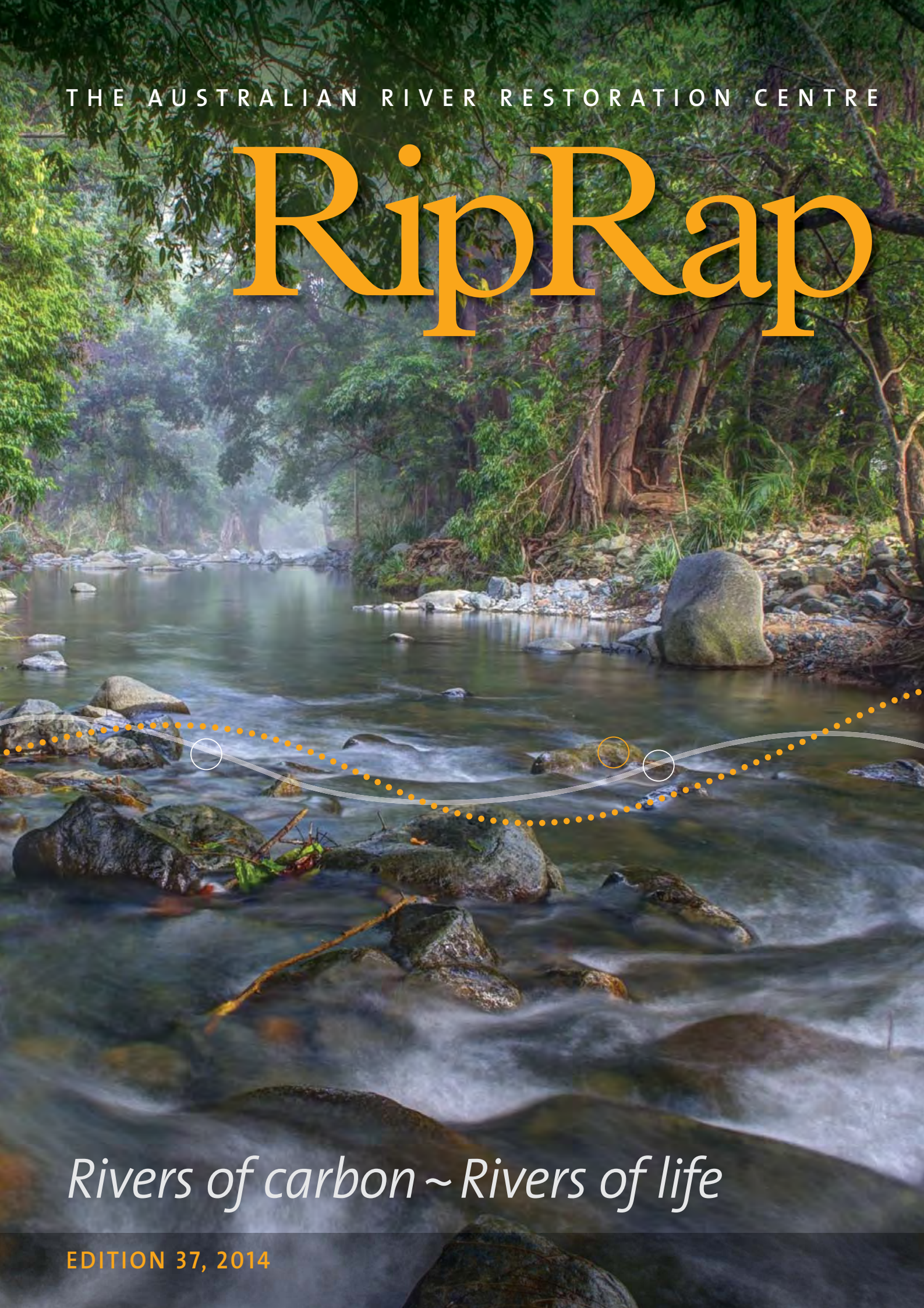

THE AUSTRALIAN RIVER RESTORATION CENTRE

RipRap

Rivers of carbon ~ Rivers of life

EDITION 37, 2014

CONTENTS

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IT HAS BEEN GENEROUSLY SPONSORED BY:

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PHOTO ANDREW TATNELL

Editorial

This edition of *RipRap* focuses on the multiple benefits that can be gained from river and riparian restoration. It provides the science of carbon in rivers and the opportunities carbon farming and carbon credits present us for promoting ongoing conservation efforts.

When I look through these articles I am struck with the quality of work and the commitment of people working in natural resources management. It makes me proud to be a part of such a great community. Thank you for all that you do and I hope you enjoy reading this edition. Please bear in mind the ARRC is a not-for-profit organisation that relies on the sales of *RipRap* to generate funds. Any ideas and actions you can take to promote *RipRap* and encourage people to purchase the magazine and support the ARRC are gratefully received.

RipRap is published by:
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Edition 37, May 2014

ISSN: 1324-6491

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Design: Angel Ink. Print: Excell Printing.

Cover photo: The Mary River, courtesy of Todd Fauser.

A convenient TRUTH

COREY BRADSHAW FROM THE UNIVERSITY OF ADELAIDE DISCUSSES THE GLOBAL PUSH FOR CARBON-BASED CONSERVATION.

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You can follow Corey's blog at ConservationBytes.com

The brave, new green world of the carbon economy hasn't exactly taken off as desired. Perhaps it's because it wasn't really planned from the outset, or maybe it is still too abstract for most people to accept, digest and incorporate into their daily lives. An emergent property of society's generally slow awakening to the challenge of climate disruption, is that it will be a long time before we fully accept its full suite of incarnations.

The infant carbon economy is, however, well and truly alive and kicking, so it is important to try and plan for its growing influence on our decision making. Bumps in the road aside, the carbon economy has mostly been a blessing (actual and potential) for biodiversity conservation projects the world over.

In principle, the aim of the carbon economy is rather straight-forward: charge people a certain amount for each unit of carbon dioxide equivalents they release, and then use that money to develop approaches that further increase carbon sequestration or limit emissions. It's a 'build-it-and-they-will-come' framework, where increasing financial impetus to restrict emissions is enhanced by society's evolution towards better approaches and technology.

The operational side of the carbon economy is unfortunately much more muddled, with vested interests and political gaming weakening its implementation. Nonetheless, we persevere.

Recently, a collection of 30 ecologists with various degrees of specialisation in landscape-scale environmental questions, produced a comprehensive review of the implications of the carbon economy for Australian biodiversity. We described how landscape-scale changes resulting from the flow of carbon finances would affect biodiversity in terms of a) environmental plantings, b) native regrowth, c) fire management, d) forestry, e) agricultural practices and f) feral animal control.

We concluded that environmental plantings were where the largest biodiversity benefits for our investment will come, but care will be needed to plant with ecological restoration in mind as we go. Regrowth vegetation in once-cleared areas is a substantial element of Australia's future biomass carbon, so we need to manage this regrowth optimally, by which we mean the action of keeping (not clearing) existing, human-modified vegetation, or avoiding cropping and continuous grazing.

Fire management is also a big player in the Australian carbon game. By applying fire at the right time, one can potentially increase carbon storage indirectly and abate emissions via the reduction in intensity and frequency of high-intensity fires, thus minimising the total fuel burnt. For forestry, the once-common practice of using fire to remove logging debris is now much less attractive under the new carbon economy. Perhaps the most-touted capacity to retain more carbon in forests subject to harvest is by increasing rotation times, which would also benefit wildlife.

For agriculture, the two best candidates for landscape change that would provide marginal biodiversity improvements would be increasing the retention and encouraging the regrowth of shrubs, and reducing grazing pressure. Finally, while feral animal reductions are without doubt great outcomes for biodiversity, the avoided emissions from their removal are unlikely to make much difference to our national carbon budget.

As a result of these aspects, conservationists have been particularly aware of the carbon economy's potential to strengthen existing and planned initiatives to preserve and restore native biodiversity. We have, therefore, been some of the first to benefit from this additional source of funding, even if it wasn't necessarily targeted to biodiversity-specific goals. Additional funding is of course always welcome, because let's face it, we don't have nearly enough to do what this country needs.

Indeed, Australia has a long history of disrespect for its own home and the vital life-support system it provides us free of charge. With only about 4 per cent of the world's forests in Australia, the little we have is too precious to degrade any further than the already ~40 per cent total forest cover loss we've realised since European colonisation. Believing the remaining 60 per cent is sufficient, ignores that over 50 per cent of remaining forests in Australia have been previously cleared or highly modified; for example, over 80 per cent of eucalypt forests have been altered in some way. Much of the remaining forest is highly fragmented, such that few areas of sufficient size remain to provide the spatial needs of many species.

While nothing can replace primary habitats in terms of biodiversity and the carbon they hold, it is not difficult to understand why so much emphasis has been placed on 'restoring' our highly degraded landscape into some vestige of its former ecological function. Combine this desire with the fact that plants incorporate atmospheric carbon dioxide into their tissues as they grow, and we have an effective means to fund some badly needed conservation initiatives in Australia.

Many questions remain, however, about the best approaches to restore an ecosystem with these two sometimes divergent aims. For example, an accounting approach to terrestrial carbon sequestration would place emphasis on planting the fastest-growing and readily available (often non-native) tree species. This 'plantation'-style reforestation might be an effective approach to sequester the greatest amount of carbon, but it does little good for native biodiversity. Such 'bio-perversities' are a real and present danger. The other extreme is planting as many native plant species as possible, while taking future climate into consideration, to benefit the greatest component of the ecosystem's other constituent species—an approach that is largely cost-prohibitive. So what's the balance, and how do we achieve it?

Fortunately, a few biodiversity-carbon replanting experiments designed to answer just such questions are in progress around Australia—one in far north Queensland in the tropical rainforests of the Atherton Tablelands, one in the semi-arid Mallee forest of South Australia, and one in the wheatbelt of south-western Western Australia. Here, experimental manipulation of various planting densities and species assists in determining what the 'ideal' mix of planting effort and species composition is required to give *both* the biggest biodiversity and carbon bangs for our buck. With greater replication of such experiments in, for example, riparian areas, arid zones, savannas and coastal heathlands, we could eventually be able to provide a generalised approach to biodiversity-friendly, carbon-financed restoration projects across the entire country.

There is no question that we can improve our landscape practices and restore vast areas of Australia's degraded ecosystems. The current lack of political will notwithstanding, the fact that at least one ecosystem service has the economic framework in place to fund such a lofty agenda gives us hope that real, effective climate change mitigation and biodiversity conservation can be achieved.

The next edition of *RipRap* is planned to be on estuarine matters. We invite you to submit a contribution.

THIS PHOTO ROGER CHARLTON. PHOTO ON PREVIOUS PAGE ALLISON MORTLOCK.

Rivers of life

SIWAN LOVETT IS ENJOYING MANAGING THE AUSTRALIAN RIVER RESTORATION CENTRE PROJECT — RIVERS OF CARBON.

The 'Rivers of Carbon' (RoC) project is extending riparian corridors into the wider terrestrial landscape of the Upper Lachlan and Murrumbidgee river catchments to facilitate species movement and mitigate climate change impacts. The project is also leveraging biodiverse Carbon Farming Initiatives in these highly productive areas. Science and local knowledge are being used to identify priority areas for on-ground works, with a particular focus on restoring and linking threatened species habitat.

The RoC project is funded through the Australian Government's Biodiversity Fund, and is managed by the Australian River Restoration Centre, working in partnership with Greening Australia Capital Region.

Since we started, the RoC project has been incredibly busy. We have been overwhelmed with requests for involvement by landholders keen to work with us, and we now have 39 sites, with 24 of those well underway. Larger riparian sites are being given priority to maximise outcomes such as water quality, biodiversity, production benefits and carbon yield.

A stretch of Jeir Creek, which flows into the Murrumbidgee (see inset photo) is one of our new sites that we particularly excited about, as the landholder has agreed to fence back at least 25–30 metres to create a riparian corridor. This site has high recovery potential, with existing vegetation, few weeds and a stable river bed. In addition, the site links to previous work upstream and downstream, allowing us to fill in the gaps to connect the creek and create a continuous riparian corridor.

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So far, we have a mix of riparian and wetland sites, with a few of these linking to remnant grassy box woodland or shrubby forest. We also have some gully erosion sites that we are stabilising to prevent sediment travelling into the river.

Our approach

Before work starting, each site is thoroughly assessed for its recovery potential, its habitat significance, riparian linkages, cost effectiveness (in terms of outcomes) and opportunities for carbon sequestration. We also ensure that we collaborate with the relevant local land services organisation to assess the priority of the site in-line with their catchment action plan.

"We wanted to protect the waterways and provide a habitat for all the wildlife which lives along the river… the river is such a real living thing. Our second motivation was purely practical and production focused, we can now graze the area which is fenced off from the river, which provides more pasture for our sheep and keeps the weeds under control."

Jane Major, 'Yurrah'

"We are doing this work for livestock shelter, the environment and aesthetics, and most importantly to leave the land in a better way for the next generation. I think trees are beautiful and an important part of our landscape. We are at the top of the catchment… so it benefits all water users, we want to keep the soil on our property and not washed away."

Tom McCormack, 'Red Hill' and 'Mt Henry'

By doing this we are bringing together the science of riparian management with the policies of the day, in this case the Carbon Farming Initiative, as well as integrating local catchment plans to ensure our project fits seamlessly into existing institutional structures and policy initiatives.

Once we have planned the works to be undertaken on-site with the landowner, we prepare individual species lists for each site based on pre-1750s vegetation (GIS mapped) and any remnants that are on site. Plants are also chosen with regard to their position in the landscape and moisture availability. Planting tubestock is a key part of the RoC project, as many sites cannot be direct seeded because of high fertility, grass competition and accessibility. For example, only two of the currently approved 24 sites have been suitable for direct seeding and are due to go ahead this year.

It is important to us that people understand why we are focusing on riparian areas, and to explain why, we have produced a technical guideline that provides the science behind our actions (see next article). The guideline is our attempt at synthesising current knowledge of riparian restoration with the carbon farming policy environment. Despite changing political imperatives, we agree with Corey Bradshaw that carbon credits have considerable potential for environmental restoration, while also providing landholders with incentives to manage their land differently.

Protecting threatened species is another aim of our project, and we had a recent thrill when we found a range of ages of Southern Pygmy Perch in the Pudman Creek (one of our sites) that showed the fish are breeding. This is significant, as the population in the Pudman Creek was translocated in an effort to save the species from the pest species Redfin Perch, in particular. The fact that they are breeding in the Pudman means these little fish may be on the road to recovery.

Story telling is an integral part of our project, and this year we have worked with four of our landholders to share their stories about being involved in the RoC project.

PREVIOUS PAGE TITLE PHOTO ROGER CHARLTON, TUBESTOCK ALLISON MORTLOCK, JEIR CREEK LORI GOULD. THIS PAGE LANDHOLDER PHOTOS KYLIE NICHOLLS, LEAF FOREST AND KIM STARR. TUBESTOCK OPPOSITE PAGE ALLISON MORTLOCK.

"Carbon credits have played a major role in my thinking, but it has come indirectly as part of a process and awakening of what this whole idea of sequestering carbon means. I can see the benefits and it will make a huge difference in our atmosphere if we can do our bit to get the carbon back into the ground… It is a a lot to aim for, I know, and it will take time."

Margie Fitzpatrick, 'Australind'

"We have a responsibility to be proactive about managing the environment and protecting our on-farm resources. It also fits with our production goals of reducing labour costs and improving stock management. Fencing off creeks and riparian areas has provided significant cost savings in running our farms."

Allan Munns, 'Suffolk Vale'

We love working with landholders who are as passionate about their rivers as we are, but who also bring other goals and ideas about their farm. Though negotiation we aim to get the best outcome for the environment, as well as on-farm sustainability and productivity. Everyone we work with has different motivations for being involved. The quotes above show just some of the reasons our landholders are working with us.

The case studies are on the newly updated Rivers of Carbon website that has a range of resources to allow people to learn from scientists and landholders about how to create and manage rivers and riparian areas for multiple benefits. We have produced the case studies in multiple formats so they are easy to read on the website, downloadable as pdfs, or available in hard copy through the ARRC Shop. You can also hear the landholders talk about the work they are doing as they have kindly allowed us to record their interviews—all these resources are available from **www.riversofcarbon.org.au**.

We are not just focusing on work in our region, and we have recently developed a facility on our website to allow anyone to register and upload content relating to projects seeking multiple benefits from riparian restoration. If you have a project and story you would like to share, then please go to our website and become a contributor. We genuinely believe Joseph Badaracco's philosophy that:

"In today's environment, hoarding knowledge ultimately erodes your power. If you know something very important, the way to get power is by actually sharing it."

What is a river of carbon?

"…the most important area of work to mitigate climate change impacts and protect and conserve biodiversity, is to plant diverse, resilient native vegetation linking existing patches of remnant vegetation to create living corridors."

(Bradshaw et al., *Biological Conservation*, 161, 2013)

TITLE PHOTO COL ELLIS. RIGHT: EUCALYPTUS GONIOCALYX. BOTH PHOTOS COURTESY OF GREENING AUSTRALIA CAPITAL REGION. TUBESTOCK ON OPPOSITE PAGE ALLISON MORTLOCK.

The living world around us, on the land and in the water, is based on carbon. Carbon is one of the most abundant elements in the universe and is an essential part of us and our environment—we need carbon to survive.

Carbon found in something living is called organic carbon. The organic carbon in living organisms comes from carbon dioxide (CO_2) in the atmosphere. Carbon can be stored in living organisms for extended periods, particularly in plants that have long life spans, for example, trees. The carbon found in non-living things such as rocks, shells, the atmosphere and oceans, is called inorganic carbon.

The *carbon cycle* describes the complex processes carbon undergoes as it is transformed from organic carbon to inorganic carbon and back again. Carbon is returned to an inorganic state in a number of ways—it is the ultimate in recycling! Both animals and plants release CO_2 into the atmosphere through a process known as *respiration*, in which complex carbon-containing compounds are broken down and energy released. When an animal or plant dies, it is broken down by bacteria and fungi and once again the carbon is released. This process is called *decomposition*. Living organisms also return carbon to the atmosphere when they are burnt.

The carbon cycle comprises a sequence of events that make the Earth capable of sustaining life. It is as important as the nitrogen cycle and the water cycle. Carbon dioxide in our atmosphere not only serves as a source of inorganic carbon for plants and certain microbes, it also helps prevents heat from escaping and, in doing so warms up the Earth's atmosphere. In a similar way to the glass of a greenhouse, CO_2 traps heat and for this reason is a primary greenhouse gas (GHG). Other primary GHGs in the Earth's atmosphere are water vapour, methane, nitrous oxide and ozone. The heat trapping capacity of GHGs helps keep the Earth's temperature at a level necessary to support life.

Why sequester carbon?

Human activities release GHG into the atmosphere—particularly through the burning of fossil fuels (coal, oil and natural gas) and land clearing. The carbon released when fuels are burned is called a carbon dioxide emission, with each fuel emitting a different amount of CO_2, as well as carbon monoxide and soot.

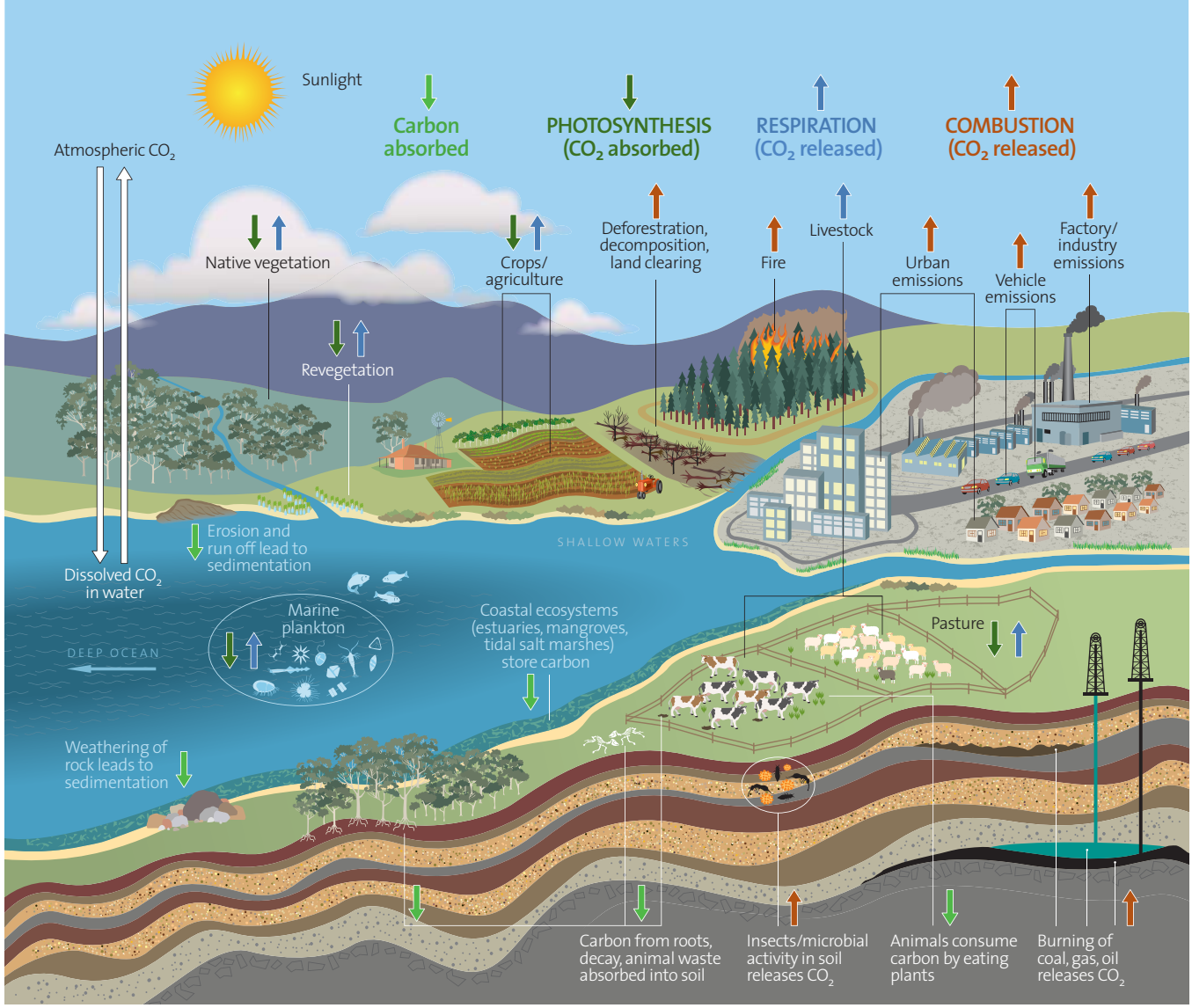

DIAGRAM ALLISON MORTLOCK.

The main elements of the carbon cycle on Earth.

The amount of CO_2 in the atmosphere today is around 30 per cent higher than it was 200 years ago. Greater concentrations of greenhouse gases such as CO_2 will trap more heat and raise the Earth's surface temperature—this is known as the greenhouse effect. This process has been linked to changes in rainfall, temperatures and extreme climate events, often with negative consequences for humanity and our environment.

Carbon dioxide is the most important human-contributed greenhouse gas. Many ways have been identified to help reduce its impact in the atmosphere by reducing or stabilising concentration levels. One approach that is being increasingly adopted is to create 'carbon sinks', where carbon sequestration (capture) is greater than releases over the same time period. Revegetating areas enables CO_2 in the atmosphere to be absorbed by plants through photosynthesis, and stored as carbon in biomass (tree trunks, branches, foliage and roots) and soils, creating a carbon sink that can have multiple economic, social and environmental benefits.

Why rivers of 'biodiverse' carbon?

When we combine our understanding of the importance of biodiversity to sustaining life on earth with the use of carbon sinks to mitigate negative impacts of climate change, we develop projects like Rivers of Carbon (RoC). RoC aims to revegetate and rehabilitate sites to provide a biodiverse carbon sink with multiple benefits, by planting a diversity of native plants. While single species plantations will do the job of sequestering carbon, 'biodiverse carbon' provides an additional array of ecosystem services such as habitat for native wildlife, a mix of native vegetation species, a supply of food, leaves, litter and shade for aquatic animals, a reduction in soil erosion, and improved aesthetic, social and cultural values.

Rivers are hotspots for biodiversity, encompassing both aquatic and terrestrial systems. A diversity of plants and animals such as trees, shrubs, grasses, native mammals, birds and fish are associated with rivers and riparian zones. A river of carbon describes the sum total of carbon that is found and can be captured in rivers, riparian habitats and the terrestrial systems they connect with.

The phrase encompasses the carbon in the plants, animals and soils that are found in-stream and on the land connected to river systems. As with the carbon cycle, rivers of carbon is a dynamic concept that is influenced by the cycle of the river itself, the prevailing climate and the management practices in place.

