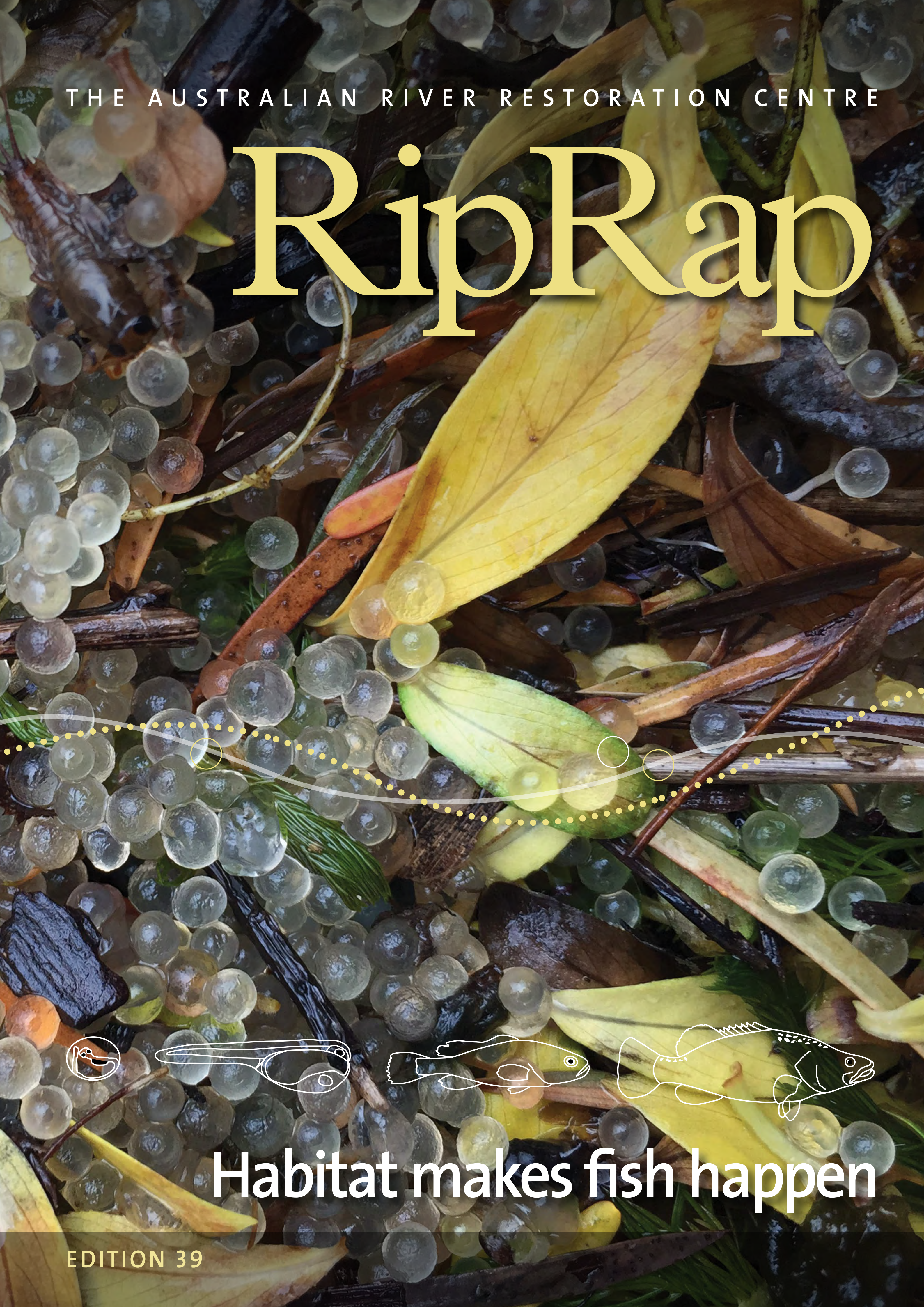
THE AUSTRALIAN RIVER RESTORATION CENTRE

RipRap



Habitat makes fish happen

EDITION 39

CONTENTS

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Editorial

Bringing together this edition of *RipRap* has been a pleasure. The stories demonstrate the depth of knowledge and effort going into understanding our native fish, and how we can create opportunities for them to thrive. A special thank you goes to Heleena Bamford at the Murray–Darling Basin Authority who tirelessly works to promote the science and practice of native fish management. John Koehn, Craig Copeland, Stuart Little and Jenny Nutter have also been great supporters, and of course Allison Mortlock, my fabulous designer who brings the stories to life with her creative skills. I hope you enjoy this edition and share it widely.

Siwan

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MAKING FISH ‘HAPPEN’

BY INTEGRATING HABITAT, FLOW AND CONNECTIVITY

BRENTON ZAMPATTI AND **MARTIN MALLEN-COOPER** BEGIN THIS EDITION OF *RIPRAP* DISCUSSING THE NEED FOR A BROAD PERSPECTIVE OF HABITAT RESTORATION FOR REHABILITATION OF NATIVE FISH POPULATIONS.

In terrestrial and aquatic ecosystems, habitat complexity and connectivity promote biodiversity and population resilience. In regulated rivers, however, dams, weirs and water extraction simplify habitats and flow regimes, and disrupt connectivity. This has major impacts on the health of aquatic ecosystems, including fish. Rehabilitation of fish populations in these rivers is dependent on three key elements: habitat, flow and connectivity. Considerable effort is devoted to habitat restoration, particularly re-snagging and riparian rehabilitation, with the premise that ‘habitat makes fish happen’, but restoring physical habitat alone is insufficient to support diverse and healthy fish populations.

Rehabilitating fish populations in the highly regulated rivers of the Murray–Darling Basin (MDB) requires habitat restoration to be considered in the context of flow and connectivity. A strategic and realistic goal is to promote mosaics of connected habitats that incorporate the complex flow characteristics of natural rivers, at a range of spatial and temporal scales. To do this we need to look in more detail at what constitutes flow, habitat and connectivity, and how these factors interact to support ecosystem function.

Restoring ecologically relevant aspects of a river’s natural flow regime is fundamental to restoring the ecological health of regulated rivers. In this context, the term ‘flow’ is generally used to describe a river’s discharge, that is, the volume of water passing a specific point over a unit of time (for example, megalitres/day). Nevertheless, water volume and discharge are not factors to which aquatic biota, including fish, respond. Instead, they are influenced by the hydraulic elements that constitute flow, such as water velocity, depth and turbulence, and how they differ in space and time. These factors combined are called hydrodynamics, and the hydrodynamics of a river form an essential component of fish habitat.

A river’s hydrodynamic characteristics are determined by the interaction of hydrology (discharge) with the geomorphology of the river channel, including channel shape and substrate, and habitat features such as large wood and bankside vegetation. In aquatic ecology there is a fundamental distinction between flowing water (river) and still water (lake), with each supporting distinct ecological processes and patterns. River regulation, in particular dams and weirs, fragments and simplifies riverine habitats, in some cases rendering flowing water habitats to be more like lakes.

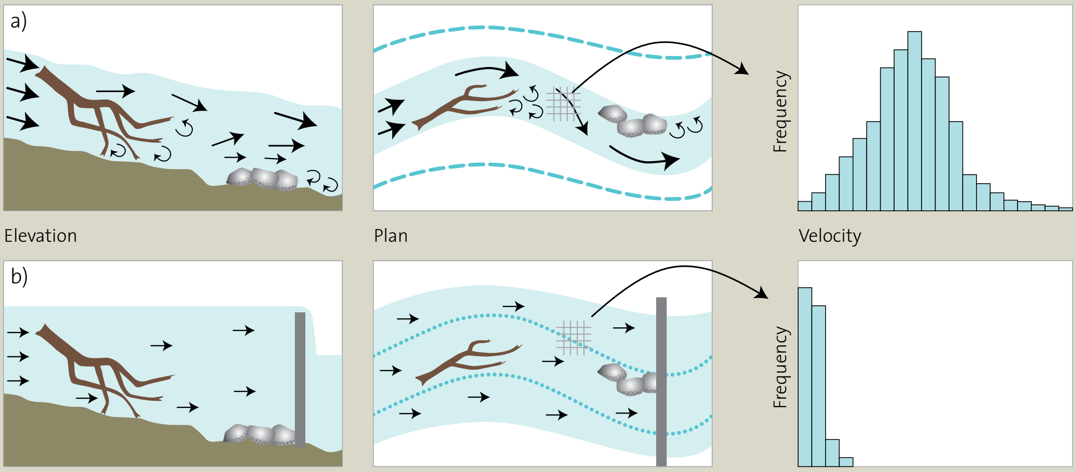

Figure 1. Conceptual diagram of a river illustrating hydrodynamic diversity and the impact of a weirpool. Elevation and plan sections of a stream are shown with vectors (flow direction and water velocity magnitude) as arrows, and a histogram of water velocities. The natural stream a) has complex changes in flow direction, higher mean velocities, a greater diversity of velocity with roughness, such as large woody debris and rocks, creating eddies. The river regulated by a weir b) has comparatively uniform flow direction, low mean velocity, a narrow range of velocities and the woody debris and rocks create very little hydrodynamic complexity due to the slow flow.

In Figure 1, a natural stream a) has higher mean water velocities and a greater diversity of velocities, with roughness such as snags and rocks creating eddies and complex changes in flow direction. In contrast, a river regulated by a weir b) has comparatively low mean velocities and a narrow range of velocities, with any snags and rocks promoting little hydrodynamic complexity. Both rivers can have essentially the same structural habitat and discharge, but the regulated river has simplified hydrodynamics that favour generalist native species (often those adapted to wetlands) and invasive species such as carp. Lost from these habitats, or present in low abundances, are riverine species that rely on the complex hydraulic habitats created by flowing water.

In the MDB, one of the most striking examples of altered hydrodynamics occurs in the lower River Murray, where the construction of barrages and weirs has transformed more than 800 kilometres of riverine habitat into a series of cascading lake-type habitats. This simplification of riverine hydrodynamics, and disruption of connectivity, has altered ecological function and biodiversity in the lower Murray, resulting in the loss of many biota, including at least three species of riverine fish (Trout cod, Macquarie perch and River blackfish), Murray crayfish and other invertebrates (e.g. aquatic snails).

