correlated more strongly with PD than with SIGNAL2 score.

Our findings suggest that the health of the Mitta Mitta River could be assessed through PD metrics using genetic data from just two macroinvertebrate orders rather than through the current method of collecting and identifying specimens from across multiple orders.

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Changes in the sediment diatom record of a new reservoir, Wyaralong

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While the use of diatoms in the monitoring and assessment of aquatic habitats is common place, their use in water reservoirs is limited and studies remains scarce. To improve the reliability and use of diatoms as bioindicators in reservoirs more studies tracking current environmental change are required. In south east Queensland a unique opportunity presented to utilise sediment diatom assemblage to monitor a stream environment transition to a lacustrine environment following completion of a new dam wall and subsequent filling of the new reservoir in January 2011 after heavy rainfall. The construction of water reservoirs changes the hydrodynamics and physiochemical parameters of the aquatic habitats significantly. Diatoms should be effective bio-indicators of these changes. Results demonstrated a distinct and rapid shift in diatom taxa from benthic to planktonic forms as a result of the stream impoundment in the sediment record. Benthic diatom taxa including *Halamphora coffeaeformis* (C.Agardh) Levkov and *Bacillaria paxillifera* (O.F.Müller) T.Marsson, dominated the stream environment. Following transition to a lacustrine environment, planktonic diatoms taxa including*Aulacoseira granulata* (Ehrenberg) Simonsen, *Aulacoseira pusilla* Meister, and *Ulnaria acus* (Kützing) M.Aboal became dominant. The sediment diatom assemblages clearly reacted to the change in water depth associated with the reservoir filling. This outcome provides a valuable insight into the historic diatom assemblages and demonstrates that diatoms can provide a low cost effective method of estimating sedimentation rates in subtropical Australian reservoirs.

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Using algae-based models to configure consumptive flows for ecological benefit in the highly regulated MacKenzie River, south-east Australia

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The flow regime of the MacKenzie River, western Victoria, Australia, has been substantially modified since the construction of a water supply reservoir on its upper reach in 1887. Water is regulated at several locations downstream of the reservoir, creating a substantially modified flow regime, impacting key environmental values of the river. The river receives an environmental flow allocation and the river channel is used to transfer water dedicated for consumptive use. Ecological response models were developed using freshwater algal assemblages to assess the water quality and ecological condition of this working river under base flow and before and after freshes that deliver water to users. To assess the impact of the different flow regimes on river condition, ten sites were repeatedly sampled along the river between February 2012 and November 2014. Physical and chemical characteristics of water were measured as well as biological properties comprising the algal periphyton communities, including dry mass, ash-free dry mass, chlorophyll-*a* concentration and species composition. The lower reaches of the river were shown to be in poor condition under low flows, but this condition improved under flows of 35 ML/day, as indicated by the reduction in green algae and cyanobacteria and an improvement in DSIAR scores. The results will be used to tailor the duration and discharge of freshes used to deliver consumptive water to improve the condition of the stream thereby supplementing the flows dedicated to environmental outcomes.

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Using acoustic techniques to monitor wetland responses to environmental water deliveries in the Goulburn Broken Catchment

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Wetlands in the Goulburn Broken Catchment (Victoria) provide habitat for a diverse fauna assemblage including many of conservation significance. Environmental water is delivered to a number of these wetlands to provide more natural wetting regimes, which have been impacted by infrastructure development, diversions and drainage works. Acoustic monitoring has been routinely used since 2008 in wetlands of the Goulburn Broken Catchment as part of the management agency's broader monitoring program to gauge fauna response to environmental water management deliveries.

Here I report on some of the ecological responses recorded using event-based acoustic monitoring at five wetlands that have received environmental water between 2008 and 2016. This information has provided insight to population dynamics and has given insight into species presence, activity periods and succession during periods of flooding, drawdown and drying at these ephemeral sites. In addition, the finding of distant anthrophony affecting some faunal vocalisations.

Acoustic monitoring has broadened our knowledge of these sites, assisted with natural resource management decision making, and improved the basis for future planning of environmental water deliveries.

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Impacts of a large dam on gene flow and population structure of three aquatic insect species

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Abstract

When riverine landscapes become fragmented by human impacts such as dams, constraints to gene flow can drive increased isolation between populations. The effects that dams have on connectivity among aquatic insect populations is largely understudied and, for most species, based on assumptions about dispersal ability. We used Next-generation sequencing to generate mitochondrial *COI*markers to study the spatial genetic structures of two caddisflies, *Triplectides ciuskus* and *Notalina bifaria,* and a stonefly, *Leptoperla primitiva*, among sites that were either separated or not-separated by a large dam in north-eastern Victoria, Australia. Despite a strong flight ability, population connectivity in *T. ciuskus* was significantly affected by the presence of Dartmouth Dam. For the other two species, the dam had no apparent effect. Results showed that connectivity of populations could not reliably be inferred from the assumed dispersal abilities of the species, with the species considered to be a strong flier (*T. ciuskus*) showing significant population fragmentation, while another species considered to have poor dispersal ability (*L. primitiva*) showed no fragmentation. Thus, our results suggest that, in order to understand the effects of dam-led fragmentation on aquatic species, population structure of individual species needs to be investigated rather than assumed through dispersal traits.