Carbon typically enters rivers in one of two ways. 'Terrestrial' carbon originates from the surrounding landscape, that is, from plants, animals and soil, carried into the river by rain, snow melt and wind. 'Riverine' carbon comes from algae and plants in the water that make their own carbon. Organic matter in the waterways is digested by micro-organisms, insects, and fish. The CO_2 they generate and the dissolved inorganic carbon carried into the rivers from on land, then return to the atmosphere or are buried in sediments. Rivers create corridors through the landscape for both terrestrial and aquatic species, and provide the perfect system for maximising both carbon sequestration and biodiversity conservation at both local site and regional scales.

www.
riversofcarbon.org.au

MAIN PHOTO AND FARMER: COURTESY OF GREENING AUSTRALIA CAPITAL REGION. SEED PODS JOHN TANN (WIKIMEDIA COMMONS).

Working with landholders to create 'Rivers of Carbon'

Carbon farming is in its early stages, but landholders can undertake revegetation now, for multiple purposes, with the added incentive of potentially being able to also claim carbon credits in the future. The RoC project supports such works, enabling farmers to achieve production and biodiversity goals now, while also getting carbon into the landscape at subsidised rates for which they may later be able to claim carbon credits.

The overall approach is one where the landholder manages the riparian zone within the context of the overall farm or land management plan means, employing different, yet integrated strategies to boost soil productivity along streams and rivers, as well as revegetating the area to create biodiverse carbon sinks. By working in partnership with landholders RoC aims to link biodiversity hotspots (centred on riparian vegetation of high conservation value and threatened species throughout the upper Lachlan and Murrumbidgee catchments) to intact vegetation and expanding their habitats will be a priority. Both in-stream and riparian habitat will be restored by enhancing and linking existing native vegetation and revegetation sites, enabling movement of wildlife across the landscape. To find out more about how the project is progressing, please visit the Rivers of Carbon website **www.riversofcarbon.org.au**.

This excerpt is taken from the 'Rivers of Carbon' technical guideline by Jann Williams, Phil Price, Michael Rooney and Siwan Lovett. Copies are available for download from the Rivers of Carbon website, and hard copies are available through the ARRC shop.

BIODIVERSITY WITH ALTITUDE

LEON MINERS OF SOUTH EAST LOCAL LAND SERVICES SPINS A TALE ABOUT 'WEAVING A WEB' OF BIODIVERSITY IN THE SNOWY RIVER CATCHMENT.

Coogee Reed admiring an excellent stand of remnant riparian vegetation, in particular Lomandra grasses, along the Delegate River. Photos throughout courtesy of the author.

A project to restore and enhance biodiversity values and riparian corridors across multiple sites in the Snowy River catchment is currently underway. This project is built on the back of almost 20 years of environmental campaigning and on-ground action to recover the iconic Snowy River.

A degraded river

The headwaters of the Snowy River are in the alpine areas of southern New South Wales. It then flows over 400 kilometres to the ocean at Marlo in Victoria. Construction of Jindabyne Dam by the Snowy Mountains Scheme in 1967 led to 99 per cent of the river's headwater flows being captured. Fed largely by snow melt, this loss of flow had significant environmental impacts, including channel contraction, sedimentation, blockage by willows and degradation of habitat and ecological values along its length. Along with grazing by livestock and rabbits, catchment erosion, and loss of riparian vegetation through clearing, the Snowy had become an environmental wasteland. Social impacts were also felt by communities for whom the river was seen as an important regional feature and component of their living heritage.

In the 1990s, 'Save the Snowy River' grew into a major New South Wales and Victorian community campaign led by the Snowy River Alliance. The strong community movement culminated in a joint decision in 2001 by the federal and state governments to invest in water savings in irrigation areas to recover up to 28 per cent of the Snowy River's average annual flows.

River recovery

The resulting Snowy River environmental flow allocation was supported by millions of dollars of investment, and thousands of hours of landholder effort undertaken on in-stream and riparian rehabilitation works. It was achieved through a coordinated and centrally delivered cross-border project involving the former Southern Rivers Catchment Management Authority (CMA) in New South Wales and East Gippsland CMA in Victoria. Many different land uses were covered as the project crossed tenure arrangements including crown land, national parks and private properties.

BIODIVERSITY WITH ALTITUDE

Map: New South Wales portion of the Snowy River catchment.

Right: A section of the lower Snowy River in Kosciuszko National Park choked with willows and sediment. Far right: The same reach after willow control.

I'm really enthusiastic about the biodiversity project and it will be good for our district.

Coogee Reed

This work was done to prepare the river to a standard that would maximise recovery after environmental flow releases. Since 1996 activities in the New South Wales section have included:

- clearing of in-stream willows and engagement by 99 per cent of landholders in riparian blackberry control along 186 kilometres of river to reduce choking and siltation of in-stream habitats,
- targeted riparian revegetation along 50 kilometres of priority river reach to stabilise sand deposits, improve bank stability and restore river structure and habitat,
- trial restocking of 200,000 native Australian Bass (*Macquaria novemaculeata*) to restore native fish populations,
- research to improve understanding of the habitat and biology of the river as it recovers,
- engagement of the wider community through community events, partnerships and publications.

In October 2011, the largest ever environmental release occurred on the Snowy River, followed soon after in April 2012 by a 1 in 50 year flood. These events were significant milestones in the recovery of the river. The 'slumbering giant' was awoken, not only because of the considerable flows, but because of the previous decade's work to remove weeds and improve riparian condition that allowed large amounts of sediment to be processed by the river. Low-flow channels took on new definition, pool and riffle sequences were re-established, and new banks were formed, pushing the Snowy River well onto a recovery pathway.

The recovered river is estimated to generate up to $20 million in new economic activity for the region with water sports and fishers being key recreational users.

Landscape scale biodiversity

The knowledge gained from the 18 years of investment in the 'Snowy River Rehabilitation' project is now being extended out to the wider catchment through a new six-year 'Weaving the Web' project funded by the Australian Government's Biodiversity Fund in 2012.

On the back of significant environmental action and a strong platform of landholder, community and agency participation that has been coordinated by South East Local Land Services (LLS), the project aims to restore, manage and enhance biodiversity values across multiple sites on private land to connect the upper Snowy River to its major tributaries in the southern parts of the catchment.

The Snowy River will provide a spine for restoration efforts, with revegetation corridors expanding like ribs into the agricultural landscape, and linking to natural reserve systems (e.g. Kosciuszko National Park and Byadbo Wilderness Area).

"I'm really enthusiastic about the biodiversity project and it will be good for our district. I would like to see increased biodiversity and less erosion along our creeks and rivers through tree planting and weed control. The project is well timed with the extensive willow and blackberry control currently occurring in the catchment and is in line what many people want to do on their farms," says Coogee Reed, a Delegate local involved in the project.

The project will take the lessons learnt from past work along the river and apply these to tributary catchments. The rate of recovery along the main artery will also continue to be enhanced by ongoing in-stream and bank revegetation works. Endangered and threatened ecological vegetation communities in the catchment will be protected and enhanced, with a focus on these communities for revegetation and restoration. Weeds, primarily African Lovegrass and Serrated Tussock, are also being targeted where they threaten remnant vegetation and reserves.

Revegetation works along the Snowy to improve stabilisation and biodiversity.

The project is also working with other programs in the region including Landcare efforts and the Bombala–Delegate 'Water for Rivers' project which is coordinating willow and blackberry control for this river system—the largest tributary catchment where willows have not yet been treated.

Specific 'Weaving the Web' activities being undertaken by South East LLS and the wider community include:

- revegetating and fencing of priority tributary riparian corridors,
- revegetating sand sheets along the Snowy,
- revegetating and fencing of remnant paddock vegetation,
- prioritising weed control to reduce grassy weed threats,
- engaging a local seedbank to enhance the collection and availability of seed supply,
- delivering a coordinated willow and blackberry control program along the Bombala–Delegate river system.

Key to the success of these works will be working closely with local landholders and Landcare organisations in the area. Over the six-year period the project aims to complete 50 hectares of revegetation, 408 hectares of remnant vegetation protection and 2000 hectares of grassy weed threat reduction throughout.

Challenges and management implications

Climatic variability and difficult site conditions are key challenges for the revegetation and weed control components under this project. Increasing landholder capacity and raising awareness about the benefits of biodiversity are also priority tasks.

This project provides an opportunity to significantly improve the recovery and biodiversity value of the Snowy River and its tributary catchments through direct on-ground action. The scale of intervention proposed is significantly above and beyond the usual environmental capacity for Snowy Monaro landholders. It will provide a unique opportunity to capitalise on biodiversity outcomes at a landscape scale, that may not otherwise have been realised in the region.

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Devices for blackwater

DARREN BALDWIN OF CSIRO'S WATER FOR A HEALTHY COUNTRY FLAGSHIP TALKS ABOUT TOOLS TO ADAPTIVELY MANAGE BLACKWATER.

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The functioning of lowland river–floodplain ecosystems depends on the two-way exchange of water, nutrients and energy during flood events. In particular, carbon export from floodplains during flood events is an important energy subsidy for lowland rivers (see page 14). During a flood, carbon compounds are leached from leaf litter lying on the floodplain, as well as grasses and other sub-storey vegetation. The leached carbon stains the water a dark colour — hence the term 'blackwater'. The amount of carbon leached will depend on a number of factors, such as the type and age of the litter or grass, the amount of material on the floodplain, the time since the last flood and the temperature. The leached carbon is then taken up by bacteria from where it can enter the aquatic food web.

The export of carbon from the river channel can, however, cause some significant dis-benefits. Following a decade-long drought, substantial areas of floodplains in the southern Murray–Darling Basin were flooded during the summer of 2010/11. Microbial respiration of the large amount of dissolved organic carbon mobilised from the floodplain depleted dissolved oxygen to such an extent that more than 2000 kilometres of river channel were affected by 'hypoxic blackwater' ('hypoxia' means low dissolved oxygen); with the hypoxia persisting at some sites for up to six months. The extensive hypoxic blackwater plume resulted in the widespread mortality of aquatic organisms, including large-bodied fish, as well as crustaceans like Murray crays and yabbies. So while carbon export from floodplains can be beneficial to the riverine environment, the occurrence of hypoxic blackwater also represents a significant environmental risk.

This risk needs to be managed within an adaptive management framework, which includes the ability to predict the likelihood and severity of hypoxic blackwater events, as well as developing strategies to mitigate the effects of hypoxic blackwater events when they occur. The Murray–Darling Basin Authority has funded a series of projects at the Murray–Darling Freshwater Research Centre (MDFRC), led by Kerry Whitworth from La Trobe University and Darren Baldwin from CSIRO's Water for a Healthy Country Flagship, to develop tools to help optimise the benefits of flood return water from the floodplain, while minimising the risk of downstream hypoxia.

The first tool that has been developed is the Blackwater Research Assessment Tool (BRAT). This tool builds on an earlier blackwater model developed at the MDFRC. The original model specifically predicted dissolved oxygen in the Murray and Edward Rivers downstream of Barmah Forest, and consisted of a fairly simple hydrological description of flooding of the forest. This was then used to calculate downstream oxygen and carbon levels in the two rivers, based on a series of process-based relationships. In developing BRAT, the assumptions, algorithms and constants used in the original model were refined and updated through a series of laboratory experiments and field observations.

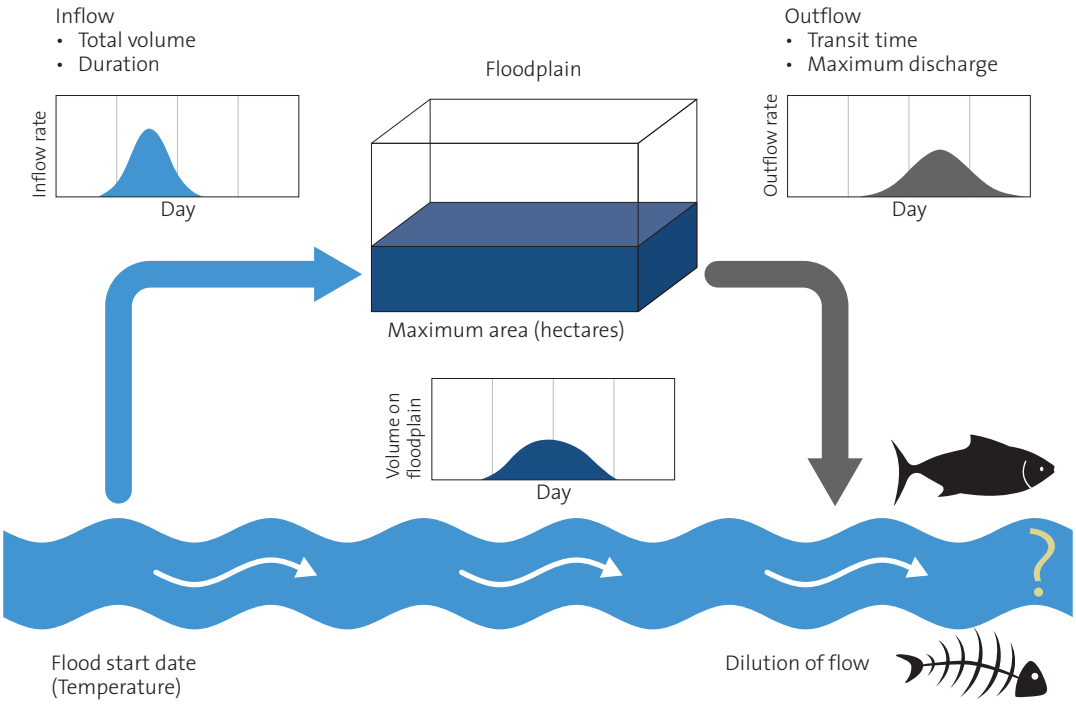
The BRAT is a generic, desktop risk assessment tool that can be used to predict the likelihood of hypoxic blackwater generation during inundation of an idealised floodplain (Figure 1). In BRAT, water is routed onto a floodplain with a defined maximum input volume, inflow duration and inundation area. Carbon leached from inundated litter on the floodplain, and carbon and oxygen consumption from the water column, are calculated on daily time steps. Water exits the floodplain after a defined transit time, with a defined maximum outflow rate. Dissolved oxygen and carbon in the outflow water, and in receiving waters immediately after dilution, is calculated on a daily time step. BRAT's outputs include the minimum dissolved oxygen, duration of hypoxia (DO < 2 mg L^{-1}) and maximum dissolved organic carbon (DOC) in both the floodplain outflow and in downstream receiving waters immediately after dilution. BRAT also estimates how much of the DOC leached from the floodplain could enter aquatic food webs. BRAT operates on a Microsoft Office Excel 2010 platform.

If blackwater generation is inevitable, or if blackwater is present due to unforeseen circumstances, management interventions to promote the rate of re-aeration may be required to protect downstream aquatic environments. A number of studies from MDFRC have identified three main intervention options that provide some benefit during previous blackwater events 1) in-channel dilution, 2) mechanical re-aeration, and 3) diversion of flows to large, shallow lake systems. A second tool, the Intervention Assessment Tool, also operating on a Microsoft Excel platform, can be used to assess the effectiveness of each of these potential management activities in mitigating the effect of hypoxic blackwater.

A number of organisations, such as the Department of the Environment and Forestry Corporation of New South Wales are currently using the tools to assist them in managing flooding of forested floodplains. If you would like copies of the tools please get in touch with Darren.

Several journal articles are available on this research, contact the author for more details.

FIGURE 1: MODEL COMPONENTS



ITSY BITSY BUGS

NATHAN NING OF THE MURRAY–DARLING FRESHWATER RESEARCH CENTRE EXPLAINS THE LINKS BETWEEN CARBON, OXYGEN, ZOOPLANKTON AND FOOD WEBS.

1. Ostracod or seed shrimp
2. Rotifer
3. Copepod
4. Copepod
5. Rotifer
6. Rotifer
7. Cladocera or water flea

Blackwater events occur when floodwaters inundate dried leaves, bark and twigs on a floodplain or in a dry river channel, resulting in the release of carbon and other nutrients leached from the organic material. While aquatic bacteria consume the leached carbon they also consume and can deplete dissolved oxygen in the water, resulting in 'hypoxia' or 'hypoxic blackwater'. Hypoxic blackwater events have the capacity to reduce dissolved oxygen to less than 1 mg L^{-1} for extended periods of time. Most fish and other large aquatic fauna require at least 2 mg L^{-1} of dissolved oxygen to survive, and stress may be induced at levels of less than 5 mg L^{-1}.

While hypoxic blackwater events pose a threat to the management of many river–floodplain systems, there is still a lack of basic knowledge regarding the effects of these events on the aquatic biota. The occurrence of hypoxic blackwater events has been shown to result in the death of larger animals such as fish and crayfish, but nothing is known about their effects on smaller planktonic animals.

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Zooplankton

Zooplankton, or planktonic animals, are a diverse group of microinvertebrates. They occupy a central position in river–floodplain food webs as consumers of algae, fungi and bacteria, and as potential prey items for waterbirds, amphibians, other macroinvertebrates and fish. Zooplankters are a vital food source for the larval and juvenile stages of many fish, and some small-bodied fish rely on zooplankton as a major component of their diet throughout their entire lives.

In the Murray–Darling Basin, common members of the zooplankton community include rotifers, Cladocera (water fleas), Copepoda (copepods) and Ostracoda (seed shrimp). Rotifers are minute to microscopic in dimension (less than 0.5 mm) and they are often the most numerically abundant and diverse microscopic animals in freshwaters. Cladocera reach a maximum length of 6 mm, Copepoda and Ostracoda are 4 mm in length at most. Zooplankton commonly produce resilient, toughened eggs that may be fixed to surfaces, or dispersed in water to sink into sediments where they can persist through varying conditions including total drying. Inundation during flooding often acts as the cue to hatch.

Exploration through experimentation

As part of a National Environmental Research Program (NERP) project investigating the effects of floodwaters returning to the river channel, the Murray–Darling Freshwater Research Centre (MDFRC) investigated the impact of hypoxic blackwater events on river–floodplain zooplankton communities. Specifically, we examined the effects of varying carbon (as measured by dissolved organic carbon: DOC) and dissolved oxygen (DO) concentrations on zooplankton emerging from floodplain wetland sediments.

Sediments containing resting stages of zooplankton were collected from two temporary wetlands; one located near Deniliquin on the Edward River floodplain, the other located on the floodplain of the Gulpa Creek system in a River Red Gum forest near Echuca. The source wetlands were chosen as representatives of temporary floodplain wetlands containing sediments highly likely to harbour a diverse range of zooplankton eggs. A laboratory experiment was undertaken where the collected wetland sediments were inundated under varying DO and DOC treatment conditions, and emerging zooplankters were sampled, counted and identified over a period of six weeks.

Our findings suggest that hypoxic blackwater events can substantially impede the emergence of zooplankton from the sediment egg bank in the short term (i.e. over a period of three weeks). Data also suggest that a return to normal conditions with adequate levels of dissolved oxygen facilitates a return to normal levels of zooplankton emergence from the egg bank. The rapid recovery in zooplankton abundance indicates that there is some level of resilience to hypoxia built-in to the life history of these freshwater zooplankton groups.

Apparent suppression of emergence could be due to hypoxia-related effects on dormancy breakage and egg viability, as well as hypoxia-induced mortality of animals soon after hatching. At a floodplain scale, the consequences of hypoxic suppression of zooplankton manifest as a potentially enormous reduction in food availability for fish, macroinvertebrates, amphibians and water birds.

Blackwater versus hypoxic blackwater

Blackwater can occur without severe hypoxia, and these conditions were also simulated in the laboratory treatments. The findings from the study suggest that where oxygen levels in blackwater remain within the normal range, blackwater itself has no negative impact on zooplankton communities.

Environmental watering

The relationship between freshwater biota (including zooplankton) and carbon on the floodplain is complex and synergistic. Carbon export from floodplains during flood events is an important energy source for lowland rivers, fuelling the microbes at the base of the food web. At times however, carbon metabolism within aquatic systems can act as the trigger for food web disruption through massive dissolved oxygen depletion. Further research is now required to determine the tolerance thresholds of river–floodplain zooplankton to different concentrations and/or durations of hypoxia. Understanding of zooplankton response to hypoxic blackwater will contribute to the knowledge needed for optimal management of environmental watering; maximising the benefits and minimising the dis-benefits of each watering event.

The project team: Nathan Ning, Gavin Rees, Rochelle Petrie, Ben Gawne and Daryl Nielsen.

To find out more about MDFRC research under the National Environmental Research Program in 2013 visit www.mdfrc.org.au and search for food webs.

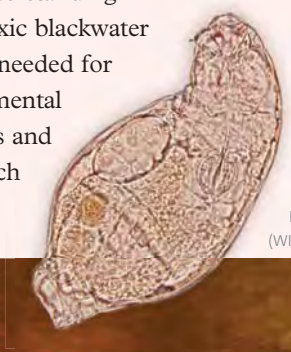
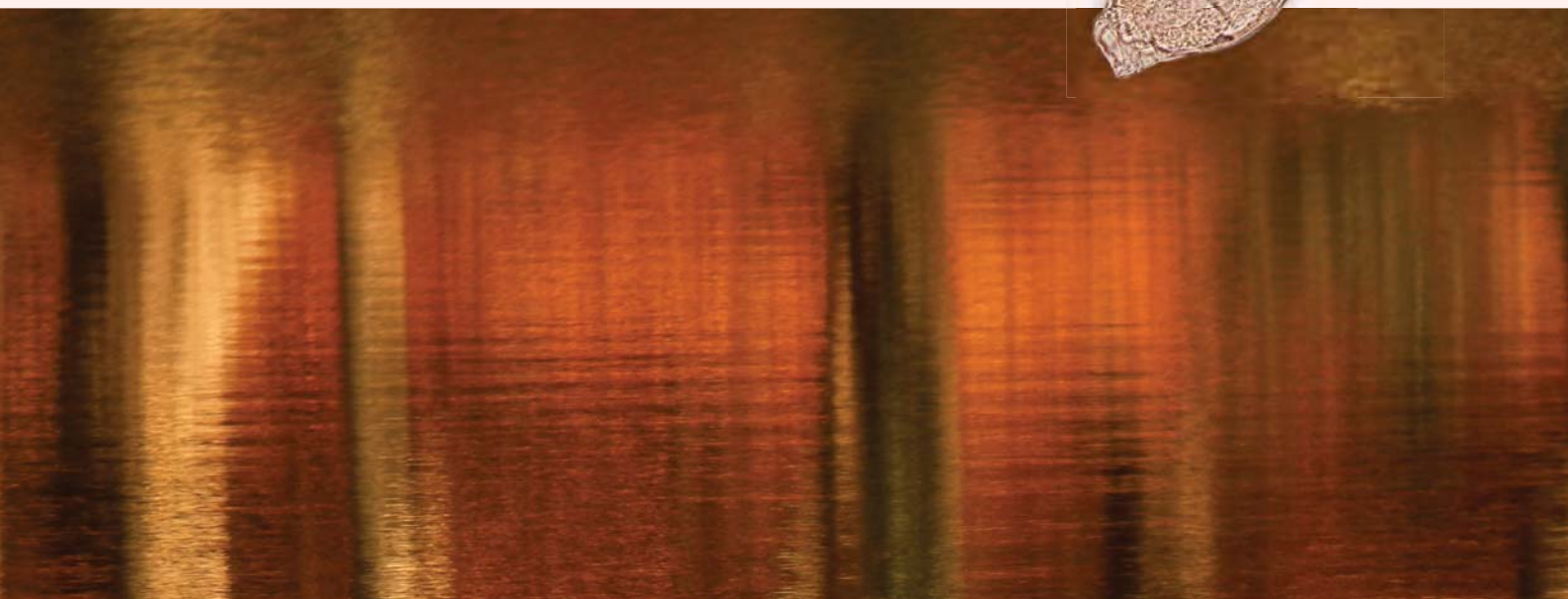


PHOTO NEVIT DILMEN (WIKIMEDIA COMMONS).



Awash with food webs

ROB COOK DESCRIBES THE RESEARCH THE MURRAY–DARLING FRESHWATER RESEARCH CENTRE ARE CONDUCTING INTO CARBON IN FRESHWATER FOOD WEBS.

PHOTO: COURTESY OF THE AUTHOR

Current understanding of river function in the lower Murray–Darling Basin suggests that in-stream processes, such as algal and plant growth are the major source of carbon and energy for food webs. However, many studies behind this understanding were carried out during periods of low flows in the Murray–Darling Basin (e.g. during the millennium drought), and contributions from flooding were not included in the thinking. Increased use of environmental water simulates localised flooding and can lead to mobilisation of large amounts of dissolved organic carbon. Understanding the relationship between floodplain carbon sources, flooding flows and river functions therefore, is a top priority for researchers and managers in the environmental watering arena.

Some benefits of flooding: a closer look ...