Restoring fish populations also requires an understanding of fish life histories and the spatial and temporal scales they operate over. This involves progressing beyond understanding the habitat requirements of individual fish to that of populations. In the MDB, we know that Murray cod love snags, but fundamental questions remain regarding the scales at which populations operate, and the diversity of habitats that influence population dynamics, including spawning, recruitment and migration.

Hydrodynamics influence the ecology of fishes at micro (cm to 10s m), meso (100s of m to 10s of km), and macro-scales (100s of km). At each scale, complexity and connectivity are essential. Micro-scale hydrodynamics, which can be considered from the perspective of a fish larvae, juvenile or adult, may include variation in water velocities, created by the interaction of flowing water and in-stream objects (for example, substrate and snags), providing hydraulic complexity that redistributes drifting larvae, minimising intra- and interspecific competition. This diversity also promotes slow-flowing edges and slack waters that concentrate zooplankton and fish larvae, providing refuge, and a feeding and nursery area. In weir pools, this hydraulic complexity is often absent.

SCOTT DAVIS

Meso-scale hydrodynamics reflect the diversity of habitats at the river reach-scale including pools, runs, riffles and associated off-channel habitats. Fish may move between these habitats to feed or complete key life history processes. For example, Murray cod in the lower River Murray make seasonal meso-scale spawning movements from main-channel weir pool habitats to flowing anabranch systems such as Chowilla and Lindsay-Mullaroo, or in the mid-Murray, between Lake Mulwala and the Ovens River. Maintenance of these habitats and connectivity between them is essential to the health of Murray cod populations in these regions.

Macro-scale hydrodynamics, which occur over hundreds of kilometres, may influence many aspects of fish ecology including spawning, dispersal (migration and larval drift) and meta-population dynamics. In the MDB, two notable species, Golden perch and Silver perch spawn in spring-summer, likely responding to water temperature and hydraulic conditions (potentially increasing velocity), eggs and larvae then drift for many days over many kilometres, and juvenile and adult fish move upstream and downstream over hundreds of kilometres. Continuity of flowing water habitats over a macro-scale is vital for the completion of essential life history processes of these species. Altered hydrodynamics and disruption of connectivity, either through direct obstruction of fish movement by a weir, or drifting eggs and larvae settling out in weir pools, compromises the resilience of populations.

Restoration of ecosystem health in the MDB requires more than restoring volumes of water or physical habitats; it requires an understanding of the hydrodynamics of riverine/floodplain ecosystems and the integrated re-establishment of habitat diversity, flow and connectivity at relevant scales.

This edition of *RipRap* presents a range of articles concerning the rehabilitation of native fish populations in the MDB by thinking about structural habitat, connectivity, flow and hydrodynamics. Importantly, it covers an array of species and case studies that demonstrate the variability in life histories of fishes. The stories show the many different factors that need to be considered to ensure 'habitat restoration makes fish happen' to ultimately improve native fish populations.

CIRCULAR IMAGES: CSIRO; APART FROM TOP, AUTHOR; FAR LEFT MDBA; LARGEST CIRCLE, CONNOLLYB.

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Creating recipes

FOR NATIVE FISH

FISH NEED WATER TO SURVIVE—IT IS THE MEDIUM IN WHICH THEY LIVE,

BUT AS **IAIN ELLIS** DISCUSSES, FISH HAVE A SUITE OF NEEDS, OF WHICH H_2O IS JUST ONE.

Native fish in the Murray–Darling Basin (MDB) have adapted to 'boom and bust' cycles of water availability and flow. Over the last century and a half, however, we have substantially altered the magnitude, frequency and seasonality of water flows in many river systems. These changes affect all aspects of a fish's life, and are one of the main reasons native fish have declined in the MDB.

Every creature has particular habitat, food and life cycle needs which have evolved over millennia. It is easy to understand why Polar bears can't survive in the Australian desert—it's too hot and there aren't enough seals to eat. It is also clear why Numbats wouldn't survive in Antarctica—it's cold down there and termites are hard to come by!

It is the same for fish—they won't survive if their habitat, food and life cycle requirements are not met. Water is necessary, but there are many other ingredients which are required to support a fish's needs. Let's delve a little deeper into some of these fishy requirements for those species that call the MDB home.

Habitat

Habitat for fish consists of the type of waterbody it lives in (e.g. lakes, wetlands or rivers), the hydrology of the waterbody (flow, depth, seasonal water availability etc.), physical structures like logs or plants and, what we loosely refer to as water quality. These habitat elements differ widely between fish species. Some fish (such as Golden perch) prefer to live in flowing steams where flow pulses are generally required to generate a spawning response, with some individuals migrating over 1000 kilometres upstream to breed. Their eggs and larvae also benefit from flowing water which carries them downstream enabling wider dispersal.

Murray River rainbowfish

Spangled perch

Barred galaxias

Murray hardyhead

In contrast, Southern pygmy perch avoid flowing water, preferring still pools or wetlands with lots of aquatic plants, in which they complete their life cycle.

Physical structure within waterbodies can also be important for survival. Snags in flowing rivers create sheltered nests in which Murray cod often lay their eggs. The flow outside their sheltered nests brings a ready supply of food from upstream to hungry parents, and transports zooplankton for their offspring to eat.

Aquatic plants in wetlands and lakes provide food-rich shelter in which Murray River rainbowfish hide from predators (birds and bigger fish), and a substrate on which they lay sticky eggs.

The quality of the water and the way it interacts with the environment are also very important to fish. Spangled perch live in the warm water typical in the north of the MDB. They occasionally venture into the southern MDB during big floods (i.e. the Murray River system), but are unable to survive the cooler winter water temperatures in the south.

At the other extreme, Barred galaxias are adapted for life in cooler mountain streams, and cannot survive warmer summer temperatures in lowland rivers. Barred galaxias habitat needs to be low in salinity, while the Murray hardyhead actually prefers salty habitats like floodplain lakes, with some populations recorded in wetlands with saline levels more than double seawater.

Altering parameters like temperature, salinity and dissolved oxygen (which fish absorb by 'breathing' through their gills) changes these habitat elements and can be detrimental to fish. Blackwater events are often accompanied by depletion of dissolved oxygen which can result in fish deaths—particularly bigger fish which have higher oxygen demands.

Clearing of riparian vegetation or intense grazing along river banks can cause high sediment run off which, in turn, reduces water clarity. Not only do these sediments smother plants and fish nesting sites, they also reduce light penetration, effecting dissolved oxygen production by aquatic photosynthesisers.

Life cycles

Each fish species in the MDB has a preference for where and how it breeds. Some lay eggs in a nest, others broadcast thousands of eggs into river flows. Most native fish species synchronise their breeding to occur in warmer months. This is not a coincidence, but a strategy that has evolved over thousands of years. It makes sense to produce offspring at this time of year when there is likely to be more resources available to support survival, and flow to aid dispersal.

Unsurprisingly, changes to habitats or flow patterns impact on fish life cycles. Reduced flooding isolates wetland habitat needed by floodplain fish like Murray hardyhead. Cold water releases from the depths of reservoirs behind large dams in spring can disrupt the development of tiny Murray cod in their nests. Removing snags and flow variability reduces the ‘patchiness’ of habitats in a waterbody, reducing its suitability to a variety of fish.

Connectivity, which facilitates movement between habitats, is also important for the completion of life cycles. Longitudinal connectivity along the length of the river or between catchments may be critical for completion of life cycles by species that occupy a range of habitats over vast areas (e.g. Golden perch). Lateral connectivity between rivers and their floodplain is equally important in providing access to non-flowing wetlands that are critical for other species like Southern pygmy perch.

Food

Fish also need a reliable food supply. Historically, natural flow cycles in the MDB promoted diverse aquatic food webs which, in turn, supported healthy fish communities. Without natural flow variability, nutrients and resources become depleted and food webs are compromised. This is akin to deforestation; where clearing of vegetation reduces a mosaic of terrestrial habitats to broad areas of homogenous habitat.

Using the right recipe

This diversity of habitat, food and life cycle needs means that a wide range of aquatic environments and flow regimes is necessary to support the range of fish species found throughout the MDB. Environmental flows provides us with the opportunity to try and meet these needs—but there is more to the recipe than just applying water.

A simple way to think about managing water to achieve everything fish require is to compare it with making a cake. You need all the right ingredients. Water is the most fundamental for fish, but remember it has to be the right salinity, temperature, clarity and so on. You also need snags, plants and… oh wait, don’t forget you also need the fish themselves and a good understanding of their life cycle needs. Measures to control pest fish may also be necessary—they could seriously influence your cake. Non-native fish like carp, redfin and trout may eat native fish, and also compete with them for food and habitat and can even alter water quality and habitat availability.

Finally, you need to combine these ingredients in the right order, use the right utensils (i.e. appropriate waterbody) bake your cake at the right temperature, for the right amount of time and then dress it for service (for the perfect fish recipe see opposite). We can use our understanding of fish needs to enhance productivity and support healthy fish communities. To get it right, we just need to ensure we combine all the essential elements correctly—the ingredients, method and utensils!

We are now using this ‘recipe’ to guide us as we make decisions about environmental flows for fish. You can read more about how we are applying the recipe in Kat Cheshire’s and Anthony Townsend’s article on page 8.

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A recipe for healthy fish populations

Adapt your process as required – learn by doing!