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Hyper-diversity in the amphipods of the Bogong High Plains.

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The fragile alpine freshwater ecosystems of Australia are threatened by historic land use and projected climate change, yet little is known about the fauna of these environments. The aim of this research is to analyse the diversity of two important crustaceans found in these ecosystems, the neoniphargid amphipods and phreatoicid isopods. Preliminary phylogenetic analyses using DNA barcoding techniques, found deep divergences in both taxa, leading to the definition of six amphipod and two isopod Evolutionary Significant Units in the Bogong High Plains. Subsequent next generation sequencing, allowing the analysis of a greater proportion of the genome, has shown that these ESUs represent different species. Next-generation analysis of two of the six amphipod lineages has shown further deep lineage divergence, suggesting the presence of cryptic hyper-diversity with the amphipods of alpine Australia. The majority of amphipod species exhibited highly restricted distributions, while both isopod species had overlapping distributions across the entire sample area.

This study suggests that there is a high level of undiscovered biodiversity within Australian alpine aquatic crustaceans. The highly number of species and restricted distributions have important consequences for the conservation of the headwaters of Australia's major river system. Habitat loss and/or fragmentation associated with environmental change is likely to result in biodiversity reductions, with species unlikely to shift their ranges in response to future climate change, or recover from localised extinction events.

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Power and limit of lake sediment DNA to reconstruct past socio-ecosystem evolution

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During the last decade, an increasing number of studies have used lake sediment DNA to reconstruct past environmental changes and human activities. This emerging tool has great potential as it may allow the direct identification of all organisms present in the lake, the catchment and potentially the atmosphere. However, as other proxies used by "palaeo communities", the potential of lake sediment DNA might be affected by biases related to both analytical and taphonomic (DNA source, transfer and deposit) processes. In order to ensure reliable interpretations of lake sediment DNA results, it is thus crucial that we understand these processes, which were a little studied until now.

Here we will present DNA analyses applied on several lakes in the French Alps and focused on plants and mammals. Our main results suggest that DNA (extracellular DNA) from the catchment area is more effectively archived in lakes with high detrital inputs, i.e. allochthonous sedimentation. The source of eroded material is also important. Our data suggest that the soil surface horizons are the main source of "catchment DNA" transferred to the lake bottom. However, lakes not dominated by allochthonous sedimentation provide interesting sedimentary context to study past dynamic of macrophytes.

For the Northern French Alps, we also used our data to trace past agro-ecosystems evolution. Especially, we show a first important development of pastoral activities during the late Iron Age and Roman Period, with sheep and cows at high altitude (around 2000-2500 m asl). A second important phase of pastoral activities is then recorded from 900 to 1800-1900 AD. On several lakes, we record a change of practices between the 12th and 14th century, with a specialisation toward herds mostly made of cows (i.e. without or with few sheep). In some cases, this change corresponds to enrichment in nutrient of terrestrial and aquatic ecosystems.

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Retention of allochthonous CPOM by LWD versus other structures: Implications for river restoration

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Detritus from riparian vegetation (allochthonous CPOM) is an important resource in stream systems, providing habitat and food for aquatic fauna. Increasing a stream's ability to trap CPOM (i.e. retention capacity) is, therefore, a common ecological target for river restoration projects. Improving retention capacity is one of several ecological benefits of re-snagging, and over the past 50 years river managers have taken strides to replace LWD and native vegetation removed from channels since European settlement.

However, re-snagging can be expensive, time-consuming and labour-intensive, and it is unclear whether LWD traps more CPOM than other in-stream structures such as macrophytes, debris dams, backwaters and boulders. My study examines the effectiveness of these alternative structures at trapping CPOM, and whether they

might be used to improve stream retentive capacity. I hypothesised that structures other than LWD would contribute significantly to overall CPOM retention in headwater reaches in central Victoria.

I compared CPOM retention (CPOM density (m^2/m^2), total dry mass) between seven types of retention structures in four upland creeks in the Strathbogie Ranges. Sites were large enough to contain multiple retention structures, but small enough for all retention structures to be sampled (100 - 150 m^2; n = 22). Potentially confounding hydrological and geomorphological variables (e.g. flow velocity and bed substrate) were similar at all sites (linear regression; $P > 0.05$) and so were unlikely to affect the results.

Preliminary results show that debris dams accounted for 57% of the total dry mass of CPOM retained (sites pooled), more than three times the amount retained by LWD (17% of total CPOM dry mass). Practices that focus on debris dam initiation and construction may, therefore, complement current re-snagging efforts and provide a cost-effective alternative to river managers.