The Murray-Darling Freshwater Research Centre (MDFRC) researchers used a range of methods to measure the response of in-stream algae, bacteria and food webs to waters enriched with carbon and nutrients after floodplain inundation, and have detected a range of positive ecological responses. Biofilms and macroinvertebrates are among the aquatic biota positively affected by return of floodwaters from the floodplain to the river channel. In work carried out in the Barmah–Millewa Forest after environmental watering and flooding, the following benefits were identified:

- Carbon and nutrients that leached from River Red Gum leaf litter stimulated the growth of biofilms, which is a complex mix of algae, bacteria and fungi that grow on solid surfaces (e.g. wood) in rivers.
- The amount of algae present in the biofilms greatly increased, demonstrating increased biofilm productivity.
- Biofilm microbial communities (bacteria and fungi) consuming the dissolved carbon responded within days of being exposed to leaf leachate.
- The community composition of microscopic organisms that consume bacteria changed as biofilms developed in the presence of dissolved carbon.
- Macroinvertebrates such as chironomids, snails and shrimp consumed the biofilm material, thereby ultimately getting their energy from the terrestrial carbon, not just algae from within the river.

The study tested if dissolved carbon from the floodplain could fuel food webs. In essence, the results outlined above combine to show that terrestrial carbon picked up by water on the floodplain was rapidly incorporated as an energy source for the river food web.

The latest stages and a report on this work were funded by the National Environmental Research Program in 2013 and built on work MDFRC had conducted above and below the Barmah–Millewa Forest, assessing the response of the Murray River to flooding. The Barmah–Millewa Forest project began in July 2010 and has been jointly funded by the now federal Department of the Environment, the Murray–Darling Basin Authority and Goulburn Broken Catchment Management Authority.

FOR FURTHER INFORMATION
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The project team: Robert Cook, Gavin Rees, Daryl Nielsen, Rochelle Petrie, Garth Watson, Darren Baldwin, Ben Gawne, John Pengelly and Nathan Ning.

To find out more about MDFRC research under the National Environmental Research Program in 2013 visit www.mdfrc.org.au and search for food webs.

MAIN PHOTO G. HOUSTON, INSET TOBY HUDSON. BOTH WIKIMEDIA COMMONS.

A flood of life

HEATHER McGINNESS INTRODUCES CSIRO'S RESEARCH INTO CARBON SEQUESTRATION AND BIODIVERSITY SUSTAINABILITY IN THE LOWER MURRUMBIDGEE CATCHMENT.

The biodiversity benefits of inundating isolated floodplain wetlands by managed flooding are well known. In contrast, the importance of flooding for rapid short-term biomass accumulation (and hence carbon sequestration) in the understorey, as compared to relatively delayed long-term biomass accumulation of the overstorey, is less well known.

Floodplain systems are important sinks (and sources) for carbon and nutrients, and are significantly more productive and biodiverse than adjacent dryland communities. Hydrological connection of wetlands in riverine landscapes can increase the retention, concentration and diversity of carbon sources over both space and time. Flooding generates rapid and large increases in biomass production in the ground layer, with relatively delayed increases in production in both the shrub and tree layers. With restoration of aquatic connectivity to wetlands via flooding, and improving terrestrial connectivity via revegetation and grazing management, it may be possible to achieve rapid sequestration and storage of relatively large quantities of carbon, while also providing long-term biodiversity benefits.

Most revegetation and restoration activities in terrestrial communities entail a trade-off between short-term rapid carbon sequestration and long-term carbon storage. Rehabilitation of previously isolated floodplain woodlands may yield greater combined carbon and biodiversity benefits than re-forestation of other woodland types. Restoration of floodplain communities via managed flooding could potentially yield multiple benefits: 1) rapid sequestration 2) increased bulk carbon stored long term, and 3) increased biodiversity. Importantly, the amount and duration of biomass production and storage (and hence carbon sequestration) is likely to be significantly affected by differences in flood regimes.

CSIRO research on a group of lakes and wetlands in the lower Murrumbidgee catchment is exploring the relationships between water, carbon and biodiversity. A series of levee banks and roads had isolated Paika Lake, Cherax Swamp, Hobblers Lake and other local wetlands from flooding for more than 100 years, disconnecting them from the rest of the iconic Lowbidgee floodplain system. Restoration of water to Paika Lake and surrounding wetlands began in 2011, through the cooperation of local property owners and the NSW Office of Environment and Heritage. In late 2012, environmental water was supplied from the Murrumbidgee River for the second time, and a watering program is ongoing to facilitate continued rehabilitation of these historic wetlands. As part of this project, CSIRO are quantifying carbon and biodiversity co-benefits, which could have a bearing on carbon capture legislation and our understanding of the role of floodplain wetlands and environmental flow management in carbon sequestration.

An immediate benefit has been observed in local biodiversity, with both fauna and flora responses. Black Box floodplain woodland communities, aquatic communities, and parts of the adjacent River Red Gum forest have benefited from the flows, with vegetation condition already improving. Seedling regeneration is abundant, despite the lengthy period of dry. The carbon benefits are still being quantified, but initial observations suggest that reconnecting isolated floodplain wetlands can lead to an immediate response in carbon storage, as well as longer-term sequestration.

This project is funded by the federal Department of the Environment through the Biodiversity Fund. Partners include CSIRO, the NSW Office of Environment and Heritage, and landholders Peter and Sue Morton (Paika Lake and Cherax Swamp) and Dianne Williams (Paika Lake), with support from Ron Hoare (Hobblers Lake).

FOR FURTHER INFORMATION
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A full report on the restoration of Paika Lake is on the CSIRO website. Go to www.csiro.au/Paika-Lake

RIVERSPACE

Australia's rivers, creeks, wetlands and billabongs are highly valued for the range of environmental, recreational and social benefits they provide. All of us love being near water, and across our country there are communities and organisations working hard to protect, restore and revitalise those waterways that need a helping hand.

'**Riverspace**' is a new interactive website that brings together the latest river and wetland projects, so that anyone with an interest in our waterways can find out about what is happening in their region, or in other parts of Australia.

Riverspace also features a range of tourism and recreation ventures that link to rivers and wetlands so people can learn about experiences that connect them to these wonderful parts of our world. Whether it be kayaking or house-boating, dining or fishing, **Riverspace** brings research, practice and our enjoyment of rivers and wetlands together in the one place—truly being ... a place for wetlands, rivers and people ...

Riverspace is the brainchild of Siwan Lovett and Deborah Nias, who have worked in the river management sector for many years, and who have formed a great friendship and respect for the organisations each manages. The Australian River Restoration Centre (Siwan) and Murray Darling Wetlands Working Group Ltd (Deborah) are both not-for-profit organisations passionate about restoring, supporting and inspiring people to care for their rivers and wetlands.

Why Riverspace?

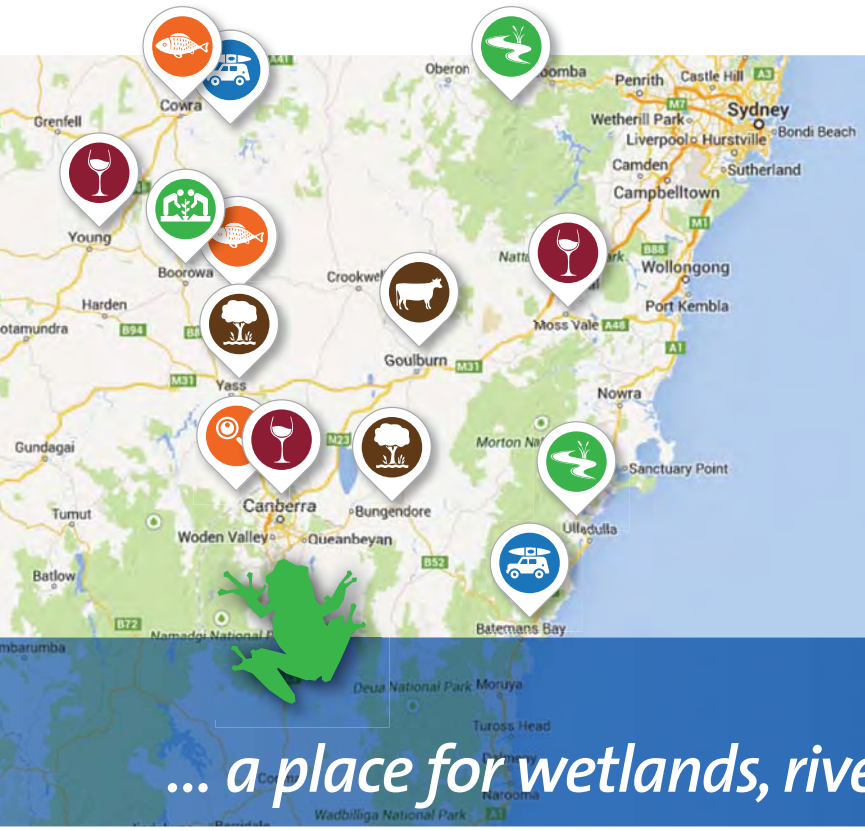
Many different groups across Australia are looking after wetlands and rivers, and there is a need to be able to go to one place to find out about all of this great work. **Riverspace** provides a 'place' where everyone can share the work they are doing within the broader context of community life.

- **Riverspace** provides organisations with an independently managed website, staffed by a professional and experienced science communication team, who can advise and assist on the best way to feature the work they are doing, in ways that make it relevant and meaningful for anyone.
- **Riverspace** is fully funded by the Australian River Restoration Centre and the Murray Darling Wetlands Working Group Ltd. This means it is truly independent because it is outside many bureaucratic and political constraints other agencies must operate within.
- **Riverspace** uses a sophisticated, yet well-known Google map interface, allowing users to zoom in and out, and discover a wealth of information at a range of scales. Beautiful images are combined with text, video and audio to give a user experience that is varied, interesting and caters for different people's learning and knowledge-searching preferences.

The Murray Wetland Carbon Storage project shown above is listed on Riverspace. For their article in this edition of *RipRap*, see page 52.

RIVERSPACE

Riverspace project categories: Biodiversity, Community involvement, Environmental watering, Food and wine, In-stream habitat, Managing livestock, Riparian rehabilitation, River research and management, Tourism —is one of these part of your space?



... a place for wetlands, rivers and people

- Riverspace is dynamic and designed to grow. There is no equivalent website in Australia (or the world) that combines and presents research and practical information on rivers and wetlands alongside other waterway activities. The scope for expansion beyond the natural resources management sector is immense, with the arts community, national parks, tourism and education sectors being examples of potential contributors and users of **Riverspace**.
- **Riverspace** is inclusive and excellent value for money for the government, non-government and private sector agencies by an annual or negotiated subscription service.
- **Riverspace** provides self-managed options through to a comprehensive project management service where organisations can employ skilled communicators to write, upload and maintain the projects they wish to feature on the site.
- **Riverspace** is innovative and exciting and provides a long-term, stable 'space' to share and celebrate our wetland and river investments.

Riverspace is for everyone, and we hope that organisations like yours, or others, will want to become a part of this exciting, collaborative, knowledge-sharing adventure.

To become a part of **Riverspace** please visit the website where you will be presented with a range of options. The packages we have developed offer multiple solutions (and start as low as $350) for how you could display your project on the website and manage your pages. For organisations that would like us to manage their account, including creating, uploading and updating project content, we can tailor a package just for you.

—Siwan and Deborah

Visit the website for great early bird deals. Hop right to it!

www.riverspace.com.au

Working on the big picture

CATHERINE ROSS OF GREENING AUSTRALIA CAPITAL REGION TALKS ABOUT THE KEYS TO SUCCESS IN RESTORING LANDSCAPES.

Some of the most degraded lands in Australia are in areas that are highly productive, and have been systematically cleared for grazing or cropping. Rivers and creeks are particularly affected being the most fertile parts of the landscape. This causes issues such as salinity, erosion, high nutrient input and loss of biodiversity, all leading to poor water quality. One of the ways of addressing these issues is through targeted revegetation using native species.

Large-scale revegetation of riparian areas can be difficult to achieve as most of the arable land in Australia is in private ownership, and river health is influenced by catchments that cover multiple tenures. As such, successful revegetation projects require a flexible approach that can be tailored to specific situations while providing multiple benefits in relation to conservation and production. Greening Australia has recognised this need, and developed a model that is designed to encourage landholder ownership of revegetation projects. Monitoring, maintenance and ongoing support is recognised as a priority, and is vital to ensure long-term success.

PHOTOS THROUGHOUT COURTESY OF GREENING AUSTRALIA CAPITAL REGION.

Many different recipes for success

One of the most important aspects of a successful revegetation project is flexibility, with access to a range of options that can be tailored to suit a specific site or situation, and meet the individual goals and capabilities of the landholder.

There are three main ways of establishing vegetation. Each has pros and cons and is suited to different situations:

- Natural regeneration is the cheapest and least labour intensive method, but is also unpredictable, takes a long time and only works where there is an adequate source of seed.
- Planting seedlings (tubestock) can achieve quick and reliable results, but is expensive and labour intensive making it prohibitive for large areas. Less commonly, long-stem tubestock are used in some riparian projects where normal tubestock are difficult to establish.
- Direct seeding is quick and cost effective for large areas, but is not suitable for steep, rocky or highly fertile areas (such as riverbanks).

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Greening Australia is a non-government organisation with 30 years' experience working with landholders to deliver environmental projects.

Configuration of revegetation is also an important consideration:

- Long narrow treebelts can provide a windbreak or wildlife corridor, but require a large amount of fencing relative to the revegetation area.
- Fencing remnant vegetation to exclude stock can result in natural regeneration for a relatively low cost, but low quality remnants may need enhancement or interventions to encourage recovery (e.g. understorey planting, cool burning, scalping and so on).
- Fencing and revegetating riparian areas can improve water quality and provide a range of environmental benefits. Consideration must be given to the possible need for erosion control or provision of alternate water for stock.
- Large-scale projects such as Greening Australia's 'Whole of Paddock Rehabilitation' (WOPR), provide a range of environmental and production benefits over a large area at relatively low cost, but the landholder must be willing to accept the loss of production during the establishment phase of five years.
- Connectivity of vegetation is an important consideration with any revegetation project, and more so for riparian vegetation. This maximises ecological function which influences water quality and production. Connectivity forms the basis for many riparian rehabilitation programs.

Slowly, slowly or jump right in?

Landholders may be unwilling, or unable, to commit to large and expensive projects straight away. Starting small or working in stages gives these landholders the opportunity to be involved, to gain a full understanding of what they are doing and why, and to become committed in a personal capacity. This increases the likelihood that they will be receptive to bigger and more ambitious projects in future. Other landholders prefer to jump straight in at the deep end and revegetate large areas of their properties in a short time frame. Providing landholders with a range of options means that the available funding can be used effectively to achieve the best environmental, social and economic outcomes.

What's in it for me?

Landholders have a range of reasons for getting involved in environmental projects, but they are unlikely to commit if they see no benefit to them. Revegetation projects need to be designed to provide multiple benefits for both conservation and production and this was reflected in a survey of landholders involved in the Boorowa River Recovery project (page 22). It was found that fencing off rivers meant better stock management (fewer losses from drowning or falling down steep banks), improved water quality and reduction in water borne disease, along with aesthetics and (perceived) increased land value. More generally, revegetation may also provide shelter and fodder for stock, mitigate erosion and salinity, and improve soils and pasture.

Under future climate change, revegetation will become increasingly beneficial, as it has the potential to absorb and store carbon, as well as providing additional income to the landholder through carbon farming. Although financial incentives may attract landholders to a project, it is these additional benefits to production that really make their involvement in a project worthwhile over a longer time period.

Revegetation projects need to be designed to encourage landholder engagement and ownership of a project over the long term. Community consultation and face-to-face visits are important to foster personal relationships and make landholders feel they are involved in the process from the start. There must be a mutual understanding about the goals of a project and the reasons why it is important. Greening Australia projects provide financial incentives such as stewardship payments or fencing subsidies to assist with up-front costs, but expect the landholder to make a similar contribution by additional costs, labour or loss of production. This co-contribution model requires the landholder to personally invest in a project and as such, is more inclined to maintain it in the future.

In it for the long term!

Ultimately, the success of any revegetation project relies on commitment and ongoing support, including monitoring and maintenance. With any project there is some risk, and environmental projects in particular are subject to unpredictable and extreme events such as flood or drought. This inherent risk can be managed by selecting the most appropriate site and revegetation method, and allowing a funding contingency for maintenance. Monitoring is also vital to assess the success of projects to improve knowledge and methods. As a non-government organisation, Greening Australia is less driven by political cycles (and can commit to projects long term), noting however, that it can be extremely difficult to secure funding for ongoing project maintenance and monitoring.

Over the years, revegetation in relation to riparian management and sustainable production has evolved as it has moved into the mainstream focus. Landholders are very enthusiastic, and in many areas demand is outstripping available funding. In the face of future climate change and increasing pressure on productive landscapes, governments and environmental organisations need to take advantage of this positive momentum by engaging landholders with flexible and innovative projects that provide fantastic outcomes for both the environment and production.

Keeping an eye on Boorowa

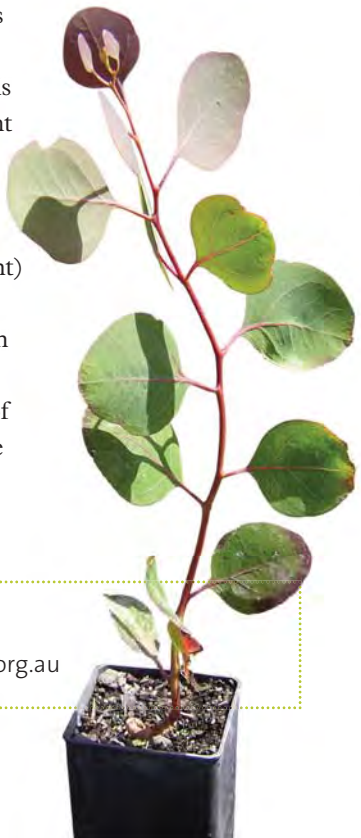
LORI GOULD OF GREENING AUSTRALIA CAPITAL REGION HAS BEEN INVOLVED WITH THE BOOROWA PROJECT SINCE IT STARTED IN 2005.

The Boorowa River Recovery (BRR) began in 2005 as a large-scale, long-term riparian rehabilitation partnership project addressing biodiversity and water quality in the Boorowa catchment in southern New South Wales. The project was implemented through a co-investment model with Greening Australia Capital Region (GACR), the then Lachlan Catchment Management Authority and TransGrid.

Sixty landholders have undertaken riparian rehabilitation along 80 kilometres of waterways covering 640 hectares of riparian land, with the average project size being 11.6 hectares. Hundreds of stakeholders and members of the broader community have been involved in related events such as river and farm walks, school activities, tours, workshops, presentations, fish surveys, revegetation, seed collection activities and a science forum.

BRR represents a common model of riparian rehabilitation: offering incentives, advice and support to landholders so they can fence waterways from stock; address erosion; control invasive willows and replant riparian areas. These incentives allow for improvement in native riparian vegetation management, and promotion of sustainable land management practices more broadly, to improve water quality, particularly (in this case) for the Boorowa town water supply.

In 2013 an evaluation of BRR reviewed its progress and assessed the project's 'success'. The evaluation started with a situation analysis (or how did the project fit within its catchment context) and then analysed the data collected over many years covering project outputs, environmental outcomes, socio-political outcomes (governance and people engagement) and economics. The analysis was structured around a purpose-built Monitoring Evaluation Reporting and Improvement (MERI) framework. This article presents a summary of results from the environmental outcomes. The full report with statistical analysis is available from the Australian River Restoration Centre.



LEAF ABOVE BENJAMINT 444. OTHER PHOTOS THROUGHOUT THIS ARTICLE COURTESY OF GREENING AUSTRALIA CAPITAL REGION.

Greening Australia is a non-government organisation with 30 years' experience working with landholders to deliver environmental projects.

FOR FURTHER INFORMATION
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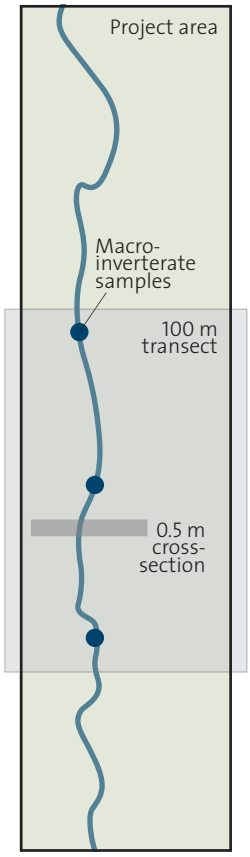
Environmental outcomes assessment methodology

Monitoring of environmental outcomes involved approaches including:

- on-ground data collection,
- investigation into water savings associated with willow control,
- fish surveys,
- photo monitoring and aerial surveys.



On-ground data collection

Environmental monitoring designs were developed by GACR in 2007 with assistance from CSIRO, and 20 river recovery sites were chosen then divided into four sites within five 'work type' categories:

1. Fencing and revegetation of erosion gullies.
2. Structural works, fencing and revegetation of erosion gullies.
3. Fencing and revegetation of streams.
4. Willow control, fencing and revegetation of streams.
5. Fencing for protection.

Each project (or treated) site was paired with a control (or untreated) site so they could be compared, with a total of 40 sites monitored. Site choice was based on condition, access, land manager support and long-term tenancy.

Indicators were chosen to show ecological improvement (vegetation, macroinvertebrates and soil stability), with the likely effects on water quality referenced to existing research.

Each monitoring site was a 100-metre transect that included the riparian zone on both sides (see figure at left). Assessments covered:

- site description, vegetation community and structure, regeneration of woody species, willow invasion and land use,
- measurement of gully and streambank erosion using CSIRO's ephemeral streams assessment[1] which estimates bank stability as an indicator of erosion activity.

Each transect contained a 0.5-metre cross-section for specific vegetation assessment including groundcover. This assessment aimed to examine changes in the percentage of plant cover.

Macroinvertebrate sampling was carried out at three sites evenly spaced along the transect where habitat was available. Presence of, and sensitivity to, water quality was noted for each genus using SIGNAL (a scoring system for macroinvertebrates in Australian rivers)[2].

Drs Rob Hale and Paul Reich used linear mixed effects models to examine if a range of response variables relating to vegetation, macroinvertebrates and stream geomorphology had responded to riparian treatments.

On-ground data results

Analysis of data collected from the 0.5-metre vegetation cross-sections revealed inconsistent statistical responses to riparian works over time, or when compared with control sites. For the 100-metre transects, differences could be seen between control and project sites over six years of sampling.

On-ground data collection discussion

The most likely explanation for the lack of response noted in 0.5-metre cross-section sampling is high-within-site variability for vegetation indicators. This is consistent with other work, such as the Riparian Restoration Experiment (contact author for details). It was concluded that more transects per site would be required for BRR, or transect data collection dropped altogether.

Results for 100-metre transect data show that ecological responses are strongly linked to the type of work done and the site's condition before intervention. For example, willow control works produced a different response for bare ground compared to other treatment methods. Also, protection works (where existing riparian remnant vegetation was protected) showed a response for both regeneration and shading, where other sites were not mature enough to produce a shading response.

1. Machiori, Tongway & Loch, 2003.
2. Chessman, 2003.

These images show that after this gully was fenced in 2006 (photo at left), grass cover had increased by 2010 (photo at right). Not pictured is that after 2010, growth from planted trees and shrubs continued. However, these two photos show that changes to ecology take time.

Conclusions drawn from response variables in project and control sites over six years of monitoring

- **Bare ground** related to the types of works, but for CFR and GEW projects it decreased while control sites stayed constant. Bare ground decreased in GFR sites but increased later (possibly from high rainfall). For willow sites, bare ground increased while protection (P) sites remained static.
- **Shrub distribution** increased at all project sites, but available control sites remained mainly stable.
- **Tree distribution** increased slightly or remained stable in project sites, except at willow control sites where tree cover decreased but this indicator was strongly linked to the works done.
- **Litter** decreased with all treatments, mainly because of flooding washing litter away in all but treatment GEW, probably due to earthworks controlling water flow (e.g. dams, contour banks).
- **Macroinvertebrates** showed little differences between project and control sites, or over time, and all sites followed similar patterns from year to year.
- **Soil stability** did not differ between project and control sites but did between treatment methods, being higher at willow and protection sites. CFR sites were more stable than both gully sites (GFR and GEW). GFR sites were more unstable overall than those where earthworks took place (GEW). Soil stability improved over time. It was notable in 2008–10 and decreased slightly in 2010–12.

Key to work type categories
CFR: Fencing and revegetation of creeks
GEW: Structural works, fencing and revegetation of erosion gullies
GFR: Fencing and revegetation of erosion gullies
P: Fencing for protection
W: Willow control, fencing and revegetation

Other monitoring complemented the on-ground data collection, and included investigating willow water use, surveying fish and photo monitoring (see next paragraph). Interestingly, it was estimated that willow control along a 29-kilometre stretch of river saved about 39–57.2 megalitres per annum directly feeding into Boorowa's water supply which has a capacity of c. 200 megalitres—a significant saving during periods of drought.

Photo monitoring

Visual monitoring of the BRR has been extensive, not only from on-ground photos but with aerial photography from helicopters in 2005 and 2008. These images have shown the extent of works, changes in groundcover, growth of revegetation, and changes relating to willow control. Almost all sites have shown some visual improvement, and though this does not measure ecological function, it is useful to show project progress, and changes to landform and vegetation that could complement the ecological monitoring program over time (and provides some fabulous photographs).