Ingredients

- ***Water***. *This can be all of the water in the system and held environmental water*
  - *Flows and hydrology (volume, magnitude, timing, duration, rates of river rise and fall)*
  - *Flow diversity (water depth, width, velocity, and turbulence)*
  - *Appropriate water quality (temperature oxygen, salinity, turbidity etc.)*
- ***Habitat***
  - *Waterbody (rivers, creeks, wetlands etc.)*
  - *Physical structures (vegetation, snags, rocks)*
- ***A variety of different native fish*** *and knowledge of life history requirements*
- ***Food and healthy food webs*** *(nutrients, bacteria, algae, phytoplankton, biofilms, plants, zooplankton, water bugs, crustaceans, small fish, bigger fish)*
- ***Connectivity*** *(longitudinally between stretches of river or catchments, or laterally between rivers and their floodplain)*

Method

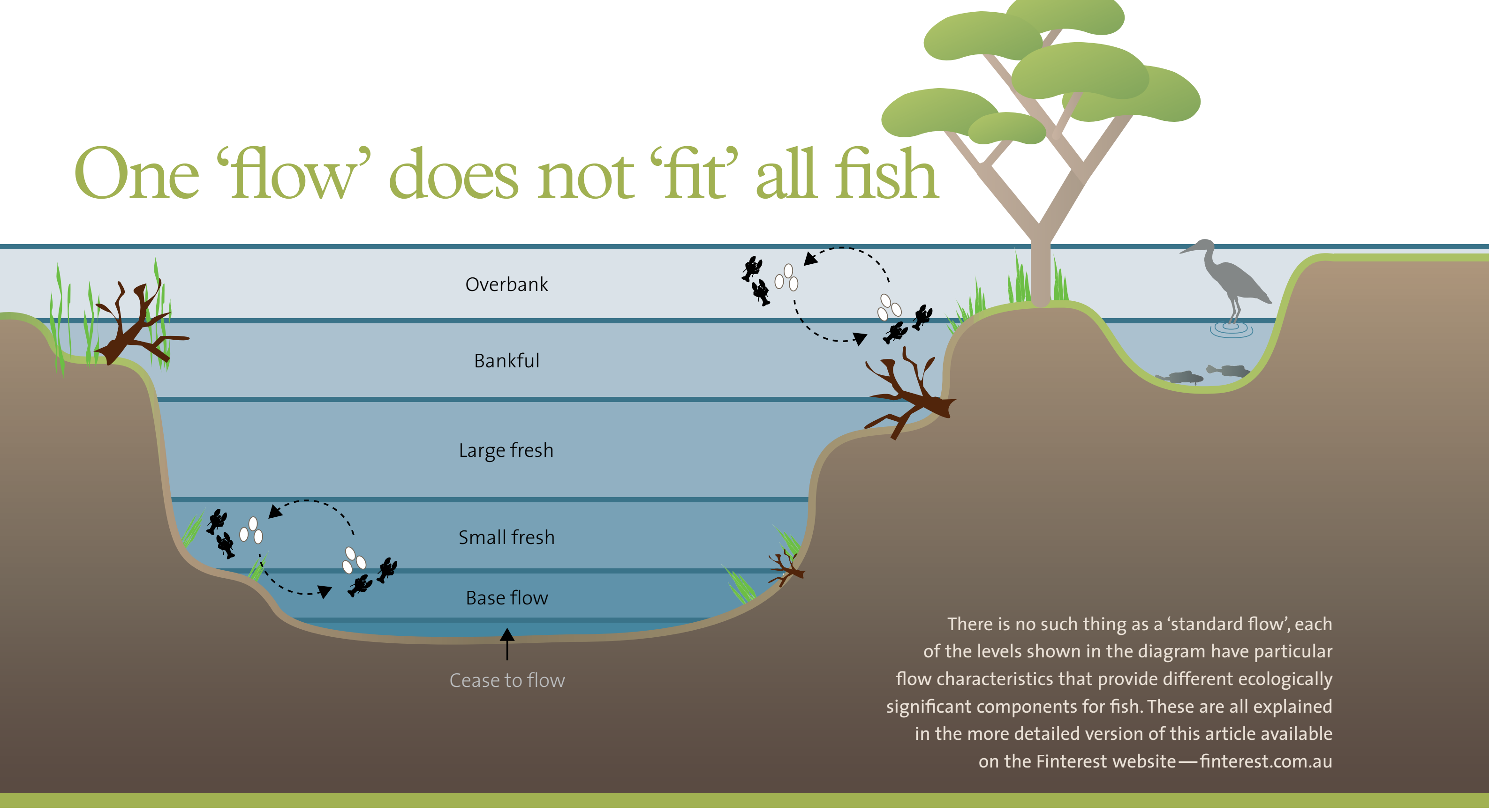
1. *Select all of the above ingredients in the right measures (will vary from place to place) for your water management area.*
2. *Determine the type of waterbody you are dealing with (habitat).*
3. *Check what native fish are present, and make sure it has appropriate, diverse habitats and physical structure.*
4. *Decide which fish or groups of fish you want to support using water management.*
5. *Identify their life history requirements and how water can be used to support these. It might be more efficient to use a 'functional group approach', where the fish present are sorted into groups based on shared life history characteristics and responses to flow.*
6. *Ensure your water connects different habitats at the right time of year to support movement of adults and juveniles. Some fish will have survived nearby in refuge areas, others need flows to undertake movements to breeding or nursery habitats.*
7. *Ensure your water management supports primary productivity and allows food webs to develop over time.*
8. *Determine what type of water management the selected fish or functional group needs based on life cycle requirements. Use conceptual hydrographs adapted to your area to design your water delivery.*
9. *Add water as often as needed to get the right consistency in the fish population (based on meeting the life cycle requirements for your fish, following natural flow regimes as much as possible).*

Warning: too little, too much or the wrong temperature of water at the wrong time may produce unexpected/negative results!

Consider and manage external complications (such as pest species, losses through irrigation extraction, cold water pollution, and the requirements of other users).

You may need to undertake complementary actions, like habitat augmentation or re-stocking, to support your water management.

One ‘flow’ does not ‘fit’ all fish



IT IS SOMETIMES ASSUMED THAT PROVIDING FLOWS OF ANY MAGNITUDE, VELOCITY, RATE AND FREQUENCY WILL BENEFIT FISH, HOWEVER, AS **KAT CHESHIRE** AND **ANTHONY TOWNSEND** EXPLAIN, WE NEED TO PROVIDE A RANGE OF FLOWS TO MEET DIFFERENT FISH NEEDS.

There are 46 native fish species in the Murray–Darling Basin (MDB). Each of these species has evolved differently, over millennia, to the boom and bust nature of the Australian riverine landscape. Water and fish go together, and different fish have adapted diverse life cycles in response to the varying flow conditions (i.e. floods and droughts) of the Basin. When we look at fish species in the MDB there are some basic differences in life cycle strategies:

- some are dependent on intermittent high flow pulses to spawn,
- others require fast flowing riverine habitats to live in,
- some require the inundated wetlands on our floodplains, and
- others can complete their life cycle in almost any conditions, including low flows.

Due to their dependence on different flows, our native fish populations are suffering from changes in the system. These changes occurred over just a handful of decades as a result of water extraction and river regulation. Fish play a critical role in the whole river system by cycling nutrients, providing food for other parts of the food web like waterbirds, and sustaining a billion dollar a year recreational fishing industry. Looking after fish, therefore, provides a range of environmental, social and economic benefits.

We know that restoring fish populations through smarter water delivery and protection of natural flows can be an effective way to manage river health (see Box 1). Fish respond differently to different flows, and this means that assuming any water will have positive outcomes for all fish is too simplistic.

It is not feasible to manage water delivery specifically for each of the 46 different fish species in the MDB, but our team did want to manage water more effectively so that we optimised outcomes for fish. Our response to this problem was to develop an approach using ‘functional groups’, where we sorted the fish into groups based on shared life history characteristics and responses to flow.

NSW DPI Fisheries, in collaboration with fish scientists and managers from across the Basin, used these functional groups to develop a simplified management framework for fish and water management called the ‘Fish and Flows’ projects. We built on previous functional group approaches for fish and integrated the latest science and knowledge about flow related responses and life history requirements of fish. This enabled us to develop different functional groups of species for the southern and northern Basin.

These projects focused on how water and flow influence key characteristics of fish life cycles (Figure 1), with these shown below:

- egg, larval and adult habitat preferences,
- distances of juvenile and adult movements,
- if cues are required to initiate spawning,
- how and where they spawn (e.g. nesting or not),
- how many eggs they produce,
- how frequently they need to spawn to maintain populations,
- life span, and
- survival and maintenance of populations (dependent on food availability and water quality requirements).

Using these characteristics we identified five different functional fish groups that are now being used to simplify water management targets for fish (Figure 2 on the following page).

BOX 1:
Benefits of water management for fish

- Improves completion of native fish life cycles, which have adapted to the natural boom and bust of the MDB system, including providing cues for some fish to spawn (e.g. Golden perch).
- Maintains water quality for fish health, including levels of dissolved oxygen, salinity and temperature.
- Ensures access to a diversity of habitats (wetlands, flowing water, river channels, drought refuges) during dry times, and nesting sites (woody debris, aquatic vegetation, gravel or cobbles).
- Water that inundates river benches and floodplains provides food for adult and baby fish, helping maintain their condition. Healthy fish are more likely to spawn, move and respond to different cues, increasing their survival potential.
- Supports lateral and longitudinal movement of fish throughout the Basin (e.g. Murray cod and Silver perch have been recorded moving hundreds to thousands of kilometres), ensuring genetic diversity of fish and allowing dispersal to different locations.