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Secrets and Surprises of Black Box, the guardians of the floodplains

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The working hypothesis for black box (*Eucalyptus largiflorens*) phenology on the South Australian floodplain is that the majority of mature trees flower in summer, geared to soil moisture provided by flood events in late spring-early summer (Jensen *et al.* 2007). A minority of trees flower in winter, and rely on winter rainfall and the main water source for their flowering cycle.

A major regeneration event occurred for black box at medium elevations on the South Australian River Murray floodplain following the flood sequence of 2010-2012, enhanced by significant summer rainfall in 2012 and 2014. This extensive regeneration highlighted the fact that almost no seedlings have survived from flood events in the 1970s and 1990s. The last mass germination to survive to recruitment was that triggered by the 1955-56 floods.

Environmental watering in the SA Riverland region has focussed on sustaining these black box seedlings to enhance their chances of survival. Monitoring of the ecological response to environmental watering is providing useful data on phenological cycles and crop volume. Early results since March 2015 supported the working hypothesis, until the June 2016 field trip found mass flowering in more than 70% of mature black box trees. Is this a return to 'normal', a recovery from 10 years of serious drought 2000-2010? Or is it a new 'normal', responding to the very late flood peaks in February 2011 and April 2012 and unusual rainfall patterns? Monitoring continues, to try to answer these questions.

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Early functional and floristic outcomes of vegetation restoration around the Coorong Lower Lakes

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Determining the success or otherwise of restoration activities is a key requirement for land managers and ecological practitioners. Broad-scale clearance of land for agriculture and other purposes has resulted in degraded ecological communities through loss of biodiversity and function.

Restoration programs require clear goals and carefully chosen metrics to be able to demonstrate restoration success or otherwise both in the short and long term. Functional targets are increasingly the goal of managers who aim not only to conserve species, but the functional components and ecosystem services provided. Species traits provide an important link to the function of ecosystems and the potentially the ability to asses recovery of ecological function.

We assessed the recovery trajectory of a landscape scale restoration around the Coorong, Lower Lakes in South Australia. We used traits relating to resistance and resilience strategies to determine functional diversity of revegetated plots varying in age from 0 to 3 years since planting compared to remnant vegetation. We hypothesised that the older plantings would be more similar to remnant than newer plantings in community composition and functional diversity. We developed functional targets from reference sites for further assessment.

Contrary to prediction our results showed that years which were planted most recently were more similar to remnant in community composition while functional diversity showed limited patterns over time. The presence of introduced species had a large bearing on these results. Further assessments overtime are required to assess the continued restoration of these sites both functionally and floristically. Trait based metrics show promise for these assessments.

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Restoring remote arid wetlands for cultural and environmental outcomes

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In central Australia, the maintenance and restoration of waterbodies are often listed as the highest management priority by local Aboriginal Traditional Owners and rangers, often because these waterbodies have high cultural value as sacred sites and support local plant and animal species. For the past decade we have documented the severe degradation of central Australian waterbodies by large feral animals, mainly camels and horses. These waterbodies, large and small, have also suffered from a lack of active management by Traditional Owners and custodians, who historically cleaned out and protected these sites. During the recently completed Australian Feral Camel Management Project, we quantified the impact of camels on water quality, aquatic invertebrates and native wildlife. Current efforts are on restoring a sub-set of sites from the Tanami Desert in the north, to the Petermann Ranges in the south. Restoration efforts, which in most cases involve local Aboriginal ranger groups, employ a multifaceted approach. These efforts include providing alternative water sources, weed control of buffel grass and bulrushes, the installation

of data loggers to record change over time, and restoring hydrological connectivity. The restoration of water sites in central Australia will provide both environment and cultural benefits, and is essential if aquatic biodiversity is to be restored and maintained in this arid region.

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A DST for evaluating the likelihood of wetland vegetation recovery being successful

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A recent review on vegetation recovery for inland wetlands in Australia (Roberts, Casanova, Morris and Papas, 2016, in press) noted there has been a huge grass-roots effort in this area since the 1980s. The review also noted a chronic lack of case histories, retrospective evaluations, and conceptual framework. This lack of documentation was recognised as a constraint in improving on-ground practices. The decision-support tool presented here uses a conceptual framework of vegetation recovery that was specifically developed as part of that review, and its purpose is to improve on-ground practice and increase success rate. Target users are individuals or groups planning wetland recovery (NRM agencies, NGOs, individuals, landholders) and managers considering whether or not a funding proposal is soundly based. The tool is in the form of a decision tree (DT) with an accompanying User Guide. It evaluates the likelihood of successfully achieving a specific outcome for a particular wetland. The tree is structured as a set of seven questions, covering three topics important in vegetation dynamics and recovery: site conditions (abiotic considerations), regeneration potential (vegetation attributes), and establishment conditions (biotic interactions). The evaluation is done by comparing what the site offers as a habitat for vegetation (current, or proposed future) with what the vegetation type needs for growth and sustained persistence. This requires that the User selects *a priori* one of five objectives for the wetland, and one vegetation type for the wetland. The decision tree can be used as a single pass to evaluate a proposal, or iteratively to refine a proposal, and so learn and improve. The development of this decision tree in Victoria has been greatly facilitated by resource materials such as a wetland regionalisation, and wetland vegetation typology wiht banchmarks, but the principles and the approach have a wider application.