Conclusion

Overall the picture forming is good, with on-ground works being completed and maintained. Positive trends are emerging in terms of ecological response for a number of variables, including improvements in water availability because of willow removal, and more native fish in a major tributary of the Boorowa River. However, it has been found there is significant variability within, and between sites, and results did not often follow clear patterns. Many results related to the quality of sites before projects began, and/or the types of works that took place, but they were also influenced by drought, floods, and pest animals. These results highlight the complex and long-term nature of ecological improvement (and associated monitoring), and the importance of ongoing long-term maintenance of sites.

The Boorowa River Recovery project has laid the foundations for the Rivers of Carbon project which is a legacy that has meant more work can be done and even more riparian restoration can occur (see page 3).

Even more seeds for the GreenGrid

PHOTOS COURTESY OF THE AUTHOR

STUART JOHNSTON TALKS ABOUT TRANSGRID'S INSPIRATIONAL PROGRAM 'GREENGRID'.

'GreenGrid' is TransGrid's award-winning environmental partnership with Greening Australia. The seed was sown back in 1997 through a sponsorship to plant more trees in the Murrumbateman district of south-eastern New South Wales, as part of Greening Australia's national 'Corridors of Green' program. What was believed to be just a one-off sponsorship soon evolved to become a series of 'greening' projects around Yass, Bredbo, Gunning and other parts of the Southern Tablelands.

Most notable was a targeted bird conservation project to create and link Box–Gum Grassy Woodland habitat for the threatened Superb Parrot. All of the initiatives were funded by TransGrid and facilitated by Greening Australia Capital Region (GACR).

In 1998, TransGrid and GACR decided to consolidate GreenGrid's early gains by committing to a single over-arching program. This was seen as a bigger, broader and more focused statement of environmental action. The aim of the partnership would not only result in community planting events, but interconnected financial incentive.

After generating considerable community interest and results on the ground, TransGrid and GACR recognised that GreenGrid's vision of active, partnership-powered conservation could bring together land managers and community volunteers. Guided by the best scientific advice, the result was significant environmental outcomes. It proved to be a recipe for success.

Since its start, GreenGrid has rehabilitated and protected 1864 hectares of land in New South Wales, including erecting 450 kilometres of fencing and planting 280,000 native tubestock. The approach of broad-scale revegetation has direct-seeded 2000 kilometres of treelines and, in the past decade, sequestered some 32,000 tonnes of carbon.

Importantly, GreenGrid shows how successful partnerships can be developed between corporate and natural resource management (NRM) organisations. The initiative is described as being a "multi-million dollar dedication to bringing life to landscapes and landscapes to life", and has been recognised by many awards, including in 2011 the NSW Premier's Public Sector Sustainability award. This success is something other NRM organisations can learn from when trying to engage commercial businesses in environmental activities.

The partnership continues to grow, with projects now addressing landscape-scale biodiversity, water quality and sustainability issues in many different parts of New South Wales. TransGrid is now building relationships with hundreds of landholders, as well as Landcare and other volunteer groups; leading scientific organisations like the CSIRO and generous philanthropic supporters such as the Vincent Fairfax Family Foundation.

NatureLinks

RIVERSMART IS DOING CLEVER THINGS IN A STRETCH OF THE MACQUARIE RIVER.

The Macquarie River flows from its headwaters near Oberon in New South Wales for about 625 kilometres. The upland portion (elevation of 900–1000 metres) lies above Burrendong Dam near Wellington. Below the dam the river flows north–west, being joined by several major tributaries, through Wellington, Dubbo, Narromine and Warren. Below Warren the river becomes increasingly braided as it becomes the Macquarie Marshes. The river continues beyond the Marshes, where it joins the Castlereagh River and then the Barwon near Brewarrina. Photo above Roger Charlton.

The 'NatureLinks' program is part of the Macquarie RiverSmart initiative that began in 2009 with assistance from the Central West Catchment Management Authority (CMA). NatureLinks aims to connect high conservation value riparian remnants and aquatic habitats through protection and improved management, restoration of degraded areas, and actions to help species migrations, or life-history movement patterns. Overall, we work to reduce habitat fragmentation, build resilience to climate change, improve biodiverse carbon storage, and provide an adaptation pathway that services both terrestrial and aquatic habitats in the Macquarie River lowlands through to the uplands (see map at left).

The focus for NatureLinks is from the Macquarie Marshes to Burrendong Dam, a distance of more than 400 river-kilometres (broken down into 40 reaches). This corridor is predominantly agricultural, with significant areas of intact riparian zone in some areas, though fragmented by areas of moderate to severe vegetation loss.

Data collection to underpin actions

In 2009–10, with funds raised by RiverSmart (from the Central West CMA and the Native Fish Strategy of the Murray–Darling Basin Authority), an underwater and riparian condition assessment was undertaken by a team from the fisheries arm of the New South Wales Department of Primary Industries. This used side-scanning sonar to map the underwater 'landscape' and visual assessment to record weed species and areas of erosion or stock damage along the riparian margins. This dataset, now housed within a GIS framework, is guiding the implementation of the NatureLinks program which, in 2012 received funding of $1.8 million from the Australian Government's Biodiversity Fund. With these resources, work is underway to control riparian weeds and erosion along the Macquarie River between Narromine and Warren.

This dataset is also now underpinning the development of reach-by-reach action plans to guide landholder and manager actions. To our surprise, the survey revealed much higher than expected level of public land ownership (in various forms) along the Macquarie River. There are 291 parcels of crown and other forms of public lands, representing about 20 per cent of the riparian corridor. This means that government land managers have a significant role to play in developing and maintaining the stepping-stone foundations for an adaptation corridor. In addition, there are also some 40 nature reserves and other protected areas along the river corridor, mostly managed by the four local councils.

Improving riparian condition and connectivity

Initially the survey data was analysed at a scale of 20-kilometre reaches, but this has been reduced to 10 kilometres to provide greater clarity. Key findings from the survey are in the table on the opposite page and show the areas we need to work on to rehabilitate the Macquarie River. We are currently focusing on improving in-stream connectivity and habitat. Along the Macquarie River below Burrendong Dam are nine structures, two of which have fishways. Discussions are underway about adding a fishway to the South Dubbo Weir.

The availability and complexity of snags is another focus for our work. The following extract from the "Macquarie RiverSmart Habitat Action Plan" (2010) details snag availability and complexity. The scale used in the report is 20-kilometre reaches.

Key findings from the riparian condition and connectivity survey

Erosion sites	Recorded in 33 out of 40 reaches
	Total riparian area impacted 24.3 ha (estimated *)
	Length of riverbank impacted 13.9 km* (1.8% of riparian margins)
Stock damage sites	Recorded in 38 out of 40 reaches
	Total riparian area impacted 29 ha*
	Length of riverbank impacted 18.9 km* (2.4%)
Invasive weeds	In total, weed species are impacting 512.9 ha, some 306.3 km (39.2%) of riverbank. The major weed species of concern are as follows.
Willows	Recorded in 40 out of 40 reaches
	Total riparian area impacted 260.7 ha*
	Length of riverbank impacted 173.6 km* (22.2%)
White cedar	Recorded in 29 out of 40 reaches
	Total riparian area impacted 72.1 ha*
	Length of riverbank impacted 32.3 km* (4.1%)
Castor oil plant	Recorded in 21 out of 40 reaches
	Total riparian area impacted 63.7 ha*
	Length of riverbank impacted 43.6 km* (5.6%)
Boxthorn	Recorded in 29 out of 40 reaches
	Total riparian area impacted 47.7 ha*
	Length of riverbank impacted 21.6 km* (2.75%)
Green cestrum	Recorded in 20 out of 40 reaches
	Total riparian area impacted 19.4 ha*
	Length of riverbank impacted 8.9 km* (1.1%)

White cedar is being considered for declaration as a feral native species in this region.

"Woody habitat [snag] loading in each reach was recorded to identify areas of low snag loading for future rehabilitation. The accepted benchmark for snag loading in the Macquarie River was determined to be 13 per kilometre, equating to 254 snags per reach. This snag loading was deemed to provide adequate habitat for aquatic fauna. The number, complexity and orientation of large woody habitat [snags] within each sub-reach were mapped using side-scanning sonar and GPS/GIS interface software. In the 391 kilometres that were surveyed, 4234 snags were recorded, which averaged out to less than 11 snags per kilometre. Sixteen reaches were found to be below the accepted benchmark (13 per kilometre) in terms of snag density."

The benchmark loading determined by the 2010 Plan is 13 snags per kilometre (or 130 per 10 kilometres) means that only 10 out of 40 reaches currently meet or surpass that level.

Of greater concern from a fish habitat quality and connectivity perspective is that 13 of the 40 reaches have snag loadings below 10 per kilometre, and these are identified as NatureLinks' priorities for attention especially when reaches with such light snag loading are contiguous.

A river with this amount of snags is perfect for native fish. Photo Bill Phillips.

How we are using the survey data?

The data is being used to develop reach action plans (RAPs) at a scale of 10 river-kilometres, with this approach underpinning the work being done by NatureLinks. Each RAP brings together what we know about the underwater and riparian condition for that reach, identifying structures and issues such as weirs, and ownership arrangements such as public lands and reserves. Projects are being developed to re-snag those areas where loadings are less than the 'norm' for the Macquarie River. We are also using the data to develop 'weed-by-weed' action plans that look at transmission methods, growth patterns and life cycles, to develop sensible control and reduction plans. The data has been made available to the four local governments along the river to guide their weed control work.

The dataset also includes information on deep holes in the river, and in future this could be vital for protecting critical refuge holes if the trend back to drought conditions continues.

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Connecting communities

IN NORTH-WEST NEW SOUTH WALES CONCERTED EFFORTS FROM LOCAL COMMUNITIES AND GOVERNMENT AGENCIES HAVE BEEN FOCUSED OVER MANY YEARS TO RETURN FISH TO THE NAMOI. THROUGH THE AUSTRALIAN GOVERNMENT'S BIODIVERSITY FUND, THE LATEST GUISE OF THESE EFFORTS WILL PROTECT AND LINK THE RIPARIAN CORRIDORS OF THIS BIODIVERSE REGION UNDER THE 'CONNECTING RIVERINE COMMUNITIES IN THE NAMOI' PROJECT. **ANTHONY TOWNSEND** AND **MILLY HOBSON** FROM FISHERIES NSW TELL US MORE ABOUT THIS STRETCH OF PARADISE.

Moving along the Namoi River, it's easy to get lost in the tranquil flow of this iconic waterway. That is, until the call of fleeing Sulphur-crested Cockatoos shatters the silence, filling the air and rippling the waters with their raucous cacophony.

The noise is enough to spook any unsuspecting visitor, but it doesn't disturb the bird's previous resting perch, the branches of the mighty River Red Gum. These magnificent trees are scattered along sections of the Namoi River providing an insight into how the banks of this river once looked, and a vision of a future system rehabilitated to former glories.

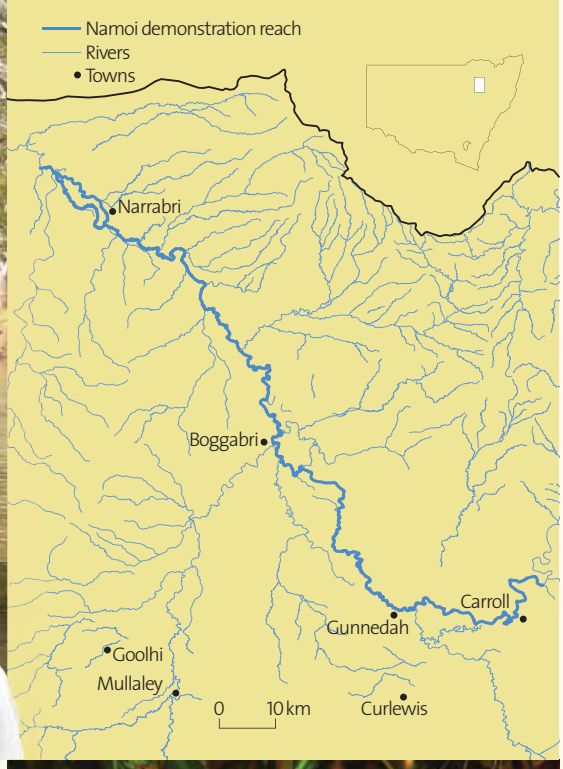
This vision is what drives on-ground action in the Namoi, including the 'Connecting Riverine Communities in the Namoi' project which will address the loss and degradation of riparian and aquatic habitat along a 150-kilometre priority reach of the Namoi River between Gunnedah and Narrabri.

The Namoi River is located in the north-eastern area of the Murray–Darling Basin, and travels over 700 kilometres from its headwaters near Manilla, through the major centres of Gunnedah and Narrabri before flowing into the Darling River near Walgett.

The reach of the Namoi River between Gunnedah and Narrabri has been identified as a key aquatic asset for inland New South Wales (NSW). Freshwater research by the NSW Department of Primary Industries compared 10 years of monitoring data across the state and found that the reach is home to a significant biodiversity of native fish and threatened species when compared to other waterways in the state. Threatened species found in the system include the nationally-threatened Murray Cod, and the state-listed Purple-spotted Gudgeon, Silver Perch, Olive Perchlet, and the Freshwater Catfish.

Title image: The aim of Connecting Riverine Communities in the Namoi is to link areas of healthy riverbanks along this important waterway. Photo Milly Hobson.

The project covers over 150 kilometres of the Namoi River from Gunnedah to Narrabri.



Above: Sulphur-crested Cockatoo. Photo Michael Korcuska (Wikimedia Commons). Right: Purple-spotted Gudgeon. Photo Gunther Schmida.

The Namoi River also forms part of the aquatic endangered ecological community of the lowland catchment of the Darling River. This includes all native fish and aquatic invertebrates that occur within the river and its associated tributaries downstream of Keepit Dam and recognises the rarity, vulnerability and habitat importance of the region.

These attributes highlight the high conservation value of the reach and emphasise the need to restore and protect the aquatic and riparian habitat along the Namoi River.

Like many lowland floodplain river systems of the Murray–Darling Basin, the Namoi River is now highly regulated. Just above the town of Gunnedah, the major water storage infrastructure of Keepit Dam can be found, with other structures including Mollee and Gunidgera weirs found further downstream near the town of Narrabri. These in-stream structures help service the communities of the predominantly agricultural region, which includes irrigation, cropping and grazing practices. However, this development along the Namoi River has placed significant pressure on the local environment, most notably on the quality and quantity of important riparian habitat found along riverbanks and floodplain areas.

Riparian land acts as the last line of defence for the waterway, helping to stabilise banks, improve water quality, drive food webs, and provide habitat and connectivity to the broader catchment. All of these services are vital for the recovery of threatened aquatic and terrestrial species in the area. The loss of riverbank and floodplain vegetation in the Namoi catchment, is estimated to be about half of its original cover, with only 42 per cent of these areas now having woody cover. This has impacted the key ecosystem services that riparian habitat provides.

Recognising these impacts, but also valuing the high conservation value of the Namoi River, a demonstration reach was established along the waterway downstream of Gunnedah. Demonstration reaches are an initiative of the Murray–Darling Basin Authority's former Native Fish Strategy that focus on river health rehabilitation activities, community engagement, and monitoring and evaluation along priority waterways.

Established in 2007 as a collaborative project between the NSW Department of Primary Industries, Namoi Catchment Management Authority (now North West Local Land Services), and the local community, the Namoi demonstration reach has achieved a significant amount of planning, aquatic habitat rehabilitation, and community involvement, including:

- reintroducing 300 snags at priority sites,
- replanting 5700 aquatic plants at priority sites,
- planting over 9000 native trees and shrubs,
- completing 33.5 kilometres of woody weed management,
- completing 33.5 kilometres of riparian fencing,
- installing 20 off-stream watering points,
- constructing eight in-stream and gully erosion protection works,
- undertaking three years of condition based monitoring along the demonstration reach to improve understanding of fish communities in the project area,

- engaging with over 3000 people in the local region through workshops, field days, fishing events and education days,
- collaborating with 30 stakeholder groups, including all levels of government, community groups, Indigenous communities, landholders, businesses and schools to achieve on-ground outcomes.

Despite the initial success of the Namoi demonstration reach, it was recognised that greater investment was needed to progress major on-ground outcomes. 'Connecting Riverine Communities in the Namoi' will deliver this by undertaking works on 600 hectares of important riparian and wetland habitat along the demonstration reach to help sequester between 120,000–312,000 tonnes of carbon dioxide equivalents per year[1].

The project will strengthen partnerships with local landholders and community groups to plant native riparian and aquatic vegetation, protect remnant native vegetation, and control invasive weeds. The three year-program, which started in 2012, has received strong support from the local community, with on-ground works already undertaken on over 300 hectares of land adjoining the Namoi River.

The interest and involvement from landholders is for a variety of reasons, with some looking for natural solutions to bank erosion problems on their property; others wanting to benefit from improved stock management that results from protecting the riverbank and floodplain areas; while some are purely looking to improve the natural values of their piece of the Namoi.

The riverbanks of the Del Rio property (left hand side of photo above) will be protected as part of the project. Photo Anthony Townsend.

"I simply want to make my property look good by being natural," said Ronauld Ireland from the Del Rio property in Narrabri, and by planting new native trees, protecting existing vegetation and undertaking weed control works on his property that's exactly what will happen.

These activities, repeated across this significant reach of the Namoi River, will enhance the resilience of the local ecosystem, helping to improve the connectivity, abundance and distribution of native flora and fauna in the Namoi. With focused efforts and commitment we hope to return more fish to the river, as well as continue to connect the communities that rely on this important waterway.

1. Calculated using methods in 'Trees for Carbon Sequestration', *Primefacts*, no. 981 (NSW DPI, 2010).

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Tree planting days are a great way of fixing the riverbanks while engaging with the community on the Namoi demonstration reach. Photo Milly Hobson.

FINTEREST

finterest.com.au

WHAT IS FINTEREST?

Finterest is a new website that shares the research, practice and experiences of the many people and organisations involved in delivering the first 10 years of the Murray–Darling Basin Native Fish Strategy. The Strategy commenced in 2003, and initiated a range of fish management projects spanning fish recruitment and breeding, through to fish passage, migration and habitat.

A network of demonstration reaches was also established to show how science could be put into practice in different riverine environments and at different scales. Community engagement and empowerment were central to the success of the on-ground components of the Strategy.

Overall, a wealth of information and knowledge has been generated in the Strategy's first phase, with the Finterest website ensuring this legacy is protected, easily accessible, and forms the basis on which work can continue.

THE FINTEREST VISION

"Provide inspiration, knowledge and insight for anyone interested in Australian freshwater fish."

Collaboration is the key

To realise the Finterest goals, collaboration with others is essential. The website has been built as a collaborative space, and it is hoped that financial, intellectual and social support can be gained from fish researchers, managers, recreational fishers, and anyone passionate and interested in 'bringing back native fish'.

Why support Finterest?

The development of Finterest has been funded by the Murray–Darling Basin Authority and produced by the not-for-profit Australian River Restoration Centre (ARRC), an organisation committed to managing rivers, valuing people and sharing knowledge. The team at ARRC now want to work with others to ensure Finterest adds value to the great organisations and networks already working in fish management. Communication and social media specialists, the ARRC team are keen to complement other organisations already working in fisheries research and management.

Are you Finterested?

You can become a contributor to Finterest by logging in and sharing your stories, it is free to join and we welcome your input. Please have a look through the website and get in touch with any ideas you might have about how to make Finterest an even better site for fish-related research and practice. Finterest Manager Siwan Lovett **siwan.lovett@arrc.com.au**

FINTEREST GOALS

1. **Provide** a dynamic, easy-to-use website and social media platforms for sharing fish management knowledge and enable people to have conversations about 'bringing back native fish'.
2. **Expand** the scope of the site to be Australia-wide and include estuarine fish management.
3. **Synthesise** fish management knowledge and practice around issues of interest (e.g. fish passage, fish habitat) and present it in ways that are meaningful, relevant and easy to access by a range of different stakeholder groups (recreational fishers, scientists, river managers).
4. **Produce** an edition of the *RipRap* magazine each year that focuses on fish-related research and practice.
5. **Become** a knowledge and advice hub on how to establish, operate and maintain demonstration reaches and work with local communities to reach their fish management goals.
6. **Collaborate** with organisations working in fish management and research to add value to the work they are already doing and provide another avenue so they can communicate their findings and spread their message.
7. **Continue** to pursue ways to communicate fish management knowledge through innovative approaches such as "True Tales of the Trout Cod", oral histories, workshops, field days etc.
8. **Supply** high level project management, collaboration and communication skills to organisations wishing to outsource some aspects of their work to a reliable, professional and successful Finterest team.
9. **Enjoy** working with 'fishy' people and celebrate our joint achievements in 'bringing back native fish'.

Melbourne stream works

GRAHAM ROONEY DISCUSSES THE STEPS THAT MELBOURNE WATER IS TAKING TO LINK WATERWAY REHABILITATION WORKS WITH BIODIVERSITY OUTCOMES.

Wouldn't it be wonderful if we knew that stream rehabilitation works went beyond improvements in channel shape and riparian vegetation? What if we knew that works would lead to actual improvements in platypus numbers and diversity of aquatic invertebrates, fish and riparian birds?

Waterway health practitioners within Melbourne Water are attempting just this. The recently completed Healthy Waterways Strategy adopted an ambitious vision around tying our stream works to genuine biodiversity (dubbed 'key values') outcomes. Community and regulatory feedback supported this vision, and great things are being achieved.

What's novel?

Our new approach has meant a big change in the way we collect data about river health. We have to understand those cause and effect relationships connecting stream works with key value outcomes. To do this we have created causal link models that will be refined over time. Importantly, we can commission data collection—often at river-works scale—that targets poorly understood links in these causal models.

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There must also be a means for determining whether these key values are trending upwards over time and we have focused significant effort into designing metrics for each key value. Our metrics are now used to rate biodiversity condition between 'very poor' to 'very high', for defined regions within the greater Melbourne Water operating area.

What our biodiversity metrics are telling us

Metrics for most key values are in good shape, and current ratings are presented in the strategy document, along with 20-year and long-term targets for where we want to see change. Melbourne Water Senior Aquatic Scientist, Dan Borg, is using Sustainable Rivers Audit metrics for fish, Senior Biodiversity Scientist, Will Steele, has worked with Birdlife Australia and other expert ornithologists to develop a riparian bird metric, and Aquatic Scientist, Eddie Tsyrlin, has divided up SIGNAL scores into a five-category metric for aquatic macroinvertebrates. Eddie's collaboration with Cesar consultants has led to a way for categorising platypus presence and breeding into a five-rating metric.

Above: Links are being explored between riparian revegetation and fish presence and abundance.
Right: Stabilising channel habitat is believed to encourage platypus presence.
Photos throughout this article courtesy of Melbourne Water.

Vegetation metrics are based on the Index of Stream Condition streamside zone sub-index. Now that the Department of Environment and Primary Industries has shifted measurement of streamside zone to LiDAR data, the metric holds promise as a far more useful descriptor of the state of riparian vegetation.

Vegetation tools

Serious effort has been invested in publishing 2030 templates, or visions, for riparian vegetation quality for any location on our waterways. Templates are being shared with our stakeholders so that we have a common understanding about where we want vegetation quality to be in 2030.

Senior Vegetation Specialist, Rob Dabal, admits that the templates don't replicate pre-European ecological vegetation classes, but they do convey the character of original communities by having similar structural elements. When it comes to urban streams, Rob admits that expectations must be lowered for good vegetation outcomes. "With highly modified hydrology, weed-seed supply, and tenacious invasive species, you should forget about anything approaching restoration, especially the understorey, which is the most difficult to reliably reinstate," said Rob.

He advocates protecting the best. Look after the intact remnants, then identify and manage resilient patchy remnants where ecological processes can be re-engaged, especially if they are close to largely intact areas. As Rob says, "we understand the importance of re-planting, but large-scale resilient vegetation is the most important for managing biodiversity".