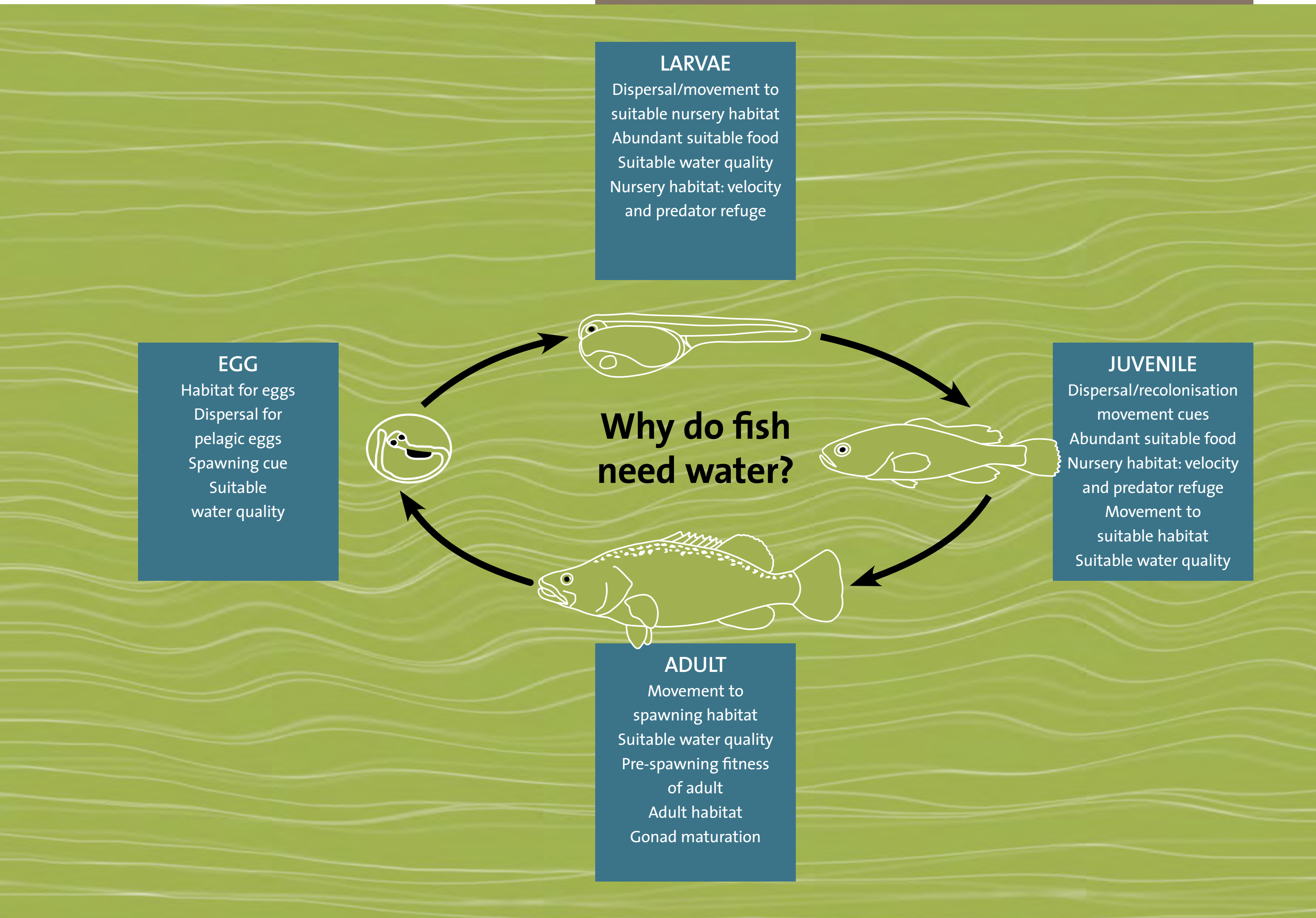


Figure 1. The influence of flows on the different stages within the life cycle of fish. Adapted from MDBA and Arthur Rylah Institute.

Figure 2. Functional groups of fish developed during the Fish and Flows projects, highlighting their flow-related attributes and example species.

Group 1: Flow pulse specialist

- Flow pulses during warm temperatures generally required for spawning
- Growth and recruitment success potentially enhanced by flows
- Lots of eggs, broadcast spawning
- Eggs and larvae drift in flow
- Move long distances in response to flow
- Medium–large bodied, long lived
- Golden perch, Silver perch

Group 2a: Riverine specialist (lotic)

- Prefer faster flowing riverine habitats
- Spawn annually in response to temperature, independent of flow
- Growth and recruitment success potentially enhanced by flows
- Moderate numbers of eggs, nesting species
- Move moderate distances for spawning
- Large bodied, long lived
- Murray cod, Trout cod, Macquarie perch

Group 2b: Riverine specialist (lentic)

- Prefer slower flowing river habitats: anabranches and lakes
- Spawn annually in response to temperature, independent of flow
- Growth and recruitment success potentially enhanced by flows
- Medium numbers of eggs, nesting species
- Move shorter distances for spawning
- Range of body sizes and life spans
- Freshwater catfish, Purple-spotted gudgeon

Group 3: Floodplain specialist

- Slow flowing well vegetated streams and wetlands, may have unique water quality needs
- Overbank flows may inundate required habitats and provide access or dispersal
- Spawn annually, may repeat spawn, in response to temperature, independent of flow
- Low numbers of eggs, may have spawning substrate preferences
- Small bodied, short lived
- Southern pygmy perch, Murray hardyhead, Olive perchlet, Flat-headed galaxias
- Gambusia — non-native

Group 4: Generalists

- Able to occupy a range of streams and waterbody types
- Flexible spawning and recruitment strategies
- Spawn annually, may repeat, in response to temperature, independent of flow
- Low numbers of eggs
- Move short distances
- Small–medium bodied, short–medium lived
- Australian smelt, Carp gudgeon, Flat-headed gudgeon, Bony herring, Murray River rainbowfish, Unspecked hardyhead, Mountain galaxias, Spotted galaxias, Climbing galaxias

Group 5: Generalist non-native

- Able to occupy a range of streams and waterbody types
- Flexible spawning and recruitment strategies
- Spawning, growth and recruitment success may be enhanced by flows
- Spawn annually, may repeat, in response to temperature
- Moderate to high numbers of eggs
- Move short distances
- Small–medium bodied, short–medium lived
- Carp, Goldfish, Redfin perch, Oriental weatherloach, Rainbow trout, Brown trout

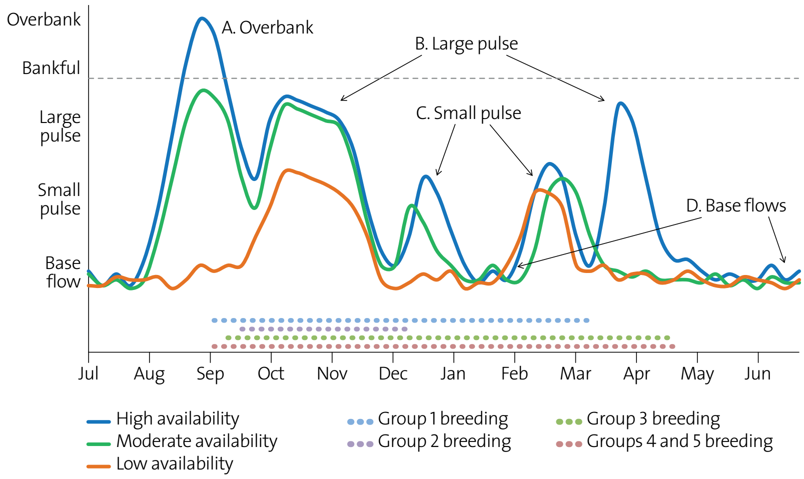


Figure 3. Conceptual flow hydrographs for three water availability scenarios (high, moderate and low) and breeding season windows for each functional group of southern MDB fishes (dotted lines) that are shown on the opposite page. This diagram has a far more detailed explanation which is available on the Finterest website (finterest.com.au).

These groups of fish all rely on water and flows, but respond differently to various parts of the flow regime (see title page image). We want to improve our understanding of how the magnitude (both volume and height), frequency and duration of different flow events influence each group. This will allow water management strategies to be fine-tuned over time to achieve outcomes for specific functional groups.

In addition, we want to discover the thresholds required to maintain populations during drier times. We hope this understanding will enable us to improve their condition during wetter periods and refine our capacity to achieve outcomes under various water management scenarios.

As part of the 'Fish and Flows' projects, conceptual hydrographs were developed. These describe specific elements of flows needed to support the spawning, recruitment, maintenance and condition needs of each of the fish functional groups (Figure 3). Fish have adapted to historical flow patterns, so the hydrographs consider the natural variation in flow magnitude, seasonal timing, and duration for a system. It is expected that these generic hydrographs will be adjusted by water managers to suit different locations across the Basin in the design and prioritisation of watering actions.

While water is the most important element to keep fish alive, fish cannot live on flows alone. We can achieve greater outcomes from environmental water by undertaking parallel complementary actions including: improving fish habitat through re-snagging, restoring instream and riverbank revegetation, fixing fish passage, screening pumps and diversions, and controlling invasive species. Flow management and complementary actions working in parallel will support bringing native fish back into a healthy working Basin, and will increase the potential to achieve long-term social and environmental outcomes through water management.

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Fish friendly suburbs

MANAGING WATERWAYS AND NATIVE FISH POPULATIONS IN URBAN ENVIRONMENTS PRESENTS A SUITE OF CHALLENGES. **ANDREW NORRIS** SHARES A STORY FROM QUEENSLAND THAT IS SUCCESSFUL FOR FISH AND PEOPLE ALIKE.

Establishing a healthy riparian zone with all of its essential ecosystem services in an urban area is challenging. In rural zones riparian habitat is frequently improved through stock exclusion fencing, off-stream watering points, weed management and replanting of native species. In urban areas, however, numerous small properties often border the waterways, and landowners are frequently reluctant to use their valuable waterside land for riparian vegetation. Additionally, footpaths, roads, community parks and picnic areas further limit the potential extent and width of the riparian zone.

The section of Myall Creek passing through Dalby in southern Queensland, typifies many inland urban creeks. Edward Street Weir was constructed to provide a permanent pool of water, with the streambanks a mixture of private residences, roads, parklands and walking trails. A significant proportion of the bankside land is managed by the Western Downs Regional Council (WDRC) as parkland, and this is where our activities were focused.

The fish assemblage in Myall Creek was limited in abundance and diversity, as was the instream habitat and riparian vegetation. In 2013, a restoration project commenced as part of the Dewfish Demonstration Reach, to restore the native fish populations and aquatic health in this section of Myall Creek.

Initial intervention activities targeted improving stream geomorphology and bottom roughness. Dredging and the introduction of snags and boulders created a variety of depth contours and standing structure into an otherwise relatively homogenous stretch of creek. The structural enhancement primarily benefited larger fish species, and the response from Golden perch and Murray cod populations was positive. Unfortunately, a number of blackwater fish kills and lack of flow impacted these species and confounded results.

Little response was observed in the numbers of smaller-bodied native fish following these intervention activities, with the lack of aquatic and bankside vegetation identified as the likely limiting factor. Our research team talked to WDRC about how such vegetation could be improved by leaving an unmown buffer strip along the water's edge. This approach would enable the vegetation to overhang and grow out into the water, while having minimal impact on the amenity of the adjacent parklands. There was no cost to implement the buffer zone, and it could potentially reduce the labour involved in the maintenance of the parks.

In conjunction with the unmown buffer zone, students from Our Lady of the Southern Cross College in Dalby propagated a number of important aquatic and riparian plant species which were then planted in a degraded area of Myall Creek.

Myall Creek before (inset) and after the intervention activities. Photos courtesy of the author.