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Sustainable water future programme - balancing water needs for people and nature

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There are virtually no places in the word today where a high degree of water security for humans has been achieved without threatening biodiversity. This reflects the 'traditional' management strategy of tolerating degradation of ecosystems and then applying costly remediation strategies (if at all) after the damage has been done. Competition for water between societal needs and ecosystem demand will intensify in the future, and at the same time securing water for other vital human needs such as food and energy production, as well as safeguarding the quality and quantity of water for ecosystems, should not be neglected in pursuance of water supply and sanitation goals. Thus while framing the SDGs, there is further need for knowledge to understand how to safeguard Earth's life-support system on which the welfare of current and future generations depends. There are still gaps in our knowledge of global environmental change on how to support the economy and the society to move on a trajectory which ensures resource-efficiency, sustainability and wellbeing. Unless we address those knowledge gaps, we will bear a high cost of inaction.

The Sustainable Water Future Programme, a core programme of Future Earth, will maximize the value of water research in the stewardship domain, co-balancing the needs of humankind and nature through the protection of ecosystems and their services provided, offering solutions based on interdisciplinary science with the involvement of all relevant stakeholders. The key note lecture will describe the newly developed programme and focus on the knowledge gaps and the research questions and issues that may be relevant in the next decade to enable human development and to set tolerable ranges for the water system to remain in a steady state and within planetary boundaries.

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Adaptation pathways and water markets

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Adaptation pathways are increasingly being promoted as an effective way to manage water resources. They seek to achieve management goals despite uncertain future conditions through sequences of actions that are implemented in anticipation of changed circumstances. Adaptation pathways share features with water markets in that both promote flexibility, responsiveness to changed circumstances, and the efficient allocation of resources over time. This talk contrasts these two approaches to water resource management, highlights critical differences between them, and considers the potential for both to co-exist.

Adaptation pathways are an environmental planning instrument built on the principles of adaptive management where the allocation of public goods across communities of stakeholders is controlled by responsible authorities and is adjusted in response to new information from monitoring and evaluation. Water markets convert the public good of water into a private good delivered to individuals, and adjustments take the form of relatively constrained set of regulatory interventions.

Where they are being developed adaptation pathways are applied at local and regional (i.e. catchment) scales. The authorities responsible for their development are known and so they are more likely to be accountable for flaws. Water markets, in contrast, are applied across far larger scales, promote only the commercial value of water, and it is not clear who is accountable for flaws.

Environmental sustainability is the *sine qua non* of adaptation pathways in that they seek to sustain the benefits of resources for all sectors and most users over time. In contrast, efficiency is the primary goal of water markets, and sustainability is a secondary outcome to be achieved through caps, purchases of environmental water, and decreasing use of water per unit of output.

Both instruments have their merits and a system that harnesses the best of both approaches is desirable.

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Adaptation pathways - managing wetlands within the Corangamite region under a changing climate

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The Corangamite CMA is responsible for setting regional management directions for the region's natural assets, including wetlands. In developing regional approaches, it needs to recognise and allow for changes in the climate, as well as associated social and economic values. The Corangamite CMA has been trialling a planning approach, adaptation pathways, that addresses the uncertainty and challenges of climate change decision-making. Adaptation pathways enables the consideration of multiple possible futures and allows the analysis and exploration of the robustness and flexibility of various options across those multiple futures. Case studies of adaptation pathways have been applied for wetlands in the region and these will form the basis for Chris's talk.

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Assessing the vulnerability and adaptive capacity of coastal wetlands to climate change

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The climate of Australia is changing and will continue to change. These changes will have significant impacts on Victoria's wetlands, not only via direct effects on hydrology but also indirectly through changes to myriad related processes such as sedimentation, erosion, nutrient cycling, salinisation and ecological connectivity. Coastal wetlands are especially susceptible to climate change because of their position near to the ocean and thus their exposure to rising sea levels and storm surges.

To better understand the vulnerability and adaptive capacity of Victorian coastal wetlands to climate change, the Victorian Government's Department of Environment, Land, Water and Planning (DELWP) and Jacobs Group Australia developed a Decision Support Framework (DSF) to guide wetland managers through a vulnerability and adaptive capacity assessment for coastal wetland systems likely to be affected by climate change.