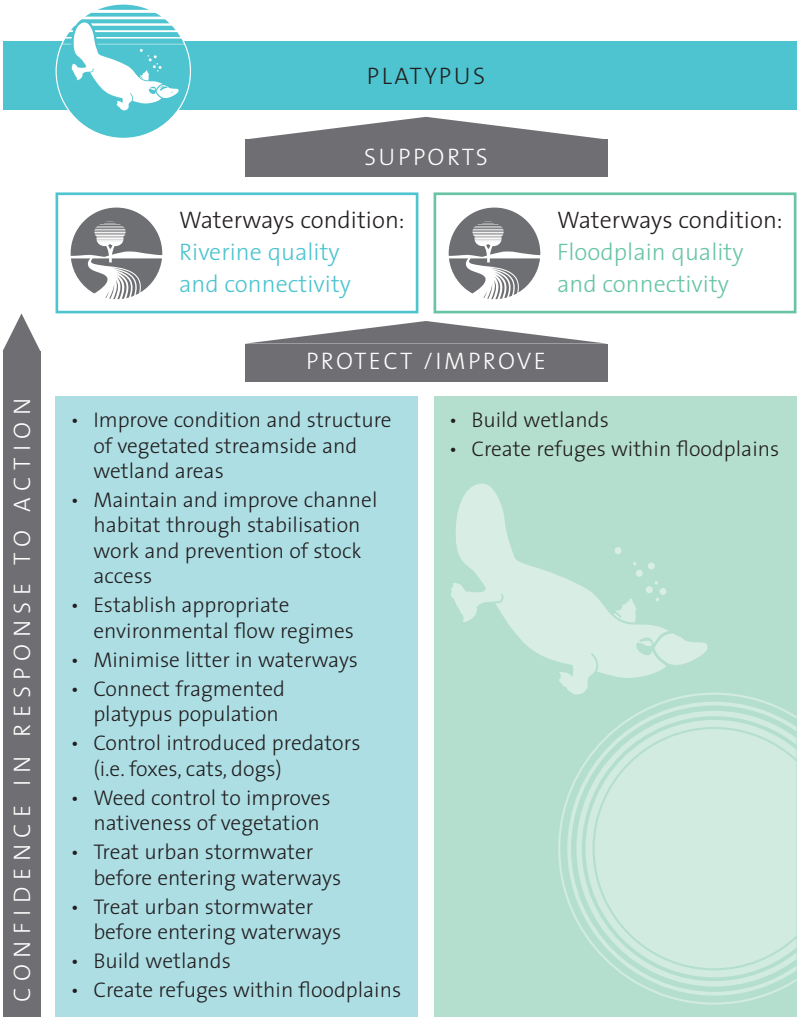
Rob is involved with a number of works-scale projects and advocates returning to older projects and assessing success or otherwise, and reasons for that outcome. Some projects are about natural regeneration but some sites preclude this because there is no remaining seed bank. Current evaluations include treatments around tubestock, direct seeding, soil biology, and using site-scale metrics to track vegetation trajectories for different capital rehabilitation works.

Aquatic invertebrates

We have learnt much about the catchment-scale factors that influence aquatic invertebrate diversity. Work started over a decade ago though the Cooperative Research Centre for Freshwater Ecology. Eddie Tsyrlin's role is to refine the cause-effect model. He still collaborates with those early researchers. Eddie believes that there are three thresholds influencing aquatic invertebrate diversity.

The first is presence of flowing waters. "Not surprisingly, adequate flow in a stream significantly influences aquatic invertebrate diversity," says Eddie. A second threshold emerges when a stream leaves its forested catchment. Non-forest hinterland, of any land use, affects in-stream diversity. It may be the increased hydrologic response to rainfall, or the worsening runoff water quality, or both. A third dramatic threshold is the proportion of catchment that is impervious (by being paved, roofed, pathed, roaded), with those surfaces directly connected to flowing streams—through pipes—our traditional drainage solution.

Evidence indicates that 0.5 per cent directly-connected imperviousness (DCI) is sufficient to damage in-stream aquatic invertebrate diversity. Two per cent DCI produces a much stronger effect. Eddie



Platypus conceptual model: Actions and influences to improve conditions

believes that even a small amount of urban development has an effect that is likely to be irreversible. Riparian revegetation width does emerge as important, but 10 metres on either side is inconsequential. If DCI is low enough (less than 0.5 per cent), then reclaiming 20 to 100 metres on both sides may improve the ecological processes that lead to improved outcomes for aquatic invertebrates.

Eddie suggests being selective in your choice of revegetation and stick to areas already vegetated upstream, extending them further for aquatic invertebrate outcomes.

Platypus

Greater Melbourne's platypus populations are fragmented. Growth of human settlement has been influential, through modifying channel form and leading to isolation of populations; for example, Dandenong Creek, where long distances have been concrete-channelised, and form a barrier to movement and inter-mixing. Drought and low stream flows exacerbate stresses on populations. There was a crash in population numbers during the recent drought.

Understandably, people really value this iconic egg-laying mammal and we feel it is worthy of special attention and protection. Eddie, working with consultants Cesar, has a significant program of work underway and is tagging individual animals with electronic devices to provide insights into movement distances. Interesting data is being gathered about platypus night travel information and the different movement patterns of males and females.

By returning to selected streams year after year, we find out what is happening to platypus populations. The good news is that numbers are improving since the drought broke. Cesar has developed an excellent website that reveals contemporary platypus finds and health—http://platypusspot.org/

Birds

Another of our metrics focused on bird diversity. With all the magnificent riparian revegetation works that are being done around the country—much less our area—we wanted to find out if multi-structural vegetation habitat was also contributing to opportunities for non-aquatic fauna, as well as investigating the social, educational and health values associated with birds.

Will Steele is pursuing elements of the causal-link model with relish. A key study is collecting data from a number of sites where willows have been removed and sites revegetated. Four treatments have been selected; currently intact willows, intact native vegetation, willows removed less than eight years ago, and willows removed more than 10 years ago. Data collection is on-going, but preliminary results are now being assessed and should help guide future willow control sites and riparian revegetation projects.

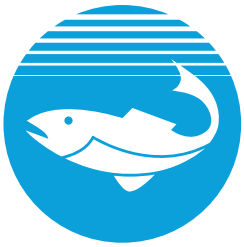
"Birds represent a value in their own right, but then there is their connection as great indicators of whole ecosystem health; their contribution through ecosystem services—such as pollination, seed dispersal and pest control—and also their importance in amenity and the enjoyment of riparian areas," said Will.

Big advances have been made on the metric for establishing 'state' or condition of bird diversity. Will knows that at least 40 surveys per unit area are needed for valid results. He is confident in setting up excellent, reviewed 'expected' lists for each of the Commonwealth drainage basins. These lists will suit smaller areas within each basin, such as our strategy priority areas and sub-catchments.

A good number of surveys provide that 'observed' number of species so that a time-trend may be realised. We are fortunate having access to a mass of bird atlas data, which provides us with a unique opportunity measuring future improvements and long-term cyclical patterns of abundance and distribution.

Yarra River's Dights Falls fishway is new and functioning well, but all fishways should be evaluated regularly for effectiveness.






Like most evidence-based data collection in landscapes and riverscapes, the topic of scale crops up repeatedly. When it comes to birds, there is no exception. Will points out that while an observed divided by expected metric will work at large scale, for the stream rehabilitation works-scale, you have to adopt a more precise approach; counting species and numbers of species.

A key value that needs to be mentioned here is 'amenity'. What we know is that people value interactions with birds—sight and sound—and that this is integral to the restorative experience people have when enjoying their local stream. This is something we look forward to reporting on in future *RipRaps*.

Fish

We have a marvellous dataset on fish species, abundance and distribution. It has proved invaluable in describing current condition for our streams and priority areas in the strategy. This good quality dataset allows generation of meaningful fish metrics. 'Nativeness' and 'expectedness' fish metrics were developed for the then Murray–Darling Basin Commission. We are piggy-backing on that great work and intend to generate maps of similar fish metrics for our operating area.

Dan Borg is refining the cause-effect model and sees great possibilities with current evaluation studies. "We seek increasing confidence around cause-effect links, and our monitoring and evaluation program is a stand-out," says Dan. One link thought to be weak is the connection between riparian vegetation and fish presence and abundance. Addressing this weakness led Dan to instigating an evidence-seeking literature review on just this subject.

Data collection on benefits of in-stream wood, environmental water releases, and effectiveness of fishways, are part of this evaluation program. Fish barriers naturally play a large role in the cause-effect model so evaluating effectiveness of fishways is receiving special attention.

Preliminary data collected at the lower Yarra River Dights Falls fishway, point to its construction being a major success in enhancing river health. Hundreds of kilometres of upstream waters have been opened to native fish. A program of evaluating fishway effectiveness is seen as crucial for not only river health outcomes, but also evidence for fishways being a sound commercial investment.

Cause and effect evaluations also extend to broader catchment-scale influences. Species distribution models are exploring catchment-scale variables, including DCI. In the case of fish diversity and abundance, urbanisation and DCI creates problems beyond modified runoff volumes and water quality. Channel cross-sections are invariably re-shaped by the modified hydrologic response. This contributes to a reduction in habitat complexity. Modelling may show the crucial catchment and local-scale influences on fish diversity.

Future

Causal link models exist for all of these biodiversity measures. We know there is room for lots of refinement, and keeping our eyes on the external environment adds to cause-effect understanding. Our specialists often talk about the issue of scale; scaling-up from works, and scaling-down from regional data collection. Comprehending scale will always be a challenge for environmental practitioners. Another challenge we face is how to choose where to do stream rehabilitation works to achieve multiple benefits, such as achieving biodiversity outcomes beyond one taxonomic group. We will continue to investigate these issues in our ongoing stream rehabilitation efforts.

Glenelg: A well-prized river

ADAM BESTER AND **LUCY CAMERON** WRITE ABOUT THE LONG-TERM RESTORATION OF THE GLENELG RIVER IN VICTORIA.

PHOTO DAVE NICHOLS.

The early years

When explorer Major Thomas Mitchell first arrived at the Glenelg River in south-west Victoria in 1836 he described the land with abundant water and good soils as 'Australian Felix'—the origin of the term 'the lucky country'. Early surveyors also described the fertility of the area as 'a pastoral El Dorado'. For thousands of years the Glenelg River was known by the Indigenous Gunditjmara people, as 'Bocara'. The river remains important to the region's Indigenous people, particularly because of its diverse and unique native fish assemblage that includes Short-finned Eel as well as the EPBC-listed Glenelg River Spiny Crayfish.

However, when pastoral stations were established in the region the landscape began to change—quickly and dramatically. Early settlers noted that where soil was trodden by stock, springs of salt water appeared in many of the watercourses, killing most of the native grasses. Land clearing and rabbit infestation destabilised the naturally erodible soils of the Glenelg River Basin, washing soil and sand into the river and its tributaries in the upper catchment. Major floods in 1946 worsened the problem, with large amounts of sediment being swept into the waterways.

EPBC: *Environment Protection and Biodiversity Conservation Act 1999*.

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In the decades following the floods, the Glenelg River Improvement Trust (GRIT) embarked on a campaign to desnag the river in a misguided attempt to reduce flood risk to townships such as Casterton. Science now tells us that such activities have little impact on reducing flood risk and, in many cases can increase risk by creating higher-velocity flow. In the 1960s, local communities noted changes in the river as a result of desnagging, particularly the loss of deep waterholes that were treasured as popular swimming spots.

The construction of Rocklands Reservoir in the 1950s substantially altered the natural flow regimes in the river. This reduced water quality and exacerbated sedimentation issues, reducing structural diversity and connectivity for aquatic species. Further pressure was added to the river with the introduction of a number of pest plants and animals to the area, most notably blackberry, pine, bridal creeper and carp.

Restoration of the Glenelg River

Restoration in the Glenelg Basin began in the early 1960s, at the same time the GRIT was removing timber from the Glenelg River. The Soil Conservation Authority built hundreds of soil erosion control structures in the upper catchment to slow the rate of erosion. Despite these early restoration works, in the mid-2000s the river was on the brink of ecological collapse, due to low flows, poor water quality, loss of habitat, weeds and carp invasion.

PHOTO STEVE RYAN.

In the early 2000s, the Glenelg Hopkins Catchment Management Authority (CMA), in conjunction with community groups and other agencies started the Glenelg River Restoration Project, an ambitious undertaking to look at an integrated and long-term approach to restore health to the river. The major challenge of the project has been the scale and diffuse nature of the threats to the river, which involve the cumulative impact of land-use change over 12,000 square kilometres.

The diverse nature of environmental problems needed a multi-pronged response, and has included wood reinstatement, further construction of erosion control structures, establishment of environmental flow releases, sand extraction, carp monitoring/eradication, weed control and the removal of fish barriers. However the central activity of the project has been fencing and revegetation, which is a low-cost solution to many of the river's threats.

PHOTOS BELOW:
GLENELG HOPKINS CMA.

Over 13 years, the project has worked with more than 620 individual landholders to construct 1600 kilometres of fencing, plant over half a million tubestock, and direct seed 770 kilometres of river and creek frontage. Other achievements include reinstatement of 870 pieces of large wood to the river to provide fish habitat and in-stream stabilisation, as well as opening 300 kilometres of the river to fish movement. An environmental flows entitlement has also been established and delivered, further boosting in-stream health.

These works, among many others, have led to significant outcomes and improvements in the Glenelg River system. Achievements include a 160-kilometre range expansion of Estuary Perch with a large number now being caught. According to anglers and historic records, these fish have not been captured this far upstream since the Rocklands Reservoir was built in 1954. Other outcomes include a 150 per cent increase in Variegated Pygmy Perch, a 280 per cent in Blackfish numbers at sites where large wood was reinstated, and significant water quality improvements in response to environmental flows. Sections of the river where stock have been excluded has allowed in-stream native vegetation to establish and recreate deep waterholes in the sand bed.

The project has also helped create a viable and environmentally sensitive sand extraction industry, where sand is removed from the waterway to create instant habitat holes for fish.

Community groups have been an integral part of the project, with Landcare groups doing much of the local planning and delivery of works. The 'Friends of the Glenelg' group was established with the sole purpose of connecting the community back to the river through engagement events such as the annual tug-o-wars, planting days, history days and art competitions. Brian Murrell, President of the Casterton Angling Club and long-term Casterton resident told the CMA that "residents are now able to swim and fish in areas that were previously one flat sheet of sand. The works have reconnected the community back to the river".

Along with the innumerable volunteer hours provided by individual landholders and community groups, the success of the project has relied on funding from both the Victorian and Australian Governments, with more than $16 million being injected into the project.

Key learning and future directions

The two most important lessons from the Glenelg River Restoration Project focus around the importance of planning and engagement as well as being willing to take risks and embrace novel approaches.

Integrated planning and building relationships

Since 2007, Glenelg Hopkins CMA has used a process called Waterway Action Planning (WAP) to identify and prioritise river health works. WAP is a means of carrying out detailed and integrated planning in priority waterways, focusing on the sub-catchment as a whole, rather than viewing waterways in isolation. The planning is done at the landowner/property level, and is then integrated into a sub-catchment plan.

The WAP process involves a team of specialists, typically an ecologist, an engineer and a geomorphologist who, along with a CMA field officer, visit every property within a designated sub-catchment. The team inspects the waterways on each property and documents assets and threats. Assets may include good remnant vegetation and refuge pools, presence of vulnerable species, and threats such as erosion sites, stock access and weeds. At the same time, the team devises management actions to protect assets and address threats. These management actions are later prioritised based on cost and the potential impact of 'doing nothing' (in the context of the sub-catchment).

A key learning from using WAP is not to underestimate the value of planning. Although investors were initially reluctant to fund such detailed planning, we were able to show that it resulted in better overall use of investor funds. In the long run, more money can be spent on delivery and directed to the most important threats and assets. Since using WAP, the proportion of works on priority reaches has increased from 20 to 85 per cent.

Arguably one of the most valuable aspects of the WAP process is community engagement. As the team of experts collect field data, the CMA field officer has one-on-one contact with the landholder which is essential in developing trust and a good working relationship. The act of going onto the land, learning the farm's history and the landholder's understanding of how the river works, builds trust between both parties. We use kitchen table discussions, social media and Landcare networks to promote our programs.

Leigh Thwaites from SARDI tagging a carp. Photo Glenelg Hopkins CMA.

The combined use of the CMA Grants Program for on-ground works and the WAP process have been very effective in increasing uptake and on-ground outputs. Landholder participation at WAP events has risen from four landholders at our first meeting (where we had to drag people out of the local pub!) to 63 attendees at a recent presentation.

In the first four years of the program, the average project size was 5.3 hectares at a cost of $1062 per hectare. Over the last four years, it has tripled to 16.3 hectares but the cost has reduced to $795 per hectare largely because of the WAP and sliding-scale incentive mechanism.

Innovative approaches to in-stream restoration works

A number of the important successes of the project have initially involved risking untrialled approaches to waterway management. The introduction of WAPs (each taking a year to develop and costing around $100,000) was one of these risks. Another has been the CMA's approach to managing the European Carp that were first found in the river in 2001. Initial monitoring and control measures focused on electrofishing and netting at eight waterholes with the aim of minimising their distribution and abundance. While these eradication efforts removed some carp from the system a more strategic focused approach was required.

Glenelg Hopkins CMA is now using ground-breaking approaches to track and control carp. In 2012, the CMA, with VEMCO (a manufacturer of underwater acoustic telemetry transmitters and receivers) and the South Australian Research and Development Institute's (SARDI) Aquatic Sciences Centre formed a partnership to design a focused and cost-effective carp tracking system. The resulting system takes advantage of the congregating habits of carp and uses a 'Judas' fish—a tagged fish that provides information on the patterns and distributions of large carp groups allowing effective targeting and eradication.

The CMA has also expanded its carp identification and reporting program to incorporate social media (Facebook, Twitter) and smart phone technology. Community members text carp catches to 'Text-a-Carp'. This information is used along with the Judas carp tracking project to help map carp distribution and abundance. To date, 178 people are registered with Text-a-Carp.

Other important lessons learnt over the course of the project are as follows:

- Accept that the problem is extraordinarily large, complex and may take more than your life time to fix.
- Be flexible in the delivery approach to respond to extreme events such as floods.
- Weed control programs need to be cross tenure, and long term to be effective.
- Leverage through partnerships to achieve increased outcomes.

In summary

Although the river is beginning to bounce back, there remains much work to do. Restoration of a river system can take generations and requires ongoing maintenance to protect any previous investment. Glenelg Hopkins CMA's vision for the Glenelg River is to have a noticeably healthier river system that is more resilient to drought and flooding and is able to support social, economic and environmental values into the future.

Recognition

A significant achievement for the Glenelg community was winning the International RiverFoundation's (IRF) 2013 Australian River*prize*. The funding received from the Australian Government sponsored prize will support the CMA, local agencies and communities to nominate the Glenelg estuary (see photo) and adjoining coastal wetlands under the international Ramsar convention. If successful, the listing will raise the profile of this ecologically important site, increasing support for its conservation and sustainable use, and providing greater security for long-term management.

The successes of the Glenelg River Restoration Project were also been recognised in 2013, with a prize in the inaugural River Basin Management Society Awards.

From left: Mick Murphy (Victorian Catchment Management Council Chair), Nick Schofield (International River Foundation CEO,) Mike Wagg (Glenelg Hopkins CMA Chair), the Hon. Denis Napthine (Premier of Victoria) and Kevin Wood (Glenelg Hopkins CEO) with the Australian River*prize*. Background: Glenelg River. Both photos Adam Bester.

Got it covered

ROSS THOMPSON AND COLLEAGUES HAVE BEEN INVESTIGATING WATER, CARBON AND BIODIVERSITY IN AGRICULTURAL LANDSCAPES.

We live in a world where discussions of a 'carbon market' and 'carbon credits' are increasingly part of everyday dialogue. The idea that carbon farming—that is, planting trees to absorb carbon—will offset industrial emissions has been a topic of much debate in Australia and worldwide. Our research group asked the questions:

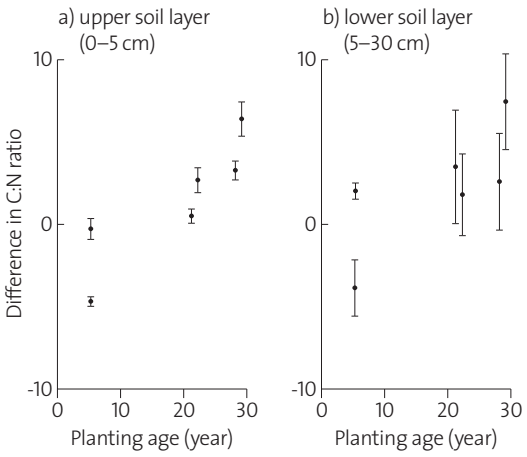
- What if carbon farming became common in central Victoria?
- How much carbon can we expect to be taken up?
- What are the implications for water yields?
- Are there biodiversity benefits?
- If so, for what species and when?

As part of an Australian Research Council Linkage Program research project that brought together university scientists, the Victorian Environment Protection Authority, Goulburn–Broken Catchment Management Authority (CMA), North Central CMA, Kilter Rural and the River Health and Economics branches of the Victorian Department of Environment and Primary Industries (DEPI), we have begun to answer these questions. The research team was led by Professors Ross Thompson and Ralph Mac Nally from the Institute for Applied Ecology at the University of Canberra.

Over the last five years, our team have explored the consequences of revegetation for carbon stocks, carbon fluxes and water yields. Along the way, we have experienced droughts and floods, shifting government policies on climate change and changes of government at both state and federal levels.

Our approach was relatively simple: firstly we identified 40 sites across central Victoria, mostly in the Goulburn–Broken catchment, that had varying degrees of forest cover, from almost complete forest cover (Whroo Nature Conservation Reserve) through to cleared and heavily modified agricultural land. At these sites we measured and monitored the vegetation communities, soil carbon stocks and fluxes, and bird and stream communities.

The emphasis in our study has been on native mixed-species plantings of trees rather than on single-species plantations. The majority of study sites had been replanted with native vegetation between five and 45 years ago. Detailed surveys were carried out of tree growth, understorey plant diversity, bird communities, and the amount of carbon in the trees and soils. Where the sites adjoined streams, the carbon in the streams and the



PHOTOS THROUGHOUT COURTESY OF THE AUTHOR. TREE OPPOSITE PETER HALASZ.

Difference (pasture–planting) in C:N ratios of a) the upper soil layer (0–5 cm) and b) the lower soil layer (5–30 cm) with age of tree plantings. Points represent means (N = 10 cores) with standard errors indicated by the bars. From Cunningham et al. (2012), *Agriculture, Ecosystems and Environment*, 158: 58–65.

biodiversity of aquatic animals was also surveyed. At a few sites we installed eddy covariance flux towers (see photo) which can directly measure the amount of carbon being taken up and given off by a forest or grassland.

The results are interesting and yield some unexpected, but pleasant, surprises. The replanting of trees has increased carbon to nitrogen ratios in soils (see figure above). Carbon to nitrogen ratios in soils are a strong driver of a range of other processes including carbon turnover and the nature of the microbial and fungal communities present.

Work on carbon dynamics in streams flowing through plantings of different ages has shown that the nature of organic matter in agricultural streams is different from that flowing through forested reaches, and that this then affects the amount of energy which finds its way into the stream food web.

Work on terrestrial biodiversity has shown that 20-year-old patches of forest have invertebrate communities which are more diverse and characterised by more native species than younger forest patches or agricultural areas.

Bird communities also change as forest patches age, however, the changes are much slower. While numbers of birds and bird diversity increases quickly over the first decade after planting of trees, these are predominantly common species. Recovery of the high-value biodiversity species such as rare birds, appears to be much slower, occurring over 40 or more years. Of particular interest was evidence that streamside vegetation had buffered aquatic biodiversity from the effects of the recent millennium drought, perhaps by reducing stream temperatures.

Work is ongoing to assess how quickly carbon uptake is happening in replanted forests by monitoring tree growth and directly measuring carbon exchange among plants, soil and the atmosphere.

The next step is to investigate how large-scale replanting across many hundreds of hectares might influence these processes. We are working with DEPI to model landscape-scale impacts on water yields from catchments after replanting, and are developing plans for managing replanted forests. We will complete work that takes replanting scenarios, such as the establishment of biolinks, and models their consequences on bird biodiversity.

Additional work will include an assessment of the effects of carbon prices on the uptake of carbon plantings by farmers. We are also going to try and assess how the return of rains after the millennium drought has affected our key indicators. This is forming the basis of a new Australian Research Council Linkage grant with Parks Victoria as a lead partner.

If you would like to find out who was involved in the research team or read the published articles relating to this work, contact the author.

FOR FURTHER INFORMATION

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SOIL DEEP

TIM CAVAGNARO, **PAUL REICH** AND **SAM LAKE** EXPLAIN THREE STUDIES THAT ARE IMPROVING OUR UNDERSTANDING OF RIPARIAN SOILS.

Riparian zones provide critically important ecological functions, including the interception of nutrients and sediments before they enter waterways. Consequently, riparian zones, and the vegetation they support, are important acting as the 'final buffer' between waterways and adjacent land. In recognition of this, strategies to minimise the flow of nutrients and sediments from agricultural land use and into streams, concentrate on riparian zone management.

The revegetation of riparian zones can bring about many ecosystem changes, and this includes riparian soils. The long-term Riparian Restoration Experiment (see *RipRap* edition 35) has been investigating these changes with three studies focusing on soils now having been completed. Each study explores the links between riparian condition and soil properties and a brief overview of key findings is provided here.

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STUDY 1—TRAJECTORIES OF CHANGE: RIPARIAN VEGETATION AND SOIL CONDITIONS FOLLOWING LIVESTOCK REMOVAL AND REPLANTING

In this study we aimed to identify patterns of change in soil and vegetation properties in riparian zones, under different management regimes, adjacent to tributary streams in northern Victoria. We compared riparian zones that were:

- heavily impacted by agricultural activities,
- in remnant condition, or
- had been fenced and replanted, and were thus in a transitional state.