Since the buffer zone was implemented there have been significant, ongoing improvements in the quantity and variety of aquatic vegetation in Myall Creek. Leaving a 1 metre unmown buffer has resulted in bank side grasses, sedges and other low vegetation becoming much more prominent. Water primrose became far more plentiful at the site, extending into the water and providing excellent fish habitat.

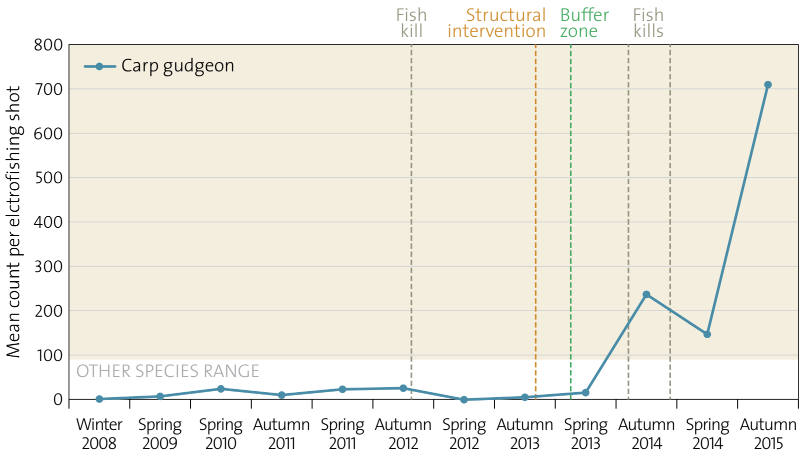
In the unmown buffer there has also been a 10-fold increase in the number of native tree saplings appearing, compared to when the area was mown to the water's edge. This natural regeneration eliminates the need for trees to be planted. As they grow the trees will help bind and stabilise the banks, providing natural structural complexity to the waterway.

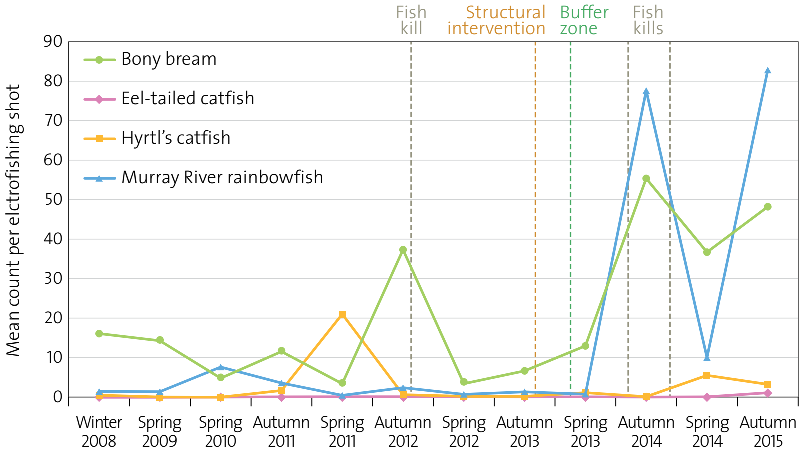
The cumulative impact of the intervention activities has seen significant improvements in the condition of both the fish assemblage and habitat, with the riverbank trending towards those seen at more pristine sites.

The improvement in aquatic vegetation has improved native species richness, with significant increases in the abundance of carp gudgeon, Bony bream, Murray River rainbowfish, Eel-tailed (or Freshwater) catfish and Hyrtl's catfish (Figures 1–2). Since the vegetation has returned, the number of carp gudgeons is now similar to the pristine Durah Creek reference site, and the abundance of Murray River rainbowfish and Bony bream is considerably higher. Both catfish species are using the aquatic vegetation, and there is evidence of successful recruitment occurring for the first time. The growth of aquatic vegetation also helped smaller native fish better survive blackwater fish kills. Carp gudgeons appear to be a key indicator species for the health of smaller waterways. Tributary sites with good habitat typically have very high numbers of this species, while they are less common where the habitat is poor.

The improvements in habitat and the fish assembly resulting from changes in land management practice at Myall Creek have the potential to be replicated at other urbanised sections of waterway. This project provides an ideal demonstration of how taking time to have a conversation, and finding simple changes to the way things are done, can result in great benefits to aquatic ecosystems with little or no impact for nearby residents.

... of local finterest





Figures 1–2: The abundance of carp gudgeon (top) and other small native fish (below) before and after establishment of the bankside buffer zone.

Natural gum tree regeneration in the buffer zone.

ACKNOWLEDGEMENTS

Major funding has been provided by Arrow Energy, Murray–Darling Basin Authority, Queensland Department of Agriculture and Fisheries and Condamine Alliance. The Western Downs Regional Council are also commended for their role in the project.

FOR FURTHER INFORMATION

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Buffering BUMPY RIVERS

GREG RINGWOOD ENCOURAGES US TO ACCEPT FLOODS, BUT USE RIPARIAN VEGETATION TO 'BUFFER' THE BUMPS.

Healthy riparian zones are great for fish, yet sometimes the task of restoring our degraded river edges places fish managers at odds with land managers. Recent research following the south-east Queensland floods of 2013 shows, however, that a good riparian zone is not only good for fish, but extremely valuable for farmers.

The Condamine River has experienced five large flood events in recent years causing localised and widespread damage. The 2013 event was so severe that a flood recovery program was funded by the Queensland and Australian Governments through natural disaster relief and recovery arrangements. The program aimed to restore agricultural productivity and build resilience against future extreme and 'bumpy' weather events.

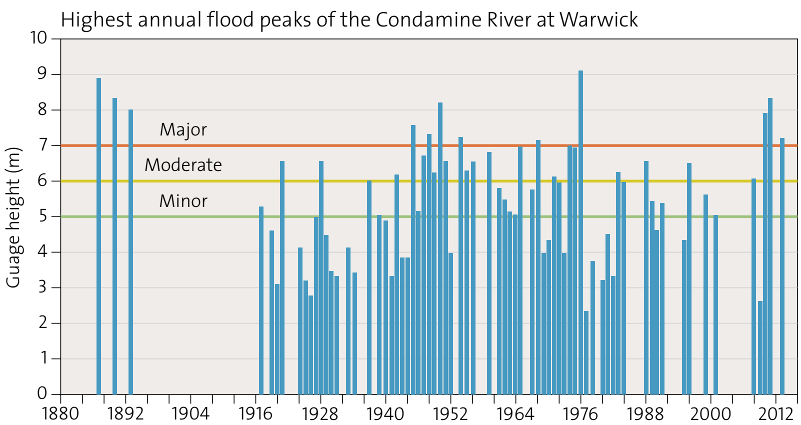
The 2013 flood was due to a major rainfall event that dumped 1000 millimetres of rain in 72 hours across the Glengallen and Swan Creeks' floodplain. This area has experienced flooding on a regular basis, with major events occurring on average once every decade. Long-term landholders said:

> "Higher floods occurred in the 1950s and 1970s than the 2011 and 2013 events. The recent floods were angry, particularly the 2013 flood … never heard anything like it, the speed of the water was so fast and the damage was much worse this time."

Lost productivity and estimated damage

It was visually evident that high-water velocities had caused extensive erosion along creeks, waterways and across the floodplain, with many landholders losing up to 500 millimetres of topsoil. The Queensland Reconstruction Authority estimated that tropical cyclone Oswald caused $2.4 billion worth of damage across 90 Queensland towns and 6500 homes, including the Condamine catchment.

Specialists in soil conservation, agronomy and river restoration evaluated the flood damage and recommended activities to restore productivity and build reliance against future events. This specialist group worked with landholders to estimate productivity losses and damages.



River height data for the Condamine River supports landholder's view that previous floods were higher.

KEY MESSAGES

Water is not the enemy, it is water velocity that causes the damage.

Riparian vegetation provides individual and cumulative benefits to landholders upstream and downstream.

Australian rivers are meant to be rough and bumpy.

Opposite: Limited erosion occurred because of some riparian vegetation and good groundcover. Above: This is the same creek but the next bend downstream where the creek bank has suffered greater erosion due to excess water velocity and limited riparian cover.

Productivity losses and damages

The value of lost productivity and damage were estimated and collected in a consistent manner across the program:

- crop loss with a dollar value per hectare,
- percentage per hectare of reduced productivity for up to five years,
- cost of stored feed and grain lost,
- cost value per cubic metre of soil moved to repair flood damage,
- amount of nutrients per hectare for up to five years, required to restore soil productivity,
- cost per kilometre of fencing replaced,
- cost of debris clean up, and
- cost per kilometre of riparian restoration.

The results also showed there was a cumulative cost to the local community.

Water velocity, damage and lost productivity

Historically, water took **1 day** to travel from Killarney to Warwick. Now it takes **12 hours** due to land-use change and flood mitigation measures. Recent work in the area showed erosion starts at 0.4 metres per second squared ($m.s^{-2}$) on local soil types and, unfortunately, water velocities were modelled to reach 4 $m.s^{-2}$ in the creeks and 2 $m.s^{-2}$ across the floodplain during the 2013 flood event. As a consequence, erosion damage was high.

Interestingly, there were a number of properties on the floodplain where the estimated cost of damage and lost productivity was much lower than the rest. The common factor was that each had riparian vegetation in reasonable to good condition. The three properties with a mix of trees, shrubs and grasses in their riparian zone vegetation were assessed to have suffered around **two thirds** less damage compared with the average across the whole program.

Average approximate cost per:	Whole program	Three floodplain properties with riparian vegetation
Hectare	≈$700	≈$210
Kilometre of creek bank	≈$50,000+	≈$13,300

Estimated lost productivity and flood damage

Riparian vegetation played an important role in reducing the water velocity along the waterways as well as slowing down the water entering and exiting the floodplain.

This study clearly indicates that good riparian zones are extremely valuable to farmers and that, with their value to fish well-known, maybe it is time for a large-scale program to support farmers in restoring their creeks and river frontages. This would be timely, as with more intense flood events predicted due to climate change, current and past waterway and riparian management actions (often for flood mitigation) are costing landholders, primary productivity and regional communities' money. A formal study is warranted to gain a complete economic value of individual and cumulative flood damage for various levels of riparian vegetation (flood mitigation management activities). In the meantime though, the message is clear, good riparian vegetation makes good environmental and economic sense.