The DSF is a three step approach, the first being identification of the type of coastal wetland under study. This decision uses a combination of spatial data and local site knowledge. The second step assesses potential impacts from the different components of climate change, and is supported by a suite of conceptual models. The final step requires wetland managers to identify site-specific constraints to management and to develop management objectives based on wetland value and existing local and regional objectives. They then draw from a suite of actions that could be useful for the wetland to adapt to climate change.

The Powlett River estuary in West Gippsland was used as a case study to demonstrate the approach used in the DSF. The DSF and its supporting report can be used to help guide investment and inform wetland managers about the diversity of impacts climate change will have on coastal wetlands, how those wetlands might respond, and the suite of management responses available to mitigate undesirable changes.

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The importance of protecting headwater streams

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Headwater streams are the small flow lines (swales), creeks and streams that are the origin of most rivers. These streams are generally very small in size and may only flow or have ponds of water occasionally. While relatively small in size, these waterways can constitute 75% or more of the waterway length in a catchment, and therefore drain a substantial proportion of the land surface area of a catchment. Because of their extent, they account for a large proportion of the water that flows in the downstream reaches of a waterway. Headwater streams are important in regulating the flow of water, sediments and nutrients throughout a catchment. They also contribute to local biodiversity values, often providing habitat for rare and threatened species. If not managed appropriately, they can be major sources of sediment and nutrient inputs to downstream waterways. These streams are increasingly under pressure with urban development often transforming them into a stormwater network comprising impervious surfaces and pipes. The values and functions of headwater streams can be protected through integrated urban and drainage design with benefits to the environment, the community, land managers and developers. This paper outlines the values of headwater streams and the benefits of protecting them in urban growth areas.

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Assessing the ecological costs and benefits of artificial wetlands in urban landscapes

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The nature and distribution of wetlands around cities is changing at an unprecedented rate, with artificial wetlands increasingly dominating urban landscapes. The consequences of these changes for animals, however, are largely unknown. Some wetlands might play an important role in conserving animals in areas where natural wetlands have been lost or highly degraded. In contrast, if the fitness of animals using artificial wetlands is compromised, they pose a risk to biodiversity in urban landscapes. This risk will be exacerbated if such wetlands are acting as 'ecological traps' – poor quality habitats that are mistakenly preferred by animals.

We have recently initiated a research project to examine the ecological costs and benefits of artificial urban wetlands for native animals, to help ensure wetland construction and management maximises biodiversity outcomes. We are addressing four main aims: (1.) how does wetland quality vary (2.) does wetland quality influence the fitness of animals, (3.) can animals recognise and do they prefer high quality wetlands, and (4.) if not, what are the underlying causes? We will present preliminary results from work addressing the third and fourth of these aims, in terms of examining the responses of a native wetland fish, the Dwarf Galaxias (*Galaxiella pusilla*), to potential habitat selection cues and sensory pollutants. We will also outline our future plans for work addressing the other aims.

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Molecular identification of the precise geographic origins of an invasive shrimp species in a globally significant Australian biodiversity hotspot

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This project details the first detection of invasive freshwater shrimp into the south-west of Western Australia, a region recognised for its biodiversity and the vulnerability of its endemic species. The species was detected as part of biosecurity surveillance of Perth's freshwater lakes. Molecular taxonomy was used to identify the introduced specimens as *Caridina indistincta* sp. B, which is part of a species-complex native to eastern Australia. Phylogeographic analyses were then used to narrow down the likely source population to a small area of south-eastern Queensland, over 3,500kms across the continent from the invasion sites. The potential source area is heavily involved in the trade in freshwater species for aquaria and recreational fish stocking. This information will help in identifying the precise invasion vector and will allow more targeted management measures to prevent future imports of exotic aquatic invasive species.

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Impacts of Indian waterfern (Ceratopteris thalictroides) infestation and removal on endemic damselflies and other macroinvertebrates at Millstream, in the Western Australian arid zone.

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Removal of invasive macrophytes is a priority for managers, but the ecological effects of removing invasive macrophytes on macroinvertebrate fauna are often unknown. This study investigated the aquatic macroinvertebrate fauna inhabiting the invasive waterfern *(Ceratopteris thalictroides*) and the effects of waterfern removal on the macroinvertebrate assemblage at Millstream, in the Pilbara, Western Australia. Macroinvertebrates were sampled at unweeded waterfern-dominated reaches, reaches dominated by native macrophytes, and at weeded reaches, 2 weeks, 6 weeks and 3 months post-weeding. Unweeded waterfern harboured a diverse macroinvertebrate assemblage, including nymphs of the short-range endemic damselfly *Nososticta pilbara.* Macroinvertebrate assemblages differed between waterfern and native macrophytes. At weeded reaches, taxa richness was lowest at 2 weeks post-weeding but increased with time. Macroinvertebrate assemblages at weeded reaches became more like native-dominated reaches as plants regrew. Frequently weeded reaches supported taxa that were rare or absent from waterfern-dominated reaches, particularly suspension-feeders, which were very common at native-dominated reaches. However, odonate assemblages did not recover following weeding. Overall, *C. thalictroides* did not have profoundly negative impacts on macroinvertebrate biodiversity, and provided suitable habitat to a high diversity of macroinvertebrates including rare Odonata. Although weeding had a negative impact on some taxa, it may also increase habitat patchiness in the Millstream channels, thereby allowing a greater overall diversity of organisms to co-exist.