Our research found there was an increase in plant cover and soil carbon concentration between impacted, through to remnant sites, with transitional sites recording intermediate concentrations, suggesting that improvements in soil conditions were becoming evident following restoration activities. We also found that adjacent land use had a significant impact on the concentration of plant-available phosphorus in riparian surface soils. This in turn, has consequences for nutrient inputs into streams. This study emphasised that riparian zones need to be managed within their wider landscape context and with particular attention paid to the impact of adjacent land use.

STUDY 2—SPATIAL PATTERNS OF, AND ENVIRONMENTAL CONTROLS ON, SOIL PROPERTIES AT A RIPARIAN–PADDOCK INTERFACE

Our work in this study investigated the soil properties, nutrient dynamics and vegetation composition at the riparian–paddock interface. Soil physicochemical and vegetation properties were variable along the transition from the grazed paddock into the ungrazed and revegetated riparian zone. Importantly, levels of carbon in the soil increased closer to the stream which we believe was due to increased vegetation in this part of the riparian zone. Furthermore, we found that the forms of carbon present in the restored zone were more recalcitrant, and are therefore likely to be retained in the soil for longer periods of time. This study highlighted the dynamic nature of soil processes at the paddock–riparian interface.

STUDY 3—SCALES THAT MATTER: GUIDING EFFECTIVE MONITORING OF SOIL PROPERTIES IN RESTORED RIPARIAN ZONES

The primary aim of this study was to assess the potential use of a range of common soil indicators for monitoring responses to riparian restoration, and to use this information to provide guidance for more effective monitoring. We found that soil properties varied considerably across various spatial scales (among creeks, among sites and within sites). This was especially true for soil nutrients (phosphorus, ammonium and nitrate); in the case of phosphorus, this could be explained by fertiliser-use history. Total soil carbon and nitrogen were much less variable. This study showed the importance of understanding sources of variation within soil properties at the start of the restoration process, so that change through time can be properly monitored.

Tim Cavagnaro is from the University of Adelaide, Paul Reich from the Arthur Rylah Institute for Environmental Research and Sam Lake from Monash University.

Published papers for these studies are available, contact Tim for details.

PHOTOS OF STUDY AREAS COURTESY OF THE AUTHORS.

The emerging theme from these studies is that riparian restoration can have a strong impact on soil properties, and that if we want to manage riparian zones for nutrients and carbon, we cannot afford to ignore the soil.

On the right track

LINKING COMMUNITY AND SCIENCE ON THE PATH TO RIVER AND CATCHMENT MANAGEMENT WAS THE TOPIC OF A DISCUSSION LED BY **PETER CULLEN TRUST FELLOWS***.

Much is now known about how land-use activities can maintain or improve river condition in Australia; yet a gap remains between that 'wisdom' and actual practice. There is clearly an opportunity to better link members of the community with the practices and products of scientific inquiry to enhance catchment management outcomes.

To tackle this issue a world café-style discussion was hosted by a group of Peter Cullen Trust Fellows during the 16th International River*symposium* held in September 2013 in Brisbane. Around 40 participants pooled their thoughts about the roles of communities and local and state governments in river management, and how science might influence policy and decision making. The shared experience led to new hope for a pathway to link community and science.

Players and factors

Communities are generally the backbone of catchment management activities, and the success of catchment initiatives can strongly depend on local support. Science-based recommendations without a community context may not be realisable. Government decisions may overlook community views, but concerted community effort can have influence at local, state and national levels.

Community needs and aspirations emerge from a combination of diverse values, histories, preferences and experiences. Local people are 'on the spot' and can see environmental problems (such as riverbank erosion) without necessarily having monitoring data. However, community projects need data to show their achievements to policy makers and funding bodies.

Like the community, local government is also generally on the spot. While not solely responsible for river and catchment management, local government often deals with competing land uses, community and stakeholder expectations, and development provisions. With the added need for scientific knowledge, river management is a challenge for local government to implement.

*Peter Cullen Trust Fellows at River*symposium*:
Kaye Cavanagh, Dr Kirsten Shelly, Dr Tanzi Smith, Dr Philip Wallis, Professor Michael Douglas, Dr Richard Benyon, Dr Cuan Petheram

The Fellows' River*symposium* session is also reported in a different way in the Trust newsletter *BRIDGING*, no. 10, March 2014, available from www.petercullentrust.com.au

WORLD CAFÉ PHOTO MICHAEL DOUGLAS. BACKGROUND PHOTO ROGER CHARLTON.

The flipside is that local government is well placed to be at the forefront of linking the community and science for the on-ground implementation of integrated catchment management.

State government agencies and their staff bear strategic responsibility for river and catchment management. At this level of government, factors other than scientific analysis often drive responses to on-ground situations. Lately, it has been rare to see state government staff out 'in the field' as they used to be in the days of extension officers. This observation led café participants to wonder how state government can truly be in touch with on-ground management.

In general, participants shared a view that recent state government processes have shifted focus to more 'here and now' issues, with little emphasis on planning for tomorrow, next year or indeed the future. Some felt that science and research are injected into policy or management decisions reactively rather than proactively, and there seems no mechanism to trigger the uniting of managers with scientists.

Science sometimes appears remote from the outcomes of catchment management, participants felt, and scientists can seem separate from the communities and managers involved. Some participants suggested state governments seem to ignore science they have funded to guide management operations; others felt scientists' research was not always relevant to policy and management. Communities also may not view science as being relevant to on-ground projects but more as a tool in more efficient expenditure and problem solving.

Scientific research is most likely to have an influence and be relevant at the local scale if there is clear framing of research questions including their scope, purpose and role in solving local catchment issues. Such framing should involve the ultimate users—local people. Science certainly has a role in regional environmental problems, such as to identify crucial thresholds at which management and investment need to change.

Drawbacks and ways forward

Café participants agreed science is useful for on-ground projects, but see a drawback in the short time frames of funding models typically available at the community level. These limit the chances of testing whether research findings can improve catchment management practice.

Another drawback is that policy makers and managers are still not working *with* scientists, or the community, to make their needs clear. The knowledge-brokering model that the late Professor Peter Cullen AO initiated and advocated highlights the strength of science working with policy and that multi-stakeholder involvement is imperative.

River and catchment management is often viewed as a complex issue and too difficult to implement in-the-whole. As a result, catchment managers tend to tackle issues in isolation. Researchers and decision makers also tend to work within their various disciplines, whereas integrated solutions need integrated thinking.

However, over the past two decades, organisations have increasingly recognised they can incorporate river and catchment management understanding into daily management and planning. They have used effective communication to collect relevant science and community knowledge, and learnt to work with external partners in community, government and the water industry. Relationships have been formed, with varying success, through regional bodies and multi-stakeholder steering committees.

In almost all cases, success has been achieved when there has been clear collaboration and common understanding across all stakeholders to inform local and state government policy.

Café participants concluded that these examples signpost a possible new pathway to link science and people in integrated on-ground catchment management.

This pathway would combine traditional science with citizen science, and be facilitated by strong partnerships and coordination between organisations. It would be a multi-disciplinary approach that values and fosters respect for local expertise while drawing on the latest research as an indispensable tool in addressing pressing problems.

There is no question that we need to be smarter and more strategic if we are to improve management practices and deal better with existing challenges. By sharing their work, communities, governments and scientists may all play important roles in this quest.

FOR FURTHER INFORMATION
www.petercullentrust.com.au

Hands-on revegetation

KAYE CAVANAGH (PETER CULLEN TRUST FELLOW) AND **NINA SAXTON** (AUSTRALIAN RIVERS INSTITUTE) CONVENED A FORUM THAT DISCUSSED PRACTICAL RIPARIAN REVEGETATION IN SOUTH-EAST QUEENSLAND.

River and catchment scientists, managers and practitioners in south-east Queensland (SEQ) have amassed many years of observations, data and experience, and they want to communicate this knowledge to policy makers and investors.

A 'practical river science forum' held in September 2013 celebrated and shared this pool of local and regional knowledge. Hosted by the Australian Rivers Institute, Griffith University, this was the first of a proposed series of forums which aim to communicate practical local insights to policy makers and investors, to help them 'get it right' for the region's waterways, catchments and water security.

Photos above and at right: Erosion like this in south-east Queensland in 2013 helped overwhelm Brisbane's water treatment plant with sediment, threatening the city's drinking water supply. Photos: above Jon Olley, at right Nina Saxton.

The focus for this inaugural forum was 'riparian vegetation in the landscape'.

Many people involved in river management agree that maintaining or replanting natural riparian vegetation is essential for healthy rivers and water quality. However, there are still some sectors within the broader community that are not yet convinced on the role of riparian vegetation. Varying science messages about what and where to plant, inconsistent and conflicting policies and complexities of scale make communicating the benefits of riparian vegetation a 'wicked' problem. Decisions about revegetation—such as policy, funding, timing, species and locations—need to be collaborative and consistent between the various parties and at different levels.

At this forum, local scientists, researchers, river managers, community group and consultancy representatives, and local and state government officers gave willingly of their time to engage in an open discussion, led by five speakers.

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The speakers' messages reinforced each other, bringing to light many critical points, including:

- Fifty per cent (24,000 kilometres) of waterways in SEQ are in poor condition; restoration is urgently required.
- Risks will only worsen if nothing is done.
- We need to stimulate new investment, from new sources, and to have a strategy for applying it.
- There needs to be leadership.
- Restoration needs a fresh, consistent narrative, told in the right way, demonstrating successes.
- We know the why and the how of restoration, but need to match on-ground knowledge to landscape research, with consistent information and data sharing.
- We must inspire and support collective action.
- It is important to understand the players and the land; involve landholders; and consider whole reaches or catchments, not just sites.
- Timing, persistence and collaboration are essential.

The speakers were Professor Stuart Bunn (Australian Rivers Institute), Julie McLellan (Healthy Waterways), Tony Costantini (SEQ Catchments Ltd), Steve Skull (Alluvium) and Donald Mackenzie (Logan City Council).

Forum outcomes

The forum culminated in an agreed statement of 10 key actions, which were combined into these two 'priority initiatives' that are currently being developed by forum participants.

1. **Develop a coordinated framework for influencing change in catchment restoration**: giving a single message; identifying barriers and levers for investment and clarifying leadership and responsibilities to all stakeholders.
2. **Sharing data and information**: identifying datasets, spatial information and resources on hand and how best to manage and share them; building capacity in catchment management via a restoration manual; and showcasing outcomes of existing works via case studies.

The Peter Cullen Trust office can provide a more detailed summary of the forum outcomes.

Revegetation in the Lake Baroon catchment, south-east Queensland. Photo Nina Saxton.

Creating 'green assets' for multiple benefits

ANNE JENSEN IS A VOLUNTEER MEMBER OF THE NATURE FOUNDATION SA'S WATER FOR NATURE COMMITTEE AND IN THIS ARTICLE DISCUSSES THEIR ENVIRONMENTAL WATERING STRATEGY.

Below the Darling Junction in the River Murray valley, regulation has reduced the natural frequency of floods so much that the health of plants and animals on the floodplain has seriously declined. The resilience of the ecosystem has been affected and extensive damage occurred during the millennium drought 2002–10, with mass deaths of mature River Red Gums (*Eucalyptus camaldulensis*) and Black Box (*Eucalyptus largiflorens*) trees across Murray Valley floodplains.

While the life-saving floods of 2010–12 saved the day for the lower Murray Valley and eased the problem there is still a lot to do to build the resilience of the floodplain up to high enough levels to withstand the next drought, and to repair the large-scale damage from the last drought. In 2014, in post-flood conditions, there is a game-changing opportunity to put environmental watering into practice at an effective scale.

This huge task exceeds what can be done by government agencies alone, and will need long-term partnerships at local, regional and basin scales to get the river ecosystem back to a state of health that can sustain all the dependent users and communities. This is the story of Nature Foundation South Australia (NFSA), an environmental charity that is active in the emerging environmental watering world, working to solve the practical challenges involved in returning water to the environment, to create rivers and wetlands full of life along the River Murray for the future benefit of the whole community.

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Water for Nature — http://www.waterfornature.org.au/
Nature Foundation SA — http://www.naturefoundation.org.au/

NATURE FOUNDATION SA, is a not-for-profit wildlife charity formed in 1981 that focuses on three key areas: land acquisition and management, funding high level conservation research projects, and delivering environmental water to the wetlands and floodplains of the River Murray in South Australia through the Water For Nature initiative.

High-throw sprinklers at Clark's Floodplain deliver water over a wide area to sustain Black Box and lignum seedlings, as well as mature shrubs and trees. Photos throughout this article Anne Jensen unless credited otherwise.

Flexible watering for multiple benefits

In the early days of environmental watering, the issue was acquiring the water, and several non-government organisations set out to encourage donations of water and money to build water banks, including NFSA's 'Water For Nature' initiative. The first NFSA project in 2008 started from a dinner table conversation which led to Adelaide electrician Ian Preston fund-raising among friends and family to purchase 7 megalitres of water to be returned to the drought-stricken River Murray. Ian teamed up with Water For Nature and the Riverland West Local Action Planning group, and the water was used to sustain water-stressed majestic old River Red Gums at a Regent Parrot (*Polytelis anthopeplus*) nesting site at Hogwash Bend in the riverland. As a result, in spite of the continued drought, there was 170 per cent increase in trees hosting nests and 160 per cent increase in active nests by 2010, compared to numbers in 2004.

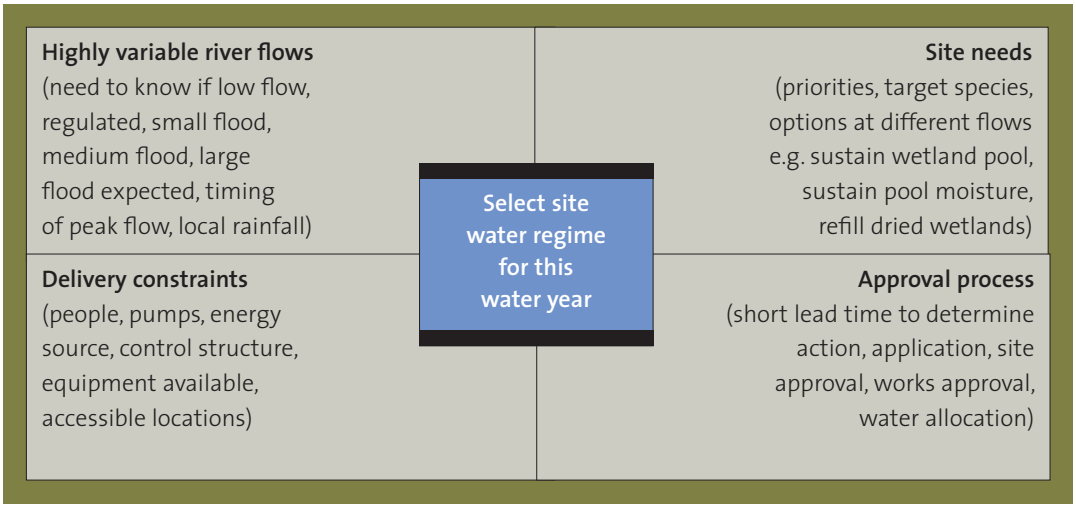
How times have changed! Conditions in the River Murray valley have been transformed from severe drought into post-flood conditions, with extensive areas of regeneration in key floodplain species. Acquiring water is no longer the issue, as NFSA now has an allocation of 50 gigalitres over five years (2012–17) because of the first ground-breaking agreement between a non-government organisation (NFSA) with the Commonwealth Environmental Water Holder. The focus has shifted to capacity building and fund raising for delivery costs and equipment, and finding resources to manage project delivery, monitoring and reporting.

The big question now is how to apply environmental water effectively, for demonstrable environmental, social and economic benefits. The focus of Water For Nature is on creating 'green assets', sites where healthy ecosystems are sustained to underpin a healthy river system which in turn supports healthy communities and local economies.

A key to achieving effective environmental watering is partnerships. This is a complex task requiring expertise, local knowledge, shared vision, energy, equipment and dedicated hours of work on the ground. Water For Nature works with private landholders, irrigators, community groups and local government. Our focus is on smaller sites, mostly on private land, to complement larger government watering projects, mostly on public land. Since most of Australia's wetlands are on private land, it is vital to engage with landholders and irrigator groups to demonstrate the multiple benefits from returning water to rivers and wetlands to maintain healthy ecosystems.

The challenge for NFSA is to apply the principles for the use of Commonwealth Environmental Water at a local scale within the capacity of the Water For Nature program. A suite of potential watering sites is evolving, with options to suit varying flow scenarios. This allows selection of the appropriate action based on flow conditions and site capacity. The key inputs are seasonal river flows and conditions (low flow, regulated flow in-channel, small flood, medium flood, large flood, timing, effect of local rainfall), which are usually known by September each year. These have to be matched with site needs, delivery constraints and receipt of appropriate approvals (see diagram below).

In 2008, severe drought conditions and a small volume of water, saw the focus turned to using irrigation technology and adding water to partnership projects for the greatest benefit from the water applied.



Water For Nature sponsors 2013/14

- Commonwealth Environmental Water Office
- SA Water
- John T Reid Charitable Trusts
- West End Community Fund
- James N. Kirby Foundation
- Harcourts Foundation
- SMEC Foundation
- Mullum Trust
- Australian Communities Foundation–Worrowing Fund

Water For Nature supporters

- Renmark Irrigation Trust
- Renmark Paringa Council
- South Australian Department of Environment, Water and Natural Resources
- Steve Clark and family
- Loxton to Bookpurnong LAP
- Bookpurnong Lock 4 Environmental Association
- Australian Conservation Foundation
- Observant (time lapse camera technology)
- Sinclair Knight Merz
- SES Berri Branch (sand-bagging control banks on flood runners)
- Riverland West Landcare
- Loxton Waikerie Council

Black Box seedlings emerged in pockets of dense germination when the flood peak of February 2011 reached some Black Box communities at higher elevations on the floodplain.

Micro-sprinklers sustain mature River Red Gums with Regent Parrot nesting hollows at Hogwash Bend.

Four small projects brought very significant local benefits during the drought. These included the Regent Parrot project at Hogwash Bend, and re-filling Little Duck Lagoon after three dry years to promote frog, fish, waterbird and waterplant life cycles. Two of the four projects focused on fish by lowering salinity levels in refuge habitats for the Murray Hardyhead (*Craterocephalus fluviatilis*) in Katfish Reach, and sustaining habitat for the Purple-spotted Gudgeon (*Mogurnda adspersa*) in the River Finniss.

Nature delivered serial floods in 2010–12, ending the drought in the River Murray and triggering mass germination in key floodplain plants including River Red Gums, Black Box and lignum. In this new post-flood scenario with larger volumes of water available, Water For Nature has turned its attention to sustaining the benefits of the floods, to increase survival of mass germination events and to build resilience in floodplain ecosystems. A key focus is on sustaining Black Box seedlings through their first two summers, to increase survival rates. This action has been given priority as most Black Box regeneration dates from the 1956 flood, with no known survivors from regeneration in the 1990s floods, and only a few pockets of survivors from the floods of the 1970s.

Filling Johnsons waterhole on Ral Ral Floodplain near Renmark to create temporary wetland conditions and promote aquatic plant and animal cycles (before and after). Photo at right Peter Hunter.

BOX 1: WATER FOR NATURE ENVIRONMENTAL OBJECTIVES

- Maintain minimum soil moisture to support growth of seedlings (River Red Gum, Black Box, lignum) until tap roots reach subsurface water sources
- Maintain pools of water long enough to complete life cycles in aquatic plants, macroinvertebrates, frogs, fish and waterbirds (8–10 weeks)
- Replenish freshwater lenses over saline groundwater
- Maintain healthy mature trees and shrubs to produce high volumes of seed

BOX 2: WATER FOR NATURE E-WATERING GUIDELINES

- Suite of seasonally adaptive options
- Protect long-lived vegetation
- Protect species of high conservation value
- Focus on refuges in drought
- Enhance natural benefits of flood
- Manage salt within ecological limits
- Ensure targets are SMART (specific, measurable, achievable, repeatable, timely)
- No grazing on watered sites

Consolidating its experience, Water For Nature has identified customised environmental objectives (Box 1) and a set of e-watering guidelines (Box 2) to guide operations in their niche of localised environmental watering.

Watering during low river flow conditions requires pumping water from the river channel to any sites not connected to the river at pool level. This requires energy and incurs significant costs for electricity or diesel fuel to run pumps, as well as extra energy required for pressurised irrigation at most sites. A further cost is monitoring the environmental responses to the water applied. While Water For Nature now has water available for projects, the cost of delivery is significant, and many sponsors and partners are contributing up to half of these costs. Without these contributions, it would not be possible to achieve effective environmental benefits.

For the future, the priority for Water For Nature is to up-scale, to deliver gigalitre instead of megalitre volumes. This will require partnerships involving large-scale gravity-fed flows using manipulations at weirs and larger water control structures to target sites within range of weir pools. Water For Nature is looking for opportunities to be more innovative, to involve more partners and to delegate long-term management and monitoring of watered sites to local agents. The big challenge will be to show the wider community the economic and social benefits of environmental watering, as well as demonstrating improving ecological health at watered sites. This is an investment in future green assets for the whole community.

Water For Nature acknowledges funding provided by the SA Murray–Darling Basin Natural Resource Management Board for publication of this article, as well as ongoing support and assistance from Board and Department of Environment, Water and Natural Resources staff in the learning process of how to deliver environmental water effectively.

Fixing wetlands for carbon

NICKY BRUCE OF MURRAY LOCAL LAND SERVICES AND **SARAH NING** FROM THE MURRAY DARLING WETLANDS WORKING GROUP LTD DESCRIBE HOW THEIR ORGANISATIONS AND LANDHOLDERS ARE WORKING TOGETHER TO STORE CARBON AND INCREASE BIODIVERSITY.

An innovative partnership between farmers, scientists, and government agencies in the New South Wales Murray catchment is seeing wetlands rehabilitated to increase their capacity to store carbon.

The first stage of the 'Murray Wetland Carbon Storage' project, involves rehabilitating 400 hectares of wetlands with a target of 2000 hectares by June 2013/14. The project is an initiative of Murray Local Land Services and the Murray Darling Wetlands Working Group Ltd, funded through the Australian Government. It has been enthusiastically embraced by landholders, both public and private, in the sheep–wheat belt of the eastern Riverina and south-west slopes of New South Wales.

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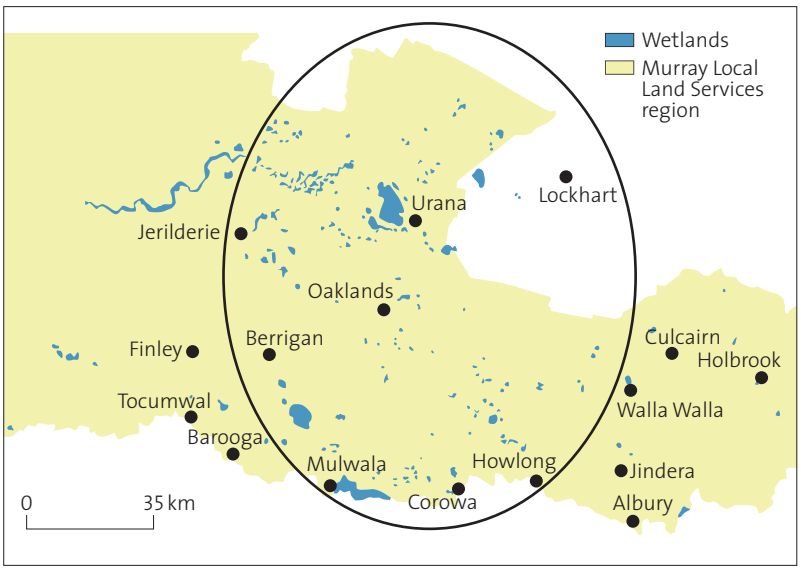
PROTECTING RARE VEGETATION COMMUNITIES. Title photo: Wetland on the Hooper's property 'Moona' near Deniliquin, photo K. & J. Hooper. From left: Milfoil, photo Murray Darling Wetlands Working Group Ltd (MDWWG); Balldale wetlands, photo Nicky Bruce; Nardoo, photo MDWWG.



The project's investment target area for 2013/14.

Shrinking capacity for wetlands to store carbon

Extensive vegetation clearing and altered land management have caused a reduction in the extent and diversity of carbon stores across Australia. Wetlands can represent a potential major carbon sink with high levels of productivity and integral incorporation of carbon into sediments, as well as contributing to biodiversity within the landscape.

A wetland inventory undertaken in 2010 found that one third of the wetlands in the Murray region have been cleared of native vegetation. Combined with changes to water regimes and grazing, these impacts are reducing both the capacity of wetlands to store carbon and maintain biodiversity values.