WHAT SNAG IS THAT?

I WAS STANDING AROUND A BARBEQUE WITH SOME FISH BIOLOGISTS WHEN ONE OF THEM REMARKED, "VIC, WE'VE BEEN ELECTROFISHING THIS STRETCH OF THE MURRAY FOR A FEW YEARS NOW, AND WE ALWAYS CATCH THE SAME SPECIES AT THE SAME SNAGS. WHY WOULD THAT BE?" THUS BEGAN VIC HUGHES' PhD JOURNEY.

Now, life for a river fish is just one long upstream swim. Which is at least one reason why snags [instream woody habitat] are so important to native fish in the River Murray. Fish are almost always found at snags which they use as shelter from the constant flow of the river [hydraulic refuge]. My thinking was that different snags might provide different hydraulic conditions, and that might be why different fish favoured particular snags.

With this as my hypothesis, I set out to study hydraulic conditions around snags, particularly how they change between snags of different physical character, and river discharges. My study was in the Yarrawonga to Tocumwal reach of the River Murray, one of the few which has largely undisturbed natural snags. I looked at 90 snags of differing physical complexity, at five different river discharges. There are three components of instream flows:

1. flow direction,
2. horizontal velocity component (i.e. the speed at which the water is flowing in that direction,
3. a vertical velocity component (the speed at which the water is flowing up or down relative to the horizontal).

I measured these three hydraulic conditions with an acoustic doppler profiler (ADP). The ADP provided measurements in 25 centimetre depth cells through the water column to produce a velocity profile—a three-dimensional 'picture' of flow through the water column. I recorded about 50 profiles at each snag (and at each discharge) and summarised the data. This gave a 'snag scale' picture of hydraulic habitat.

So, what did I find? At very low river discharge (base flow of 2000 megalitres per day), there were no significant differences in hydraulic conditions between simple and complex snags. As discharge increased, however, the differences became apparent. They were maximised at the highest discharge measured (15,000 megalitres per day), where 11 out of 19 hydraulic variables showed differences.

These variables provide some insight into the different hydraulic complexity of snags, for example, while the mean horizontal velocity was higher at very simple snags (single logs parallel to the flow), it did not show a lot of difference between other, more complex snags. Variability of velocity did, however, increase with snag complexity, meaning complex snags had more areas of low velocity than simple snags. This is shown in their more positively skewed distribution of velocities (Figure 1).

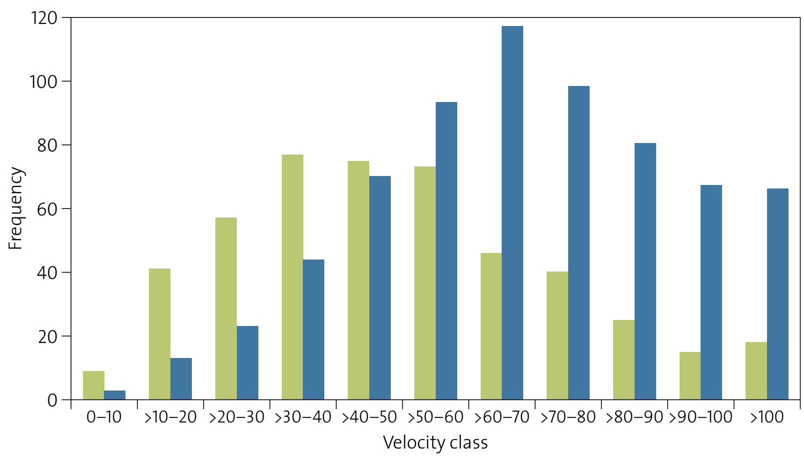


Figure 1 shows the distribution of velocities at a complex and a simple snag. The complex snag (green) has a positively-skewed distribution and more areas with lower velocities than the simple snag (blue). In so doing, it provides more hydraulic refuge for fish.

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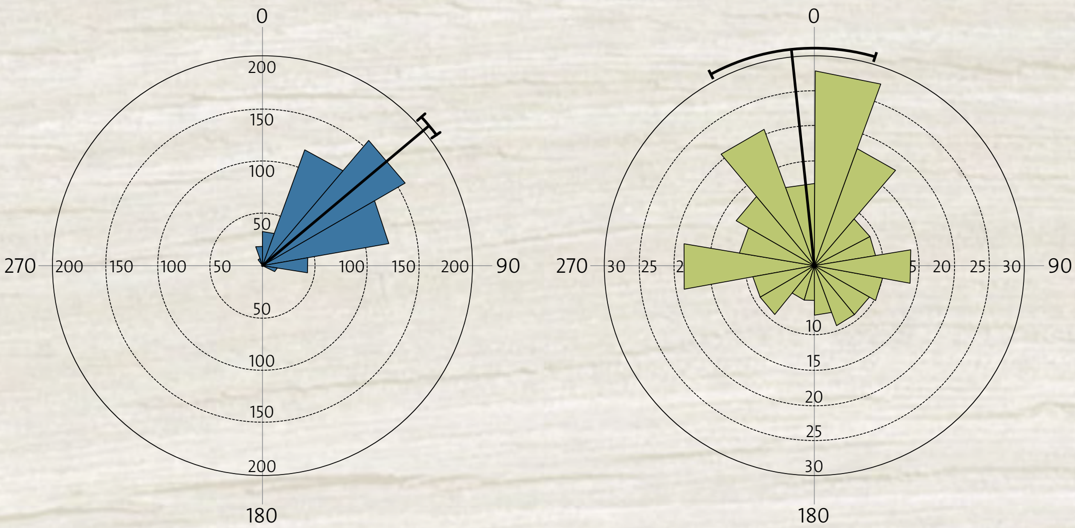

Figure 2: Variability of flow direction at simple (left) and complex (right). Discharge is 15,000 megalitres per day. The solid black line shows the mean flow direction, and the coloured segments show how many flows are going in other directions.

Opposite: Vic Hughes in a snag pile recording details of the snags.

Something else that varied between simple and complex snags was the variability of flow direction. We can show this with a circular histogram, which depicts how many flows are going in different directions. Figure 2 illustrates a simple and a complex snag.

The simple snag has most flows concentrated in a 90-degree arc close to the mean flow direction. The complex snag has flows going to all points. While a fish can't read a histogram (!), it can use areas where the flow is not going downstream to help it maintain stream position with minimal energy use. These findings show how hydraulic conditions vary between different snags at the same (high) discharge.

I also looked at how conditions changed between low to high discharges, and found some broad general trends. Unsurprisingly, mean and maximum velocities increased as discharge did, but they increased more at simple snags than at complex ones. Variability of horizontal velocity decreased as discharge increased, and velocity distribution became less positively skewed (meaning fewer areas of low velocity for fish refuge). Variability of flow direction also declined, again suggesting less hydraulic refuge for fish.

A 'snag rich' stretch of the Murray. Photo Vic Hughes.

Do these hydraulic differences make any difference to fish?

My work found that fish were more abundant at large instream wood that was physically and hydraulically more complex, and which had lower average horizontal velocities. I also investigated whether there was any relationship between different hydraulic conditions and the type of fish recorded at snags. This work is ongoing but some preliminary results that show Trout cod are associated with faster flowing water, both in horizontal and vertical directions.

I have only briefly touched on the results of this study, and once my data is fully analysed I will let you know more results through the Finterest website (finterest.com.au) and other 'fishy' publications. In the meantime, there are a couple of take home messages I would like to leave you with:

1. Snags aren't just snags—they vary hugely in their complexity and in the hydraulic habitat they provide.
2. For a fish trying to maintain stream position with minimal energy expenditure, there is much more to hydraulic habitat than simply the average flow speed at a snag.

These points are important for anyone re-snagging rivers. Ideally, we want complex snag piles because putting in single, simple snags is unlikely to provide the hydraulic diversity that is useful for fish habitat.

BARKINDJI RANGER PROJECTS

THE **BARKINDJI MARAURA ELDERS ENVIRONMENT TEAM** (BMEET) ARE WORKING TO IMPROVE FISH HABITAT IN WESTERN NEW SOUTH WALES. IN PARTNERSHIP WITH THE **MURRAY-DARLING FRESHWATER RESEARCH CENTRE** (MDFRC), THE TEAM IS INVOLVED IN VARIOUS PROJECTS THAT ARE BRINGING TOGETHER SCIENCE AND CULTURAL KNOWLEDGE.

Colin Andrews, Dennis King and Ernest Mitchell preparing a fish hotel for installation and recording GPS location in Thegoa Lagoon. Photo Danielle Linklater.

The BMEET River Rangers are becoming experts at building hotels for fish! As part of a long term project to re-install fish habitats into rivers and wetlands on traditional Barkindji country, several different designs are being built, with each being monitored to see which fish species are using the new 'real estate'. The larger structures that have been placed in the lower Darling River are designed for Murray cod and Golden perch, and smaller ones in Thegoa Lagoon (near Wentworth) will hopefully provide good habitat for small-bodied species. This project was partly funded by the NSW Office of Environment and Heritage and the NSW Recreational Fishing Trust in 2015 with the Trust providing further funding in 2016 for the Rangers to install 20 more larger fish hotels in the lower Darling River.

Dr Wayne Robinson from Charles Sturt University is working with the Rangers to make sure the research and monitoring being used at Thegoa Lagoon and Fletchers Lake (north-east of Wentworth) is robust. This is important in ensuring that managers and other scientists can have confidence in results from the project.

The collaborative team are also trialling a new monitoring method to see if live scar trees respond to environmental water in the same way that non-scar trees do. Trees were initially surveyed at Thegoa Lagoon and Fletchers Lake Reserve in May 2015 with regular surveys due to start after that. There are many scar trees that were used for canoes, coolamons, shields and other culturally important reasons such as boundary markers. MDFRC staff have learnt a lot by doing these surveys with BMEET. This project combines cultural knowledge with Western techniques for monitoring tree health.

Another cultural science research project the Rangers and MDFRC are working on is called 'Earth Fire Water' which is based at Fletchers Creek (an ephemeral creek that, when flowing, empties into Fletchers Lake). This project looks at the impact of traditional burning and environmental water on the vegetation community along the creek line, with particular interest in the response of bush tucker plants. Small experimental trials, including seed bank studies and monitoring of environmental water at Fletchers Creek, have allowed the Rangers to understand a number of Western monitoring techniques.