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Invasive willows drive instream community structure

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Non-native invasive species are known to influence biotic communities and ecological processes. Few studies have examined the impact on aquatic communities across trophic levels because it is time consuming and requires a wide range of identification skills. Here, we examined the impacts of invasive willow trees (*Salix* spp.) on microbial and macroinvertebrate composition using a combination of high resolution ecogenomic and classical approaches. Aquatic communities were compared and contrasted between stream reaches with and without willow infestation in three temperate Australian streams. Willows significantly altered in-stream fungal, algal and macroinvertebrate communities. Macroinvertebrate diversity was similar between riparian types. Willow-infested sites were characterised by lower macroinvertebrate abundance and Australian biotic index scores, indicating the presence of taxa generally more tolerant to pollution. At invaded sites, grazers were replaced by generalist collector–gatherer taxa and the proportions of macroinvertebrate functional-feeding groups (FFG) were altered such that the primary trophic pathway was changed from an autotrophic algal-based pathway to a heterotrophic, detrital-based pathway. Riparian invasion by willows may change the primary source of energy from autotrophy to heterotrophy in small streams, with knock-on effects on community structure across trophic levels.

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Potential for offsetting a wastewater management facility discharge to improve creek condition

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Kilmore Creek, in Victoria's foothills, originates near the township of Kilmore which discharges stormwater to the creek. Much of the catchment is substantially cleared for agriculture. Some farms drain dairy waste to the creek and for much of its course there is direct stock access. Farms will often include farm dams and septic tanks. These impacts, combined with an altered flow regime from water extraction, groundwater pumping and urban growth, result in very poor creek condition. Wastewater from the Kilmore Wastewater Management Facility (WMF) is currently managed using winter storage and summer irrigation, although this approach is becoming untenable due to rapid population growth and limited irrigation opportunities. The WMF manager (Goulburn Valley Water) is exploring the potential for discharging to Kilmore creek following upgraded nutrient removal. Although the nutrient concentrations of the proposed discharge would be higher than background, modelling has suggested that with the upgraded treatment, these inputs can be offset by catchment and riparian zone improvements, including removing stock access to waterways, rehabilitating severe gully erosion sites, dairy effluent management and riparian zone rehabilitation. Beyond nutrient reduction, benefits of the proposed discharge and offsetting include reduced sediment inputs to the creek and managed flow discharges, mimicking and supplementing natural flows in an increasingly drying climate.

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Impacts of agricultural intensification on temporary wetlands in south west Victoria

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The volcanic plains of south west Victoria contain a mosaic of endorheic temporary wetlands. These occupy up to 10% of the landscape in some areas, and contain high biodiversity values in an otherwise highly modified agricultural environment. The decline of the wool industry in the late 1990s prompted a transition from grazing to broadacre cropping. This intensification of agricultural production coincided with the introduction of autosteering on cropping machinery which favours block sowing patterns.

An investigation was undertaken to determine the current and previous incidence of cropping in wetlands. There has been a substantial increase in the number of wetlands that are cropped. Cropping has been found to have a range of detrimental effects on temporary wetland ecosystems, from altered hydrology, reduced germination and plant establishment, through to being less able to support dependant vertebrate populations.

GIS techniques were used to categorise the types of cropping encroachment. Small freshwater wetlands face the greatest risk from cropping, and wetlands that are adjacent to a crop are also at a higher risk. The spatial arrangement of cropped wetlands has implications at the landscape scale. Fragmentation patterns are likely to influence the connectivity between wetlands, which is important for repopulating degraded wetlands and for biodiversity resilience.

A multi-disciplinary approach was then used to evaluate the drivers and repercussions of the land use decisions made by farmers. The perceived values associated with different elements of the landscape is dependent on the subjective evaluations of individuals. The success of future projects that aim to preserve privately owned wetlands will depend on understanding the social and economic imperatives of the land owners, as well as the biological complexity of these unique ecosystems.

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Assessing restoration success against an assumed reference state for Long Swamp, a modified coastal wetland in south west Victoria.