Increasing carbon through management and partnerships

Drawing on expertise in wetland management, the project is providing 'fit for purpose' funding to support landholders to undertake wetland management. Activities have been designed to provide carbon storage and increase biodiversity through on-ground works to rehabilitate degraded wetlands and enhance existing wetland and riparian vegetation. On-ground activities are tailored to suit each site and may involve:

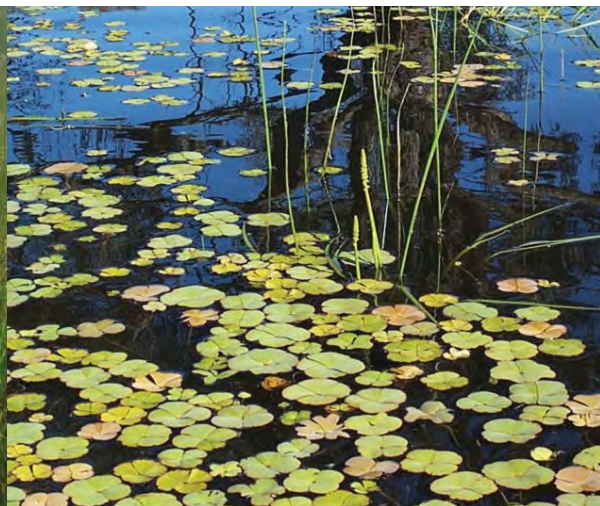
- planting of mixed local wetland, riparian and terrestrial vegetation,
- altering grazing management, with or without fencing (permanent or temporary),
- pest animal and weed control,
- environmental water delivery, where appropriate and feasible,
- providing resources such as interpretative signage, bird hides and educational visits.

The project is well underway, with the first investment round targeting wetlands in the New South Wales Central Murray area (see map at left). The target area was identified through technical and community consultation, recommendations from the NSW Murray Wetland Inventory (2010) and the 2013 Murray Biodiversity Management Plan. Additional rounds are planned for 2014–17 (subject to Australian Government funding). Participating landholders enter into a 10-year management agreement which is registered on their land title and allows for investigation of initial improvement of carbon storage and biodiversity.

Wetland diversity

Sixteen sites are being addressed through the project's first investment program, covering a diverse range of vegetation types, condition, and improved management opportunities. Sites are located in the Balldale, Corowa, Jerilderie, Savernake and Urana areas, and cover more than 1000 hectares. The wetlands comprise vegetation types such as River Red Gum and Grey Box both with grassy understorey, canegrass, sedges/rushes/grasses and lignum. Sites range from 15 to 420 hectares, with a mixture of applied management practices including a gravel quarry, travelling stock reserves and grazing for sheep and cattle.

Sites selected show potential for improved carbon storage, with evidence of an existing or known native seedbank, diverse vegetation community and/or habitat complexity; and favourable hydrological connectivity (with a low chance of being flushed or scoured and hence lose carbon). Other criteria considered were the identification of wetland local champions and the opportunity for sites to be used to demonstrate natural resource management benefits to the wider community.



Monitoring carbon dynamics

An important aspect of the project is to gain an understanding of how rehabilitation and altered management activities, such as reduced grazing pressure and revegetation, influence changes in carbon pools and fluxes within wetlands. A monitoring program is being developed as part of the project by the Murray-Darling Freshwater Research Centre. The 'Wetland Carbon Dynamics Monitoring Program' aims to provide improved understanding of wetland carbon dynamics and to develop recommendations for wetland management for carbon storage balanced with biodiversity benefits.

A series of baseline surveys and analysis will be carried out on a suite of wetlands from the project's first investment program to be completed by 30 June 2014. It is anticipated that the same method will be applied annually for a further three years to assist in evaluating and reporting on outcomes from rehabilitation of wetlands for carbon storage.

CASE STUDY: BALANCING AGRICULTURE AND MANAGEMENT OF WETLANDS FOR THE LONG TERM

Managing wetlands for carbon and biodiversity on an agricultural property presents some interesting challenges. Though according to John Simpson (pictured above), a landholder from the Jerilderie area, having an awareness of your wetlands and careful planning, can allow for parts of your paddock to become 'very easy on the eye'.

John is planning to enhance four wetlands through the project. All of the wetlands are surrounded by active cropping land with little to no stock access, and three will have no fencing to encourage native wildlife to use them, including visiting nesting waterbirds such as swans and pelicans.

John is looking forward to seeing the establishment of riparian/buffer zones, as well as the sites having overall healthy native vegetation with the absence of weeds. In 20 years' time he is hopeful newly-established trees will provide shade and there will be an increase in the diversity of plants and animals.

The Hooper's wetland, photo K. & J. Hooper

John Simpson, photo Sarah Ning. Australian Spotted Crake, photo Chris Tzaros.

Northern exposure

AMY KIMBER PROVIDES US WITH THE PASTORAL PERSPECTIVE ON BIODIVERSITY CONSERVATION ACROSS THE NORTHERN PARTS OF AUSTRALIA.

New research is underway to better understand how pastoralists and graziers could complement the national reserve system through voluntary contractual biodiversity conservation activities. Very little of Australia's tropical savannas, which cover around a quarter of the continent, are protected in the formal reserve system. Contributions by the pastoral sector are critical to safeguard endemic species, as well as rare and endangered plants and animals.

Pastoralists manage vast tracts of land with the average size of stations being around 250,000 hectares and individual decisions can have long-ranging impacts for the region's natural assets, including biodiversity. In the Northern Territory, for example, low-intensity pastoralism comprises three quarters of the total land area, while Indigenous lands and conservation reserves make up 15 and 6 per cent respectively[1]. This research explores the willingness of the pastoral sector to undertake conservation in exchange for stewardship payments. The findings have ramifications for the design and development of new programs in northern Australia and will also inform non-government offset programs and investment in biodiversity conservation.

Professor Romy Greiner from Charles Darwin University has driven more than 25,000 kilometres across northern Australia, conducting meetings and visiting remote stations to better understand how potential conservation contracts might work. This has allowed more than 100 pastoral businesses to participate in the research, including family farms, Indigenous-owned stations and corporate land managers. Between April and July 2013, scoping meetings were held in Charters Towers, Croydon, and Katherine; and research workshops in Broome, Katherine, Cloncurry, Tennant Creek, Mount Surprise and Kooroorinya. Romy's visits to individual property between Charters Towers and Broome accounted for about half the responses.

The survey explored how pastoralists manage their operations and make decisions. It included an experiment where they were presented with choices involving hypothetical conservation contracts. After making their selection they were asked about the factors that would influence their involvement. The number of responses has allowed Romy to gain a good understanding of:

- pastoral willingness to undertake contractual biodiversity conservation,
- pastoral preferences for different contract features and trade-offs,
- the amount of land potentially available for contractual biodiversity conservation,
- a whole-of-industry response to the concept.

1. Woinarski, J.C., Green, J., Fisher, A., Ensbey, M. & Mackey, B. (2013). 'The effectiveness of conservation reserves: Land tenure impacts upon biodiversity across extensive natural landscapes in the tropical savannahs of the Northern Territory, Australia', *Land*, 2(1): 20–36.

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Which activities were investigated?

Pastoralists and graziers are often dependent on one income stream so diversifying enterprises to derive income from a range of sources is desirable. Only 4 per cent of respondents categorically stated they would never participate in biodiversity conservation activities.

The conservation options included 'strict conservation' where cattle are excluded; and 'rotational grazing', where the length and timing of cattle access to land is determined by the needs of native species. For example, if someone has large wetland areas on their property where brolgas come to breed, they could improve the success of brolga breeding by excluding cattle from areas when the brolgas are hatching eggs and raising the chicks.

> "If the biodiversity conservation contracts were to be made available, that would definitely be a feasible option to look at. You would be a land manager and still make a living. It would make life on the land a lot more enjoyable."

What are the disincentives?

Participants identified risks associated with the conservation contracts, mainly institutional risk. People were worried that if they signed up to conservation activities voluntarily, those activities might later become compulsory. Some were worried about not being able to meet conditions at all times, for example, if fences were washed away during floods, and cattle then moved into nominated conservation areas.

People were also asked whether their willingness to take part would vary if contracts included carbon sequestration. A minority of respondents said having to undertake this particular activity would make them more reluctant to get involved, mainly because of the institutional uncertainty around carbon markets. One reason could be the length associated with carbon contracts, as the survey results indicated that the increasing contract length was a disincentive for participation.

Some contractual risks were also identified, for example, if people signed up to a contract and then there was a three-year drought, they would want to be able to allow cattle access to all areas of the property. For others, fluctuations in cattle prices and the amount of payment on offer were the main concerns.

How much payment is required?

The stewardship payment offer for the hypothetical conservation options ranged between $1 and $32/hectare/year, which reflected the range of grazing land productivity across the tropical savannas. As expected, land productivity was a key factor in determining the amount of remuneration required. Less productive land was offered up more readily than more productive areas such as the Mitchell Grass Downs in Queensland. Farm size did not have a significant influence on people's willingness to participate but did affect the amount of land able to be offered.

Key findings

Pastoralists were more likely to engage:

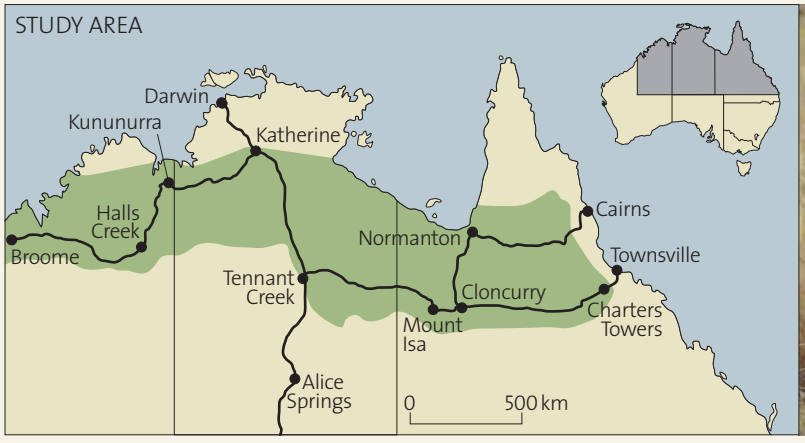
- the higher the stewardship payment on offer,
- the shorter the contract,
- the less productive their land was,
- if contracts allowed a degree of flexibility.

They were less likely to engage the:

- higher the conservation requirements,
- longer the contract,
- more productive their land was.

Contract flexibility is emerging as a key feature that will encourage participation. In the context of the research, contract 'flexibility' meant that if there were exceptional natural circumstances, people could negotiate to suspend their contracts for one year to allow cattle to graze the conservation area without incurring a penalty. If contract suspension was granted, they would forfeit the stewardship payment during that year, and suspension would not be granted in more than one of every five years.

The survey also measured attitudes and risk perception, and found a correlation between intrinsic interest in biodiversity, and the likelihood of participation. There was also a correlation between support for payment for conservation activities and participation. The profitability of a business did not have a significant impact on willingness to participate.



PHOTOS THROUGHOUT THIS ARTICLE COURTESY OF THE AUTHOR.

This research was funded by the Australian Government as part of the National Environmental Research Program.

Management implications

While some graziers and pastoralists were reluctant to engage, across the industry there was much interest in contractual biodiversity conservation. One advantage of investing in this type of conservation in northern Australia, is because of the size of the properties—if you find the right investment partner you can buy **a lot** of conservation. This is a key benefit compared to investing in some southern states where properties are much smaller. On the flip side, inviting participation in a conservation program by auction in the north might not work so well because there is much less competition. It's more a question of negotiation.

In terms of monitoring contract compliance, the study did not find a preference for self-monitoring, or external contractors monitoring biodiversity activities. There was a high level of diversity among pastoralists and graziers in the way they considered contract features, so flexibility is the key. For example contract length might be a disincentive for most, but some might be looking for a longer-term contract to improve income security.

Future challenges

Romy said the distances travelled during this field work had been rewarding. "It refreshed my appreciation of the vastness of the tropical savannas and the diversity within them. I got a pretty good first-hand account of how tough it is to be a pastoralist or grazier, and the climatic and economic difficulties and distances people face."

She continued, "There were properties I visited that were in excess of 15,000 square kilometres, so that's a lot of land. It means that the decisions of one land manager can have regional-scale implications for biodiversity. It is very encouraging that the north Australian grazing industry has shown genuine interest in the concept of providing on-farm biodiversity conservation in return for payment."

Pastoralists appreciate being asked for their input into the design of conservation programs rather than being confronted with a top-down approach. This research is a early snapshot of the opportunities on offer, and how to go about setting up potential programs. It could even have the flow-on benefit of keeping people in regional areas, and bringing people back.

On-farm activities will need to be tailored to whatever the investment objective is, but the take-home message is that the investment market is good.

Find out more

Early results are now being discussed with the pastoral industry which will allow more input into the outcomes of this research. Regional differences are also being explored and how these may affect monitoring arrangements. The final report is expected in November 2014.

"It is important for land conservationists like us that this research is being done. We have to stay viable and ensure the land we leave for future generations is healthy."

Something about Mary

TANZI SMITH, **EVA FORD** AND **DEB SEAL** EXPLAIN SOME OF THE STEPS TO RESTORING RIPARIAN RESILIENCE IN THE MARY RIVER.

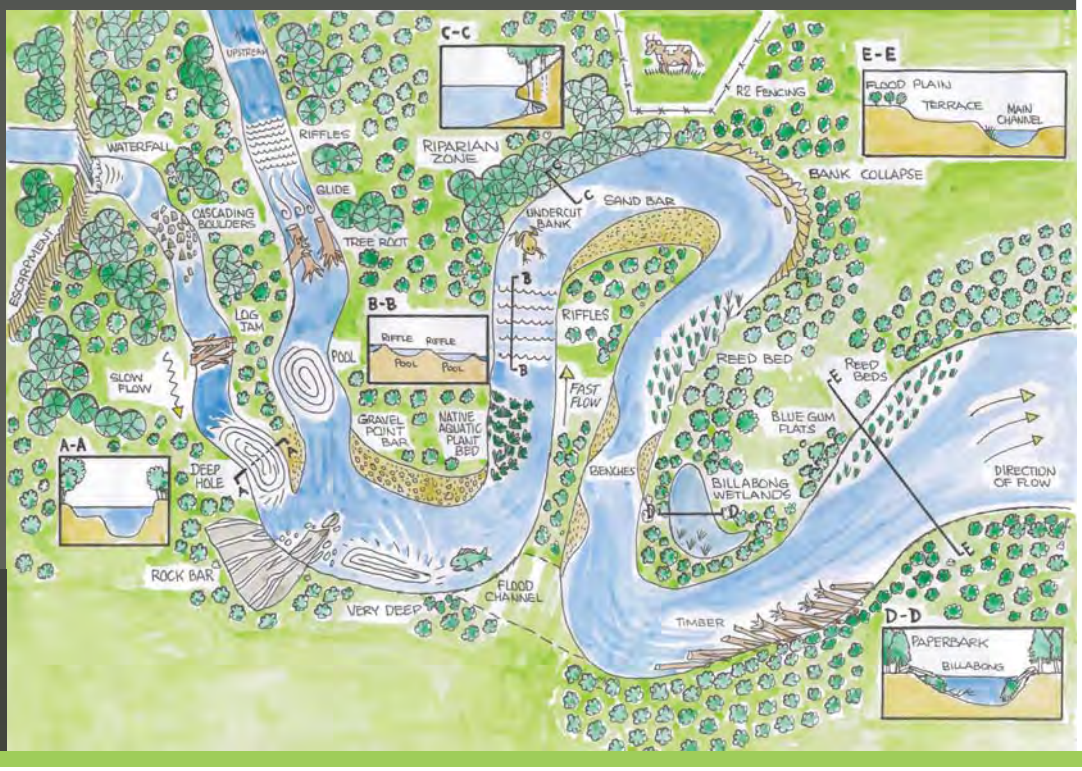
Above: Mary River Turtle, photo Glenbo Craig. This and other photos throughout this article provided by the MRCCC.

The beautiful Mary River is featured on the cover of this edition of *RipRap*. Photo courtesy of Todd Fauser.

Over the past 20 years of operation, the focus of the Mary River Catchment Coordinating Committee (MRCCC) has been on working with landholders in the catchment to achieve both conservation and productivity gains. The freshwater and estuarine biodiversity in the 9600 square kilometre catchment is significant, with more than 160 federally-listed threatened species living within its boundaries. Included are the Mary River Turtle (*Elusor macrurus*) a specialised river turtle which can breathe through gill-like structures in its cloaca, the Mary River Cod (*Maccullochella mariensis*) Australia's most endangered fish, and the prehistoric Australian Lungfish (*Neoceratodus forsteri*) which is found in only a handful of rivers—with the Mary regarded as its most intact habitat. Several species of threatened frogs are often sighted, such as the endangered Giant Barred Frog (*Mixophyes iteratus*) whose stronghold is the Mary River. Australia's most endangered bird the Coxen's Fig Parrot (*Cyclopsitta diophthalma coxeni*) is also found in the region. With a long history of concern for the catchment, community outcry and the significant biodiversity of the Mary River and its tributaries was the reason why in 2009, the then federal Environment Minister, Peter Garrett, stopped the Queensland Government from building the proposed Traveston Crossing dam on the main trunk of the river.

As a result of the ecological significance of the Mary, the first river-based recovery plan is being developed by the Australian Government Department of the Environment in conjunction with the MRCCC. Integrity of the riparian zone has been identified as a highly-rated threat to the five species that are the focus of the recovery plan (Mary River Turtle, Mary River Cod, Australian Lungfish, Giant Barred Frog and Freshwater Mullet). Recent Australian Government funding enables the MRCCC to undertake a six-year project called 'Restoring riparian resilience'. This project will improve habitat of these threatened species, increase biodiverse carbon storage, and bring benefits to landholders and community.

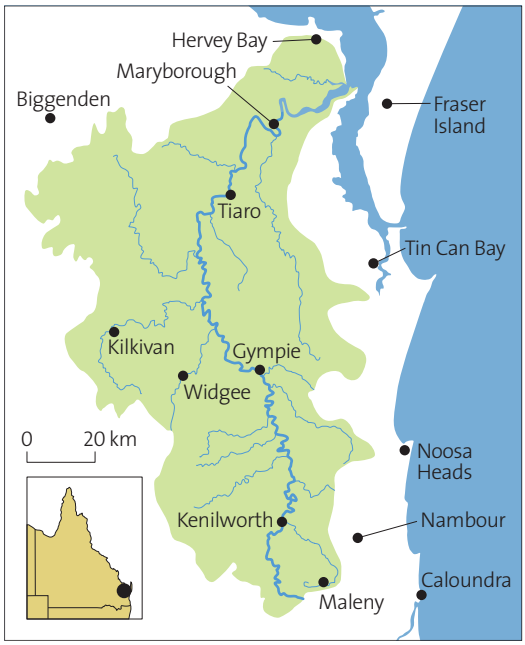
Since it began in 2012, the 'Restoring riparian resilience' project has established nine demonstration reaches and 50 individual project sites. Some of these sites involve landholders who have been active in riparian restoration, while about a quarter of the participating landholders are new to 'rivercare'. As 'Restoring riparian resilience' rolls out over the next four years, it is anticipated that a further 80 landholders will become involved. With the project expanding, the proportion of newly-engaged landholders will continue to increase, creating new community networks.



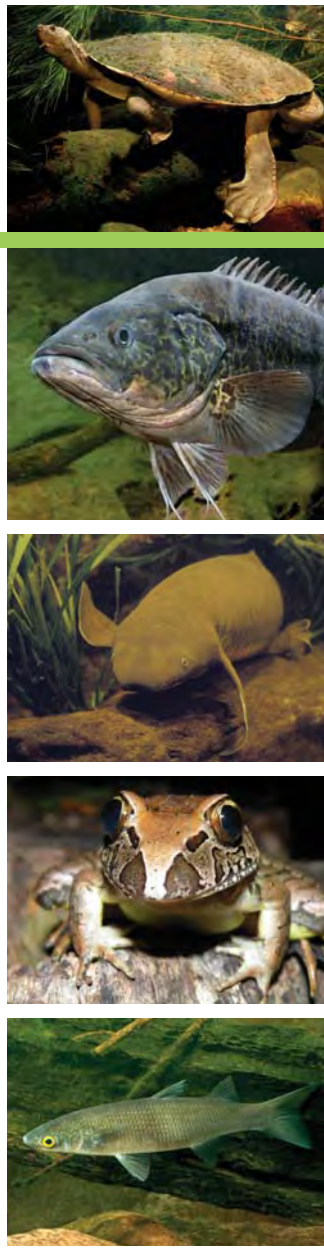
A caricature of the Mary River, showing the way the river changes as it travels from the foothills near Maleny and approaches the sea near Hervey Bay. The caricature highlights key features that create diverse habitats for aquatic life including threatened species. It was created for the "Something about Mary" publication. Illustration by Jeff Douwes.

The project is also addressing riparian restoration issues such as connectivity and bank erosion. Connectivity is being improved by targeting areas where restoration projects can be linked along a reach, providing the opportunity to maximise the benefit of both past and present riparian restoration activities. For example, in one project reach on the Walli Creek tributary, 13 out of the 14 landholders are involved in weed control and revegetation, working together to create a connected, weed free riparian corridor.

In many of the demonstration reaches bank erosion is also being addressed, particularly following the extreme flow events of the past three years. Studies have shown that erosion of riverbanks contributes 87 per cent of sediment loads supplied from the Mary River into the Great Sandy Strait and much of this sediment finds its way into the Great Barrier Reef lagoon. The project is taking on this difficult challenge by reducing sediment loads and improving bank stability. In some instances this has been made possible with funding from other sources such as the Queensland Government's Flood Recovery Program. In-stream works are being combined with revegetation, restoration and weed control activities on the adjacent riverbank. Leveraging funding from various sources in this way means the project can achieve an even greater impact.

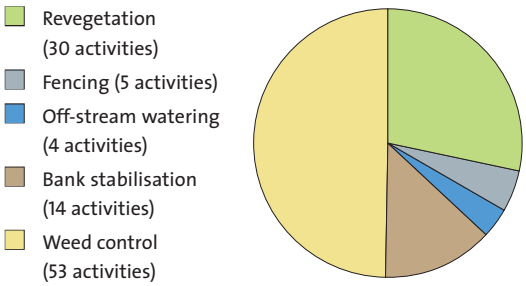


Most importantly, all project sites involve landholders in planning, implementation and evaluation. This is crucial for the longevity of the project, and creates valuable opportunities to connect people who want to care for their creek or river reach. The project is also building local capacity in some of the key skills needed to implement the recovery plan and improve riparian integrity. For example, knowledge exchange workshops are being planned where skilled environmental weed control staff will provide on-the-job training to contractors to increase local skills in controlling weed vines and distinguishing them from native vines.



Species the recovery plan focuses on, from top: Mary River Turtle, Mary River Cod, Australian Lungfish, Giant Barred Frog and Freshwater Mullet (*Trachystoma petardi*).

FIGURE 1: Riparian restoration activities to date



Working with landholders requires a flexible approach so that project activities can meet individual needs and achieve ecological and social outcomes. As shown in Figure 1, the main activities are weed control (including the release of biological controls) and revegetation (both of new sites and enhancement planting of existing sites). Weed control, in most instances, is focused on vine weeds, typically Cats Claw Creeper (*Macfadyena unguis-cati*) or Madeira Vine (*Anredera cordifolia*). Both are Weeds of National Significance, which have severely degraded riparian areas by smothering established trees and constraining natural regeneration. Biological control agents are being bred by local community organisations and the project is supporting these programs and roll-out of releases of the biological controls over a larger area. Other activities include control of stock access by fencing, provision of off-stream watering points and work to improve bank stability. All of these activities contribute to increasing the resilience of the riparian zone and improving habitat for threatened species.

A key benefit for the project is the length of time that the funding is available. Six years allows for long-term planning, experimentation with revegetation techniques, development of new monitoring techniques, trialling of biological controls and building new relationships with landholders. The benefits of the project also spread throughout the community, with much of the on-ground work being contracted to local Landcare groups. The extra funds provide these groups with a welcome boost that allows them to plan ahead for the duration of the project—a rare and important opportunity. Key partners include Noosa and District Landcare, Tiaro and District Landcare, Gympie and District Landcare, Barung Landcare and the Greater Mary Association. The project also benefits from continued collaboration with well-established partners such as Sunshine Coast Regional Council, Noosa Council, Seqwater and Burnett Mary Regional Group, and the strengthening of partnerships with other organisations such as Gympie and Fraser Coast Regional Councils.

Since the project began it has been affected by a series of summer floods (one in 2012, two in 2013) and in 2014, a drought over summer. Consequently, revegetation projects have been held off until conditions are more favourable. The impact of the weather on work of this type underscores the importance of the long-term funding cycle, which allows for project activities to be timed around when they have the best likelihood of success.

Together with the landholders' in-kind contribution, the 'Restoring riparian resilience' project will ultimately invest in control of stock access on another 50 kilometres of creek or river frontage and improved management of 2500 hectares of habitat. In addition, at least 40 new landholders will be involved in river restoration on their properties. This is a significant contribution to catchment management in our region and we look forward to expanding our network and seeing the water quality, biodiversity and productivity outcomes that should flow from this project in the years to come.