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Above: Brendan Harris and Colin Andrews on Thegoa Lagoon with fish hotels and nets in the background. Photo Danielle Linklater.
Below: Colin Andrews and Dion Harris setting nets to monitor small fish movement into Thegoa Lagoon. Photo Deb Bogenhuber.

BMEET was formed by the Barkindji Maraura Elders Council to undertake environmental research in the lower Darling region. BMEET has an Aboriginal Board of Directors, nine Aboriginal staff and one non-Aboriginal staff member.

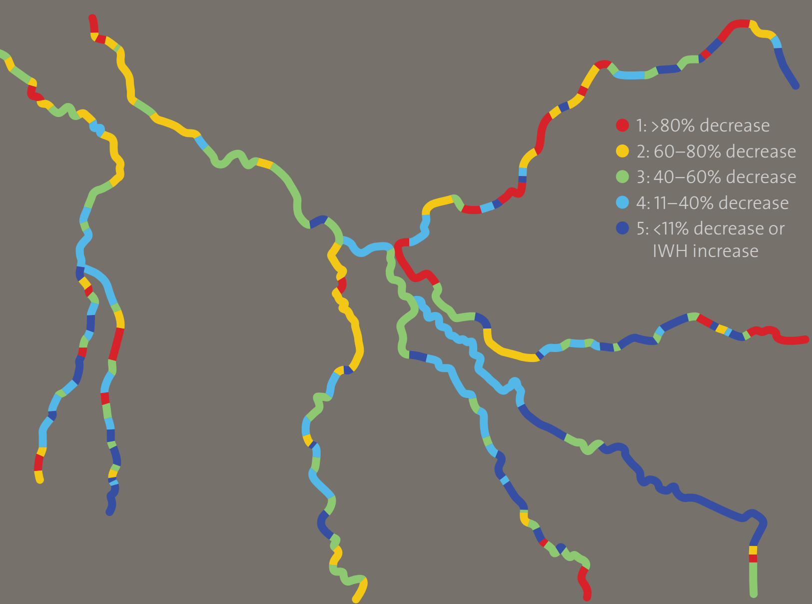
Funding partners are the Indigenous Advancement Strategy and La Trobe University. **Project partners** include NSW Office of Environment and Heritage, NSW DPI Water, NSW DPI, Murray-Darling Wetlands Working Group, Sunraysia Institute of TAFE, Charles Sturt University, NSW Recreational Fishing Trust, Wentworth Shire Council.

A range of finterests

IS WOOD GOOD FOR FISH?

PHOTO ZEB TONKIN.

RESTORATION EFFORTS ACROSS AUSTRALIA OFTEN INCLUDE THE REINTRODUCTION OF INSTREAM WOODY HABITAT, BUT ARE WE RIGHT TO INVEST IN THESE OFTEN COSTLY PROJECTS? **ZEB TONKIN** AND **JAROD LYON** REPORT ON RECENT MONITORING RESULTS THAT ANSWER THIS QUESTION.



Current condition of instream woody habitat as indicated by the percentage change from predicted pre-European levels in a 5 kilometre section of the 28,000 kilometres of stream links in Victoria. From Tonkin et al. 2016.

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Instream woody habitat (IWH or snags) are highly valued because of their contribution to catchment health, biodiversity and supporting self-sustaining fish populations, as well as providing a range of structural, chemical and ecological functions essential in maintaining riverine ecosystems. A vast amount of research has demonstrated positive associations between IWH and riverine fish populations, including:

- primary production processes of carbon input and nutrient cycling,
- local and reach scale hydraulics creating river features such as pools and riffles,
- fish habitat, homes, refuges and food,
- cover from predators, including birds, bigger fish, and
- spawning habitat, for example, the Murray cod lays eggs on or in large hollow logs.

There are often misguided community perceptions about the negative consequences of IWH on flooding, navigation and erosion, and this has led to extensive riparian clearing and the removal of large quantities of IWH from rivers across Australia. A recent investigation of IWH distribution and condition (as compared to estimates of pre-European loads) was conducted for approximately 28,000 kilometres of streams across Victoria. This work showed that Victorian streams currently have IWH volumes, on average, 41 per cent lower than pre-European loads, with 30 per cent of river reaches estimated to have more than 80 per cent reductions.

These reductions have dramatically altered how Victoria's rivers function, and have resulted in increased flow velocities, channel enlargement, and loss of critical habitat. Such changes are major contributing factors to declines in riverine health and the subsequent decline of native fish populations.

Instream habitat restoration success across regional and local scales

Fortunately, there is increasing interest and investment in river restoration programs to help improve instream habitat and fish populations. Many of these programs involve the re-introduction of IWH, with accompanying riparian zone revegetation to encourage long-term natural IWH input. Monitoring programs assessing these instream rehabilitation efforts are starting to demonstrate the benefits of these management actions to local fish populations.

CASE STUDY 1: THE MURRAY RIVER RESNAGGING EXPERIMENT

Perhaps the largest IWH restoration (and subsequent monitoring) program of its kind in Australia is the 'Murray River Resnagging' project. The Murray–Darling Basin Authority's 'The Living Murray' program has made efforts to alleviate historical degradation of IWH by 'resnagging' a 194 kilometre reach of the Murray River between Lake Hume and Lake Mulwala, with 4450 woody habitats installed along the river reach (less than 1 tonne each).

A seven-year research and monitoring program (2007–13) was undertaken by the Arthur Rylah Institute to quantify the benefits of the restoration efforts by investigating the population responses of four iconic large-bodied native species, Murray cod, Trout cod, Golden perch and Silver perch. The program's monitoring strategy estimated the annual changes in the population size of each of these four native species within the restored reach, and compared these results to two reference reaches where no restoration was undertaken.

Target species fish were caught, with those tagged at the start of the program captured and assessed through annual boat electrofishing surveys. This data was complemented with measures to determine the age structure and biomass of the fish populations; fish movements from about 1400 radio-tagged fish; and fish survival rates.

Annual changes in population size for each of the species in the target river reaches were then assessed by combining the different types of data collected. This technique enabled researchers to:

- account for migration into, and out of the different study reaches,
- investigate differences in capture rates (which is how difficult it was to capture each fish species in each year), and
- investigate temporary movements between study reaches and estimate fish survival.

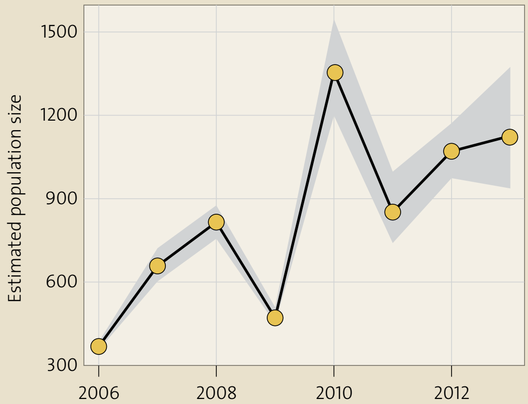
Results of the monitoring study showed a three-fold increase in the Murray cod population size following the large-scale IWH works. This increase was due to both greater survival of juvenile fish, as well as immigration from outside the reach. This activity did not occur in the reference reaches.

Another part of the project was a research angler program which started in July 2007. This program encouraged local fishers to become involved by collecting information such as catch rates, as well as taking otoliths to age fish.

A total of 55 anglers were involved and collected data from 5465 fish. These results showed greater Murray cod numbers in the resnagged reach, with catch per 'unit of effort' increasing between 2007 and 2011.

Unfortunately, the same increase in population size was not detected for other species, including Trout cod. This is likely due to the limited connectivity with source populations which are found downstream of Lake Mulwala.

This study has shown that large-scale river restoration efforts enhance native fish populations which, in turn, provides ecological and recreational fishing benefits within the Murray River. Importantly, the study also increased community awareness by building knowledge around the importance of healthy habitat for native fish and river health.



Estimated population size of Murray cod between 2006 and 2013 within the restoration reach. Grey shading represents a measure of the reliability of this estimate.

Instream woody habitat works being conducted in the Murray River. Photo Martin Casey.

CASE STUDY 2: ENHANCING HABITAT VALUES IN THE UPPER GOULBURN CATCHMENT

While the Murray River resnagging project has demonstrated the benefits of large-scale river rehabilitation, smaller localised programs can also deliver benefits to fish populations. Between 2000 and 2008, the Goulburn Broken Catchment Management Authority conducted habitat enhancement works at several sites in the Goulburn, Delatite, Rubicon and Acheron Rivers, aimed primarily to benefit local trout populations. These on-ground works were funded largely by Victorian recreational fishing licence fees and involved:

- installing lunkers (artificial habitats constructed of wood and rock to replicate undercut banks),
- constructing deflecting rock groynes,
- boulder seeding (large boulders placed in the river), and
- stabilising banks and reinstating IWH.

Surveys conducted by Fisheries Victoria confirmed that fish were using these new habitats shortly after construction.

With up to 10 years having passed since the instream habitat enhancement, questions were being asked as to whether these works continue to provide benefits for fish?

In 2015, the Arthur Rylah Institute followed up with surveys of habitat condition and fish occupancy at each of the habitat enhancement sites, as well as at several control sites (sites where no habitat enhancement was undertaken) for comparison. Results indicated significantly greater abundance and biomass of fish at habitat enhancement sites compared to control sites. At a species level, researchers reported such benefits were not only evident for the target species, Brown trout, but also native Two-spined blackfish!


Two-spined blackfish were a dominant species using instream habitat enhancement sites in the Delatite and Rubicon Rivers. Photo Joanne Kearns.


Murray cod numbers and biomass increased in the Murray River following the large-scale instream woody habitat restoration efforts. Photo Jarod Lyon.

Where to from here?

Studies such as these provide waterway managers with a solid foundation upon which to undertake further IWH reintroductions. They demonstrate that instream habitat restoration can enhance fish populations, as well as having multiple ecological and recreational fishing benefits.

There is, however, still much to learn about how best to undertake such interventions. Unfortunately, rehabilitating IWH at the landscape scales over which it has been degraded is rarely feasible. Woody structure for use as IWH is often scarce and, along with the high cost of installation, restricts the extent of restoration efforts.