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Wetlands are diverse in geomorphology, hydrology and biotic expression, often exhibiting dramatic inter and intra-annual variability. However, wetland condition is ultimately underpinned by the availability of water. Interruptions to hydrology, both in excess and deficiency, result in chronic stressors which ultimately impact on their character and their capacity to provide habitat. Their breadth of diversity makes the assignment of reference states problematic and geographically constrained. Insights into pre-disturbance states are thus a valuable commodity in establishing and measuring restoration objectives. In this presentation we outline our development of a pre-disturbance reference state description and describe steps taken to evaluate restoration objectives for a coastal wetland system in south west Victoria, using historical survey records and aerial imagery combined with contemporary biotic and hydrological monitoring data.

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Defining water quality status and issues for effective natural resource management. Case study of the Gwydir River.

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Effective water quality management requires knowledge that is scientifically sound, clearly communicated, and directly relevant to policy. As scientists our challenge is not only providing the information that meets these criteria, but doing so quickly and with existing resources. Here we outline our process of integrating different forms of knowledge including long term monitoring, literature reviews, data and spatial analysis, and expert opinion, to determine water quality status and major issues of importance. Using the Gwydir River as a case study we outline how both hydrology and catchment drivers are influencing water quality, and the challenges for natural resource managers.

POSTER PRESENTATIONS

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Critical thresholds in aquatic ecosystems: a case study of Tasmanian diatom community response to regional and local environmental change

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Aquatic ecosystems are often hyper-sensitive and rapid responders to local and regional environmental change, in large part, due to fast reproduction and short lifespans of organisms relative to, for example, terrestrial vegetation. Here, we explore the response of a local diatom community to rapid shifts in rainforest vegetation driven by climate and fire over the last 2,400 years. We use a suite of palaeolimnological data to determine changes in vegetation, nutrient cycling, sediment delivery and diatom community structure to test the response of the local aquatic ecosystems to climate-driven terrestrial environment changes. We find that the diatom community in our study lake, Lake Vera in southwest Tasmania, Australia, remains complacent through phases of substantial changes in the terrestrial environment, hinting at a degree of resilience to both regional climatic and local terrestrial ecosystem change. We also identify a major compositional changes in diatom community – a shift from a planktonic dominance (i.e. *Discostella stelligera*) to a benthic dominance (i.e. *Fragilaria* spp. and *Achnanthes didyma*) – at ca. 930 cal yr BP, prior to a climate-driven terrestrial ecosystem change at ca. 800 cal yr BP. This aquatic ecosystem state-shift reflects the crossing of a critical threshold/tipping point in response to regional drivers and/or local dynamics that, thus, provides critical insights in to the long-term drivers and responses of aquatic ecosystem dynamics.

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Improving Nutrient Monitoring Outcomes using Representative Data Collected with Novel Time Integrated Sampling Techniques.

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Most of our knowledge of the patterns and trends in nutrient concentrations and loads is based on data obtained from traditional monitoring techniques (i.e., grab samples collected every week or month) [1, 2]. While this form of monitoring coupled with modelling has provided crucial information, more representative monitoring methods are needed for water quality agencies to develop new effective response strategies, identify specific pollution sources and account for harmful events that are difficult to predict (e.g., floods) [2].

In recent years, on-site and *in-situ* continuous monitoring techniques have been developed to provide real time monitoring of aquatic environments and improve the estimation of nutrient loads. However, these techniques are not extensively used because they are costly to purchase, install and maintain [3]. Time integrated monitoring techniques, provide representative data from an extended period of time rather than a single point in time, such as grab sampling does. These monitoring techniques are robust, inexpensive and easy to use. New time integrated monitoring techniques have been recently developed to sample dissolved inorganic and particulate nutrients in freshwater ecosystems [4, 5].

The diffusive gradients in a thin film (DGT) technique passively accumulates dissolved inorganic nutrients (phosphate, ammonium and nitrate) from sample waters using a combination of diffusion and analyte specific binding components [4-6]. While, a modified version of a suspended sediment sampling technique, developed by Phillips *et al.* (2000), constantly draws sample water through the sampling device and collects particulate matter via induced sedimentation and filtration [7]. For both

of these sampling techniques, the mass of the target nutrient accumulated within the sampling device can be used to back calculate a time-weighted concentration (i.e., the hourly average concentration in the sample waters for the time period of sampler deployment). This poster will present recent optimisation and field application data of these monitoring techniques.

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Slow Wetland Response to Hydrological Change - Press Response or Regime Shift

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Lakes vary in response to minor disturbances and, where stabilising feedbacks exist, tend to return to a stable state. If the disturbance is strong enough the stabilising forces may be overcome and the lake passes a threshold whereby it shifts into a state controlled by a new suite of negative feedbacks. A typical switch in state is thought to occur in shallow lake systems whereby a pulse of sediment or nutrients may drive an increase in phytoplankton impacting the light regime. This impacts negatively on submerged plants which results in greater entrainment of benthic sediments and release of nutrients. These strengthen the competitive advantage of phytoplankton and entrench the lake in a new state.