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If you'd like to know more about the threatened species targeted by this project, download the "Something about Mary" publication free from the MRCCC's website. Printed copies are available for purchase from the MRCCC on 07 5482 4766.

PHOTO PETER McADAM.

A richer Condamine

ENRICH—HABITATS FOR LIFE IN THE CONDAMINE RIVER IS A TWO-YEAR PROJECT AND **HEATHER SMITH** LETS US KNOW WHAT THEY'VE BEEN UP TO.

Top: Condamine headwaters above Killarney. Inset: Planting trees along the Condamine River as part of 'Enrich' are Condamine Alliance Manager River Kevin Graham (back left), Southern Downs Regional Council representatives Andrew Smith and Tim Kajewski, and Warwick East State School students Justin Horne, Kate Potter and Jasmine Gibson.

Australia is home to 50 separate rainforest reserves that are inscribed on the World Heritage list for their outstanding natural universal values. Since 2007, these reserves have been collectively known as the Gondwana Rainforests of Australia and one, shaped like a boy riding a unicycle from a bird's eye view, is where this biodiversity story begins.

'Enrich' is the creation of Queensland natural resource management group the Condamine Alliance, and the legacy of the Condamine catchment community. Beginning in 2012, the project has worked with local schools, Landcare, community groups, land managers and local councils to restore biodiversity, protect riverbanks and increase connectivity to achieve a healthier river.

That river is the Condamine, whose headwaters begin in the cool, ancient Gondwana rainforest and flow off the back of the Great Dividing Range into the Murray–Darling Basin, Australia's most iconic, and largest river system.

Riparian enrichment

Condamine Alliance aims to rehabilitate 650 hectares of riparian land along some 65 kilometres of the river during this two-year project. Work is underway in two stretches between Killarney and Cecil Plains in the west. These were in poor condition and were identified as needing priority attention for rehabilitation. Land managers are being assisted to establish native plants, remove weeds, control wild pigs, install off-stream watering points and fence waterways.

"The Condamine River nourishes some of the world's most productive agricultural land and sustains many communities who live beside it. It is home to many iconic native fish species and other plants and wildlife that contribute to the high ecosystem values of this area. Our Enrich message is all about increasing carbon stores, enhancing biodiversity, and building greater environmental resilience." (Kevin Graham, Condamine Alliance River Manager)

Enrich—Habitats for Life is supported through funding from the Australian Government's Biodiversity Fund.

"Our Enrich message is all about increasing carbon stores, enhancing biodiversity, and building greater environmental resilience."

Kevin Graham, Condamine Alliance River Manager

PHOTOS THROUGHOUT THIS ARTICLE COURTESY OF THE CONDAMINE ALLIANCE.

Historical land clearing and poor land management along this riparian zone has caused serious damage, which was exacerbated by floods in 2011 and 2012. The strong flows swept tonnes of debris through the river system and caused widespread erosion and slumping of riverbanks. The floods provided ideal conditions for weeds and pests, with extensive wild pig damage along the river and many new infestations of blackberry and privet. The only way to tackle these problems was with the involvement of local land managers.

Community involvement

Engagement has been a focus for the project from the very start. To date, three community information sessions have been held for land managers, along with seven school visits, five planting excursions and numerous meetings with interested partners. Condamine Alliance appointed local environmental consultant Dawn Heath, to coordinate the rehabilitation works with land managers once they joined the project.

Land managers involved in the project range from small-lot farmers to large-production businesses like Spicers Peak Station, which includes the Spicers Peak Nature Refuge near Cunningham's Gap. The New Holland Mouse and Powerful Owl are just two of the 27 rare and threatened animals that live in the 2000-hectare refuge. Others include Spotted-tailed Quolls, the Cascade Tree Frog, the Regent Honeyeater and the Long-nosed Bandicoot. Spicers Peak Station joined the Enrich project to help protect the refuge's special residents and improve natural habitat.

Further west in the catchment, local schools have been planting eight sections along the Condamine in Warwick. Three hundred students have helped plant nearly 700 seedlings so far and more schools will join in this year.

The school planting excursions attracted strong support from Southern Downs Regional Council, Condamine Headwaters Landcare Group, Warwick Fish Stocking Association and the Warwick River Trust.

Improving biodiversity

Enrich has focused on a few key activities to help land managers increase carbon stores, enhance biodiversity and improve connectivity in the riparian zone.

- Establishing native plants is a significant part of the project and, so far, 1380 native seedlings have been planted in riparian areas on both private and public properties. These seedlings have a greater chance of survival if there are less pests, such as wild pigs, to damage or destroy them.
- Wild pigs are a serious threat to biodiversity so Condamine Alliance brought together 23 neighbouring land managers to join a wild pig aerial operation. As a result, a total of 1812 wild pigs were eradicated on 25 properties over five days—the region's most successful wild pig cull.
- Some land managers, together with Spicers Peak Refuge, have received help to install fencing along their stretches of the river to protect vegetation and keep stock out. Already, fencing has been erected along 25 kilometres of waterway and 24 off-stream watering points have been built.
- Weed control is also underway with 40 hectares treated to date.

Carbon study

Condamine Alliance engaged the University of Southern Queensland to undertake a study to estimate the amount of carbon produced by riparian vegetation and coarse woody debris (fallen trees and branches) in the two main river stretches. The riparian zone was divided into 17 sample plots measuring 10 x 50 metres. Each plot's condition was assessed for trees, shrubs and coarse woody debris and awarded a score of poor, good or excellent.

The highest amount of total carbon was found in plots dominated by River Red Gum, followed by plots with more River She-oak. The average total carbon of all 17 plots was 143.6 tonnes per hectare which compares favourably with the global average for warm temperate dry forest. Principal scientist Tek Maraseni said this indicated that relatively high levels of biomass carbon are achievable in riparian zones.

"Riparian forests are not only valuable for biodiversity and ecosystem services, but are equally crucial for carbon sequestration, mainly because of fertile soils and abundant soil moisture. Surprisingly, more than 95 per cent

"The kids love the planting excursions and it is a great way to promote the importance of biodiversity, rivers and connectivity."

Kevin Graham

of the total carbon came from trees and shrubs and less than 5 per cent came from coarse woody debris. This means if we are only interested in carbon mass then we should give more weight to trees and regrowth and much less weight to coarse woody debris." (Tek Maraseni)

Tek recommends that if Australia wants to achieve greenhouse gas emissions reduction targets, it needs to encourage farmers to implement mixed species environmental planting within a 50-metre riparian buffer along all creeks and rivers. His research shows that this would have benefits for both adaptation, such as flood control and soil erosion control, as well as carbon capture.

It would be helpful to conduct more research across a larger number of samples to determine if these results represented the broader riparian zone. In the meantime, the sample plots may be used as permanent monitoring plots to offer important reference points for future carbon trend analysis.

Sharing achievements

Over its 10-year history, Condamine Alliance has learnt the value of sharing outcomes and achievements with project participants and the wider community. From the project's start, stories have been regularly shared through an e-newsletter and the media. A 'report card' was produced in the first 12 months to let the community know about activities and outcomes. This was followed by a newsletter that was distributed to everyone involved to highlight the good work, introduce participants, and increase awareness about the benefits of riparian vegetation. To top off the first year, Condamine Alliance hosted a riverside picnic in Warwick to show appreciation for the many people and organisations who have been involved in the rehabilitation activities so far.

The legacy of Enrich

This project is just one part of the Condamine Alliance's broader river restoration program that also includes the award-winning Dewfish demonstration reach. Each project is a stepping stone to greater knowledge, awareness and progress in catchment-wide water management.

The next step is to focus on a new reach, named after the Nikki Long Cod, in the Gondwana Rainforest. This will once again bring the community together to look after the biodiversity of this unique and ancient area. Its location brings the Enrich story full circle—where one enrichment project begins and ends, another one grows.

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Neil Davidson and Justin Jonson from Greening Australia monitoring seedlings established by direct seeding a year after sowing.

Getting wild in the west

DAVID FREUDENBERGER DESCRIBES HOW DIVERSE CARBON PLANTINGS ARE HELPING TO RESTORE PENIUP CREEK IN THE SOUTH-WEST OF WESTERN AUSTRALIA.

Restoration occurs one tree, one paddock, one creek at a time, but this must happen across many paddocks and kilometres of creek and river frontages and… scale is so important. Restoration must meet the scale of degradation caused by over clearing and the demands of agriculture. To match the scale of degradation, a large-scale solution is needed. Emerging carbon markets (globally and nationally) have the potential to provide commercial-scale restoration of degraded catchments. Such potential is being tested in the southern corner of the Western Australian wheat belt.

The story begins with an engrossing vision, Gondwana Link: *Reconnected country across south-western Australia, from the Karri forest of the south-west corner to the woodlands and mallee bordering the Nullarbor plain, in which ecosystem function and biodiversity are restored and maintained.* This community-based vision and network of diverse organisations is showing how restoration can be accomplished at scale.

Tapping into the carbon market is a strategy that started in the mid-2000s. Greening Australia (GA) and Bush Heritage Australia, with assistance from donors including The Nature Conservancy, bought a handful of properties between the Stirling Range and Fitzgerald River National Parks, all within a globally significant biodiversity hotspot.

This group took on the task of restoring thousands of hectares of degraded farmland within the Pallinup River catchment including Peniup and Carackerup Creeks. GA pursued the emerging Australian carbon market with vigour and secured early funding from commercial companies seeking voluntary carbon offsets. More recently GA have funding from the Australian Government's Biodiversity Fund which is helping restore more than 800 hectares on 'Peniup', a property with frontage onto Peniup Creek.

Restoration of a diversity of woodlands began in 2008[1] with the first challenge being to decide what plants should go where. This is an ancient landscape that after millions of years of evolution has formed a fine-scale patchwork of soils on which a diversity of plants have evolved into an intergrade of woodland communities. In this part of Western Australia there are often Yate woodlands (*Eucalyptus occidentalis*) on upper slopes, which then transition downslope into a variety of mallee communities with a diversity of understorey and midstorey shrubs and acacias. GA, through the dedication of Justin Jonson, took 100 soil cores to map where these different woodlands ought to be placed across paddocks affected by clearing and 50 years of wheat and sheep. This wasn't a 'mixed-soup' approach where just one mixture of seed species was spread over the initial 250 hectares of restoration. Rather, Justin mixed and applied nine different seed mixtures, each to a specific soil type, slope or drainage.

1. Jonson, J. (2010). Ecological restoration of cleared agricultural land in Gondwana Link: Lifting the bar at 'Peniup'. *Ecological Management and Restoration*, 11: 16–26.

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The next scaling-up challenge was seeding technology. Traditional single-row direct-seeders couldn't cover enough ground during the short winter planting season. Instead, Justin modified traditional wheat-planting machinery and was then able to sow up to 14 hectares in a long day.

As the project was contracted to deliver carbon credits to its funders, GA also planted widely-spaced eucalypts along and within the direct-seeded belts. These nursery-grown seedlings were 'insurance' so there was a minimum of long-lived green carbon established in an environment where direct seeding can succeed or fail depending on the timing of a single rainfall event.

Since then a collaboration of the Australian National University, the University of Western Australia and GA has been monitoring the challenges and successes of this restoration. We started by counting the tiny seedlings from the direct seeding (see title photo). Unfortunately many died during the 'bottleneck' of the first hot, dry summer, but in places initial seedling mortality was compensated by new seedlings emerging two to three years after the seeds were first sown. Each year the monitoring gets easier as we track more than 2000 fast-growing individual trees and shrubs within 42 permanent sampling plots distributed across the major soil types.

What a transformation (see photos)! Worn-out wheat fields are now vigorously growing woodlands that are restoring habitat for birds, reptiles and small mammals. This is the colour of 'living carbon'. In spring it's a mosaic of flowering species all hard at work fixing carbon into long-lived roots and trunks. Importantly these take up and respire every millimetre of rainfall. Shallow saline watertables seem be dropping and now little sediment runs off into the healing gullies that flow into Peniup Creek.

The good and bad news is that growth is patchy. From an ecological perspective these patches of high and low plant density and growth provide a fine-scale heterogeneity of habitats. There are dense thickets for those birds, reptile and small mammals that are cover dependent. In other places a scattering of shrubs and a few trees provide an open woodland structure with a groundcover of native perennial grasses that would be outcompeted in dense patches of woody species.

The 'bad' news is that this large variation in density and growth yields areas of low carbon sequestration and makes it difficult to calculate how many tonnes of carbon are being fixed and are hence available as carbon credits. In collaboration with CSIRO, we are looking at ways to improve methods to know just how much carbon is being fixed at Peniup and other sites where plant establishment and growth is naturally patchy.

The other bad news is that Australia, along with the rest of the world, has lost momentum in reducing carbon pollution and halting the rise in atmospheric carbon dioxide. When GA first entered the carbon market, it was inundated with interest from large companies seeking 'biodiverse carbon' as part of a portfolio of carbon pollution reduction strategies. In 2007 one major corporate polluter requested a $25 million pilot proposal to establish plantings across 12 landscapes GA was working in. This and other proposals that engaged the 'real' economy of corporate leaders came to little as the Rudd administration discarded the "greatest moral … challenge of our time", and the Gillard carbon tax was too little too late.

So the Peniup carbon plantings remain as a vibrant example of what can be done when we are serious about getting carbon back in the ground from whence it came. The 'promise of carbon' is tangible at Peniup as biodiverse sequestration is restoring terrestrial and aquatic habitats at scale.

1: Justin Jonson and his handiwork shortly after sowing was completed in September 2008. 2: Plot 104d in 2010 with a combination of planted trees and direct seeding. 3: The same plot in 2011. 4: In 2012 and 5: In April 2013.

This is the colour of 'living carbon'.

Coastal carbon

SIMONE HAIGH EXPLAINS HOW WETLANDCARE AUSTRALIA IS MAKING IT HAPPEN.

Wetlands on agricultural farms are an integral part of sustainable land management in the Barratta catchment. Photos throughout courtesy of WetlandCare Australia.

Wetlands deliver a range of critical ecosystem services including water filtration and purification, providing vital food and habitat resources for numerous species of recreationally and commercially important fish species, and providing significant protective buffers from extreme weather events. Recent research has also highlighted the impressive role that coastal wetlands play in capturing and storing atmospheric carbon dioxide—often far in excess of their terrestrial counterparts. Much of the carbon stored in coastal wetlands is in the soil, which presents a challenge to account for it under the fledgling Carbon Farming Initiative.

Many coastal wetlands, particularly saltmarsh, occur along the intertidal estuarine fringe—a zone that unfortunately bears the brunt of significant and increasing pressures from recreational and commercial uses. When coastal wetlands are lost or damaged, their ability to deliver critical ecosystem services, including that of carbon storage, are also lost. WetlandCare Australia (WCA), Australia's leading non-government, non-profit wetland conservation organisation, has a number of projects underway that are improving the health of coastal and floodplain wetlands.

Restoring their natural ecosystem function restores the wetland's ability to store carbon, however the rate that newly restored systems are able to do this is mostly unquantified. Globally, it is estimated that 430 megatonnes (1 megatonne is equivalent to 1 million tonnes) of carbon is stored in the upper 50 centimetres of tidal saltmarsh soils, with an estimated annual average storage rate of 210 $g/cm^2/yr^{-1}$ (Chmura et al., 2003). There has been little research on Australian saltmarsh, but estuarine wetland carbon stores from a study in the Hunter region of New South Wales estimated there was 0.7–1 megatonnes of carbon in the Hunter estuary (Howe et al., 2009).

WCA's 'Mid north coast saltmarsh recovery' project, funded by the NSW Environmental Trust, focuses on building the resilience of saltmarsh communities between Coffs Harbour and Port Macquarie. A large component of this project will be repairing the significant amount of damage to these sites from unrestricted vehicle access, and repairing the critical upper 50-centimetre layer that stores most of the carbon. Results from projects in the far north coast of New South Wales have shown that, once the original soil levels are

restored, these systems can quickly regenerate if given the right conditions, thus reinstating their carbon storage potential as well as the numerous other ecosystem services they deliver.

WCA has assessed 25 saltmarsh sites in key areas, and mid-2014 will see the on-ground works phase start. The restoration work will be supported by a series of workshops targeting stakeholders, farmers and landowners to help them understand the benefits of repairing and protecting their saltmarsh areas.

WCA has also partnered with the Southern Rivers Local Land Services to run a series of workshops for farmers as part of the 'Realising the potential: Connectivity and carbon storage in NSW coastal wetlands' project, funded through the Australian Government. This project will strengthen wetland habitat resilience and health through revegetation, establishing buffer zones, removing barriers to flow and controlling pests in 32 priority catchments.

A WCA keystone project, 'Delivering biodiversity dividends for the Barratta Creek catchment' is making significant headway into restoring carbon to wetland soils in north Queensland through an integrated suite of on-ground works.

The Barratta Creek catchment forms the main artery of the Bowling Green Bay wetlands, the only Ramsar site in north Queensland. Barratta Creek is one of the most high integrity floodplain creek systems on the developed east coast of Queensland. Since the introduction of intensive irrigated agriculture the creek and wetlands have suffered serious impacts through a lack of active management and understanding including invasive aquatic and terrestrial weeds, hot frequent fire regimes and excessive nutrient rich tailwater flows. Now in its second year, the project, funded by the Australian Government, has united multiple stakeholders in tackling some of the major threats facing this system and improving biodiversity outcomes and carbon storage through integrated catchment-based management.

The project has prepared three revegetation sites with 3000 trees planted to increase the diversity of local native species and provide corridors for native fauna. Irrigation tailwater runoff from several large cane farms in the Burdekin-Haughton Water Supply Scheme is being diverted from the current tailwater drain system through a constructed wetland via a remediation pond. This is greatly improving the quality of water entering the Great Barrier Reef.

The benefits of restoring riparian vegetation and cleaning up agricultural runoff extend far beyond the Barratta project site. Reducing the amount of sediment and pollutants entering rivers has a direct consequence for fragile seagrass beds. Studies estimate long-term carbon burial of seagrasses as being in the order of 83 g/C $m^{-2}yr^{-1}$, which translates to global storage rates of 27–40 Tg C yr^{-1} (1 teragram = 1 megatonne) (Kennedy & Bjork, 2009). Seagrasses are highly susceptible to sediment inputs and if the turbidity of receiving waters is too high they lose the ability to photosynthesise, and hence their ability to accumulate and store carbon.

Accounting for carbon in wetland soils is an important next step in accurately developing a whole-of-ecosystem carbon budget. This will facilitate the provision of extra incentives to land managers to repair the substantial amount of damage that has occurred historically, so that wetlands may continue to deliver their critical ecosystem services as we move into a challenging future.

Severe erosion at this Coffs Harbour saltmarsh site is a result of damage by vehicles. The high carbon content of the soil can clearly be seen in the colour difference between the dark brown mud of the saltmarsh soil contrasted with the light colour of the sand substratum.

A number of journal articles are available on this research, contact the author for more details.

FOR FURTHER INFORMATION

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http://www.wetlandcare.com.au/index.php/our-work/current-projects/

BLUE CARBON

PHOTO MICHAEL BECKMANN.

COLIN CREIGHTON EXPLAINS HOW BLUE CARBON IS ONE OF THE MORE PROMISING WIN–WIN IDEAS TO REDUCE ATMOSPHERIC CO_2 AND LIMIT GLOBAL CLIMATE CHANGE WHILE ENSURING LONG-TERM FOOD SECURITY.

Coastal ecosystems—estuaries, mangroves, seagrasses and tidal salt marshes—are Australia's richest 'sinks' for carbon. They make up just 5 per cent of global land area, but their biomass and sediments store the same amount of carbon as the remaining 95 per cent of global land areas. Given Australia's aridity and sparse vegetation, the comparative storage potential of Australia's coastal ecosystems may be even greater than these global percentages. Carbon sequestration in wetlands is also a certainty when compared to the risks associated with native bush regeneration and Australia's incidence of bushfires.

The carbon stored, sequestered and released from coastal, estuarine or open ocean ecosystems and their closely-related ecosystems is called 'blue carbon'.

For the Fisheries Research and Development Corporation (FRDC), the blue carbon concept is a crucial opportunity to marry multiple government policy objectives: carbon sequestration, water quality improvement, enhanced biodiversity, coastal land protection and the repair of habitats that provide for most of our fish nursery environments. The FRDC approach to investment to wetland research and practice is to deliver these multiple benefits, along with achieving an overarching goal of repaired and rejuvenated fishery habitat and productivity.

Unfortunately, wetlands have not always been highly valued. Many of Australia's coastal wetlands and estuarine systems have been drained for farmland, barraged off from tidal flows, or isolated by roads and rail causeways. To show the economic and environmental benefits of repairing degraded wetlands, the FRDC is collating information on sequestration rates in order to develop a methodology for carbon accounting of these coastal ecosystems.

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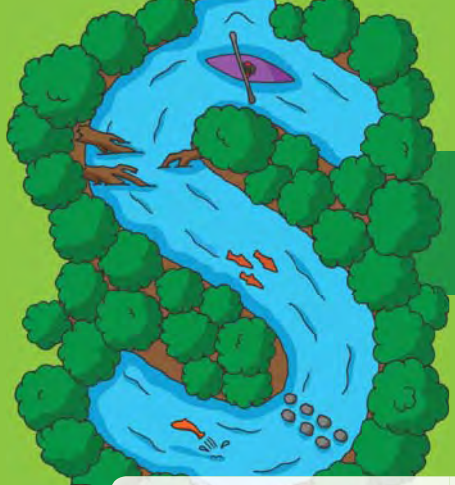
An Australian Government policy shift could allow these ecosystems to then be added to the national carbon accounts. This would enable owners of such wetlands to undertake repair work, and then using the accounting methodology developed by FRDC, participate in the carbon market.

Some of the rehabilitation activities being proposed include civil engineering projects to introduce culverts into causeways, thereby improving tidal ventilation and promoting tide-driven productivity in seagrasses, wetlands and fisheries. Other work is focusing on removing old levees and drainage systems from floodplain wetlands. Two pilot projects are underway with support from the Australian Government's Biodiversity Fund—both are repairing fish passage, reconnecting fish habitat, and reducing the problems of deoxygenated water while increasing the sequestration of carbon. These projects are being undertaken in cooperation with fishers, natural resources management groups and local governments on the Clarence River in New South Wales and the Burdekin floodplain in Queensland.

The FRDC sees their blue carbon research as an opportunity to engage the fisheries industry—commercial, recreational and indigenous—in the national carbon market. Most importantly, it will deliver on multiple government and community objectives focusing on valuing, rehabilitating and maintaining healthy and productive coastal ecosystems.



The 5 Ps:

A COLLABORATION AND COMMUNICATION FRAMEWORK

When people collaborate and share their ideas and skills, great outcomes can be achieved. To create the conditions for collaboration to flourish, the ARRC uses a framework called the '5Ps' which is a checklist to ensure the full range of factors that influence how people make decisions are considered.

1 Profit

Profit means **far more** than a commercial transaction or a result based purely on business principles—it is about the **range of benefits** that can accrue from a decision, whether they be at an **individual, family or community level**.

2 Proof

Proof becomes important when it is presented in ways that people can **relate to and understand** how it can be used in their **daily life**—when viewed in this way, proof is about providing people with the **confidence to act**.

3 People

Humans are social beings. We need to **invest in establishing strong, enduring relationships** with those we collaborate with. To do this, we must take time to **listen, understand and appreciate** the perceptions, networks and communities people are part of. When we do this we **build trust**, which is essential for effective collaboration.

5 Promise

The promises we make **underpin all our relationships**. Promises need to be made clearly so that collaborators have a **shared understanding and expectation** about their involvement. When we make promises, we can **establish the foundation** upon which trust, **confidence and a desire to work together** can be laid.

4 Place

Our connection to 'place' is **fundamental** to our identity. When we want to collaborate we need to **acknowledge the connections people have to their 'place'**, and consider how decisions can impact on that connection. We can also **create new 'places'** for people to meet, share ideas and promote collaborative action.

We are sharing the 5Ps with you and would love to hear how you use it to promote collaborative action. Please share it with others, and adapt and modify it to suit your needs. To download a high resolution PDF A3-sized poster of 'The 5Ps' that you can print out for your home or office please visit www.arrc.com.au

ARRC Australian River Restoration Centre

At the Australian River Restoration Centre we believe in sharing knowledge, restoring and protecting our rivers for all to enjoy and valuing people and the work they do. We do this by:

- Inspiring and supporting people passionate about rivers
- Creating and distributing *RipRap* magazine
- Sharing knowledge in multiple ways
- Collaborating and networking with a range of organisations
- Managing on-ground and science communication projects

www.arrc.com.au

To find out when the next edition of *RipRap* is coming out, stay in touch through the ARRC blog, it is free to subscribe and you are also welcome to provide contributions to share with the wider ARRC community.

RipRap is ONLY available for purchase through the Australian River Restoration Centre.

RipRap

EDITION 37, 2014

To get involved and find out more about what we do visit our website www.arrc.com.au and get in touch through Facebook, Twitter and LinkedIn.

"This is the colour of living carbon."

David Freudenberger