Any investment in restoration activities must, therefore, be carefully planned to preserve as many river ecosystem processes as possible, to link strategic ecosystems and, ultimately, result in catchment-scale reversal of declines in diversity and abundance of aquatic organisms. This approach works best when based on knowledge about fish species and IWH requirements, so that specific ecological objectives can be focused upon for a given river reach.

A Victorian statewide instream habitat research project is currently underway to help address such needs. Specifically, the project team are investigating the relationship between IWH attributes (and other environmental variables) and fish populations across Victoria. This will ultimately allow quantitative estimates of the IWH levels required to maximise the benefits for particular fish species in a specific river reach.

Community engagement

Instream habitat rehabilitation also offers opportunities to engage different community groups toward a common goal of restoring fish habitat. Community ownership and partnerships are critical, and successful restoration program are those that have actively engaged multiple stakeholders in building knowledge and support around the importance of healthy habitat for fish and river health. We now see groups such recreational fishers, Landcare, Waterwatch and Estuarywatch advocating for healthier fish habitats, and we are working with these organisations and government agencies to protect and rehabilitate our waterways.

Continuing to foster such links between community groups, waterway managers, policy and fisheries agencies is vital to gain the support needed for ongoing investment into waterway rehabilitation activities, community participation and long-term advocacy.

Seeking refuge at watering holes

HOW IMPORTANT ARE OUR WATERHOLES IN PROVIDING REFUGE DURING EXTENDED DRY PERIODS? **JONATHAN MARSHALL** SHARES THE RESULTS OF RESEARCH INTO WATERHOLE LOCATION AND PERSISTENCE IN OUR NORTHERN BASIN RIVERS.

In finalising the Basin Plan, the Murray–Darling Basin Authority (MDBA) agreed to do further research in the northern Basin as part of a Northern Basin Review. The review encompasses the northern Basin region as a whole, with a focus on the Condamine–Balonne and Barwon–Darling catchments for environmental science projects. The MDBA engaged Queensland and New South Wales government agencies to undertake scientific studies to inform this review.

The 'Waterhole location and persistence' project focused on how long waterholes in the study area last without flow. This research also examined how the spatial distribution of persistent waterholes changes as a drought progresses.

Australia's dryland rivers exist in an environment characterised by long periods without significant flows of water. During these periods, rivers dry into a series of waterholes, which are an important resource for agriculture, town water supplies and industry. They also serve an important ecological role by providing drought refuge for aquatic organisms, such as native fish. The length of time waterholes are able to hold water after flow ceases (the persistence time) is an important determinant of how long they can function as drought refuges for aquatic organisms (see Figure 1).

Waterholes that retain water for extended dry periods, and are persistent in the landscape, are often the most valuable. Persistent refuge waterholes need to be numerous enough, and distributed along river channels so that when they are connected during flow events, fish and other aquatic organisms are able to move through the system and recolonise other parts of the river (Figure 2).

Our work studied the location and persistence of waterholes in the Lower Balonne and the Barwon–Darling regions. We focused on the Culgoa and Narran rivers in the Lower Balonne, and the entire length of the Barwon–Darling River. The project used a number of research techniques including:

1. Time-series of LANDSAT satellite images from 1988 to 2015 to detect water within the river channels during periods of no flow to generate maps of where water was located after periods of drying.
2. Depth loggers to monitor water loss from waterholes. This was combined with depth mapping to generate water loss models that predict persistence times for 27 representative waterholes.
3. Water samples to check for chemical indicators of groundwater input.
4. Sediment probing and analysis of sediment cores collected from waterholes to give a general understanding of sediment accumulation rates within the regions.

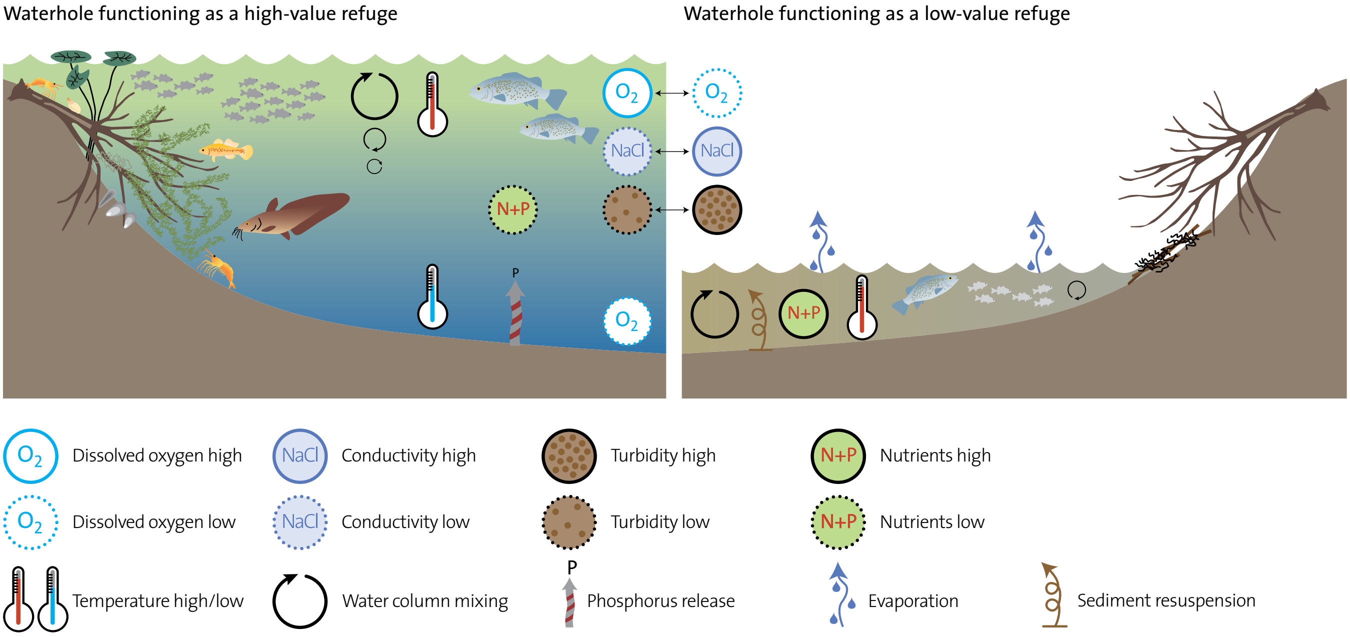


Figure 1. Function of waterholes as refuges. On the left is high-value refuge and on the right is low-value refuge.

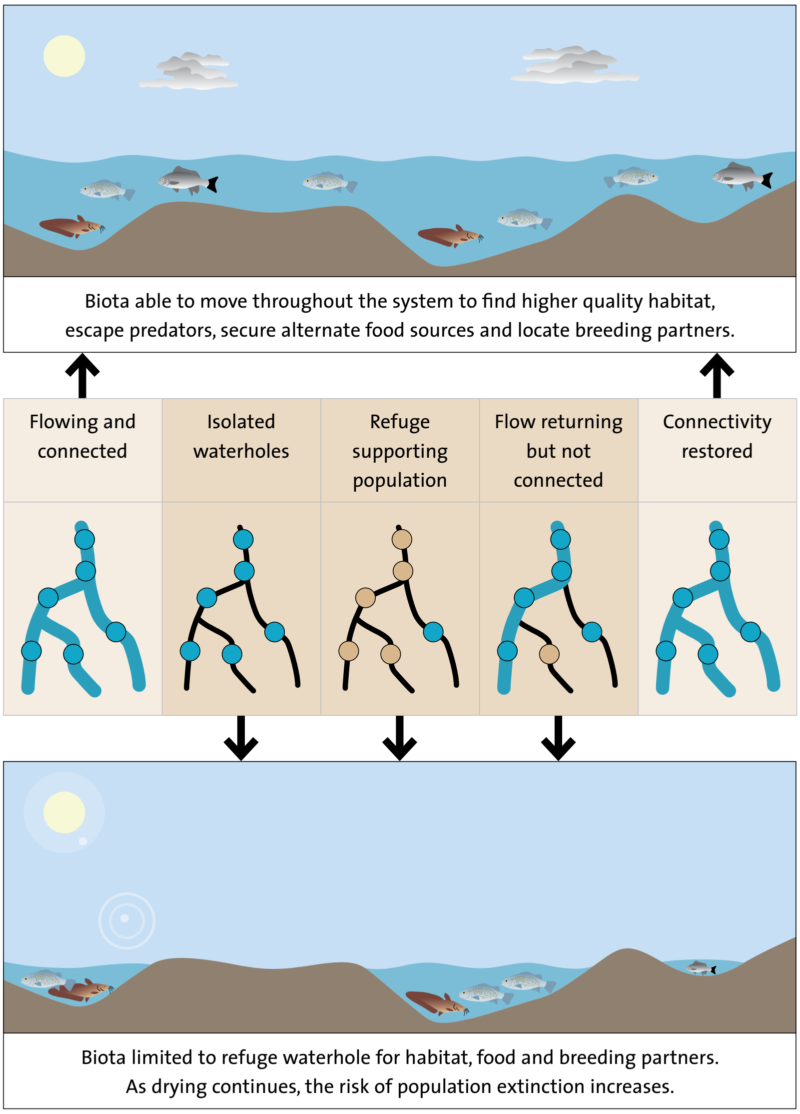


Figure 2. Spatial distribution of waterholes is key to patterns of connectivity. This is crucial to a functioning refuge; the refuge must connect back to the system in order for the biota to redistribute and 'bounce back' after a drought.

What we found

Over the last 28 years, the Culgoa and Narran Rivers had longer no-flow spells, lasting from about a year to one-and-half years, and these spells occurred more often when compared to the Barwon–Darling. No-flow spells in the Barwon–Darling were never longer than one year, and generally less than half-a-year.

We examined the data from the flow record to a LANDSAT (satellite) image database and collated a comprehensive list of images representing no-flow spells of various lengths. We found that across these three river valleys, periods of no flow tended to last about 350 days naturally (i.e. before water resource development). We considered this to be a 'threshold', which represents the level of drought stress the system would naturally tolerate. Waterholes that last longer than 350 days with no flow were therefore defined as refuge.

During the period covered by satellite imagery