Multiple diatom-based sedimentary records of change in wetlands in the lower River Murray, Australia, have revealed assemblage turnover following river regulation and impoundment. Typically, benthic and epiphytic flora have yielded to planktonic and disturbance taxa indicative the loss of aquatic plants and a decline in the light regime consistent with regime shift theory. This evidence is supported by changes in the remains of macrophytes, cladocerans and stable isotopes which reveal the loss of plants and the shift to a pelagic system. However, rather than exhibiting flickering before changing abruptly, these systems have changed gradually over several decades. It could be argued that this represents a slow response to a threshold change. Alternatively, it is merely an ongoing response to the persistent pressure exerted by increased fluxes of sediments and nutrients.

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Impacts of climate change on water quality of water supply reservoirs

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There is a close relationship between climate system and quality and quantity of freshwater resources. Due to this relation, climate change becomes an important factor affecting quality and quantity of freshwater resources for human use. Moreover, climate change is generally projected to have adverse impacts on water quality of freshwater ecosystems particularly in zones with Mediterranean climates. Many studies have evaluated impacts of climate change on water quality of elements of freshwater ecosystems such as natural lakes and streams. However, limited information is available on man-made ecosystems such as reservoirs that are mostly under influence of natural environmental conditions. This study emphasizes importance of understanding impacts of climate change and extreme weather events on water supply reservoirs to improve management practices for water provision. A deep reservoir (Lake Bellfield; max depth 36m) and a shallow reservoir (Lake Wartook; 8m) in eastern Grampians Ranges, near Halls Gap in Western Victoria, Australia have been chosen to understand historical water quality transitions. They represent good case studies as they have both experienced recent floods and fires which caused water quality issues that impacted water supply for Wimmera Mallee community. Moreover, while there are concerns about water quality, particularly after floods and fires, only irregular detailed monitoring has occurred to date. Thus, there is currently little or no coherent understanding of historical water quality transitions of these lakes. This study will measure a range of water quality parameters as well as hydrodynamic characteristics of both lakes. Monitoring to date has focused on water quality parameters which have the most potential to impact on water supply operations. Additional monitoring and paleolimnological assessments will be undertaken to better understand mixing characteristics of the lake, to help inform future operations of reservoirs following influx of sediments and inflows after extreme weather events like floods or fires.

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Nutrient pathways and processing in urban streams: implications for rehabilitation in a flat sandy landscape

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3. Cooperative Research Centre for Water Sensitive Cities, Clayton, Victoria, Australia

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The successful restoration and design of urban streams requires a clear understanding of the factors influencing the retention or cycling of nutrients at different scales or reaches. Here, we sought to determine the extent to which in stream physical complexity drives the patterning of biogeochemical activity (e.g., hot spots and hot moments) of sand-bed streams in urban Perth, Western Australia. This information will guide living stream design criteria to mitigate possible impacts of pollutants,

including excess nutrients. We used a gridded sampling design to measure a range of environmental attributes from the water column and sediment (including nutrients, turbidity, temperature, flow rate, water isotopes) and related these to physical traits (e.g. channel width, stream depth, debris density, riffles). We compared spatial patterns across highly degraded (drain) and relatively natural urban stream reaches to investigate: (i) if the diversity of biogeochemical hotspots is greater in relatively natural reaches compared to drains, (ii) the extent to which hotspot development can be predicted by environmental variables, and (iii) the geomorphic characteristics most effective at increasing rates of nutrient retention within streams. This study presents the initial findings of a PhD project investigating the links between biogeochemistry and aquatic foodwebs of urban streams.

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Evaluating and applying indicators of ecosystem degradation for effective ecosystem management and conservation of biodiversity

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Human activities have led to the extensive modification to ecosystems and rapid decline of biodiversity globally, with freshwater ecosystems such as estuaries among the most affected. Environmental risk assessments are critical to inform ecosystem management and policy decisions, however decisions are often made on local or national scales, resulting in inconsistencies in both methodology and outcomes within and between countries. In response, the International Union for the Conservation of Nature (IUCN) Red List of Ecosystems was recently developed as a global standard for assessing the risk to ecosystems and their function. This framework has been adopted in Australia and provides a standard set of protocols for assessing the status of ecosystems and their risk of collapse against five key criteria: A) declining distribution, B) restricted distribution, C) environmental degradation, D) disruption of biotic processes or interactions, and E) quantitative modelling of the probability of ecosystem collapse. Consistent methods for selecting and applying ecological indicators to evaluate decline in ecosystem processes and functions are critical to assess ecological condition, yet current protocols remain relatively undeveloped, particularly in freshwater systems. Our research focuses on further developing approaches for 1) conceptualising and modelling ecosystem dynamics to aid indicator selection, 2) integration of multiple indicators to evaluate functional change, and 3) effective use of expert knowledge to reduce uncertainties. Our work to advance the protocols for conducting ecological risk assessments will allow for more effective management and conservation of freshwater systems.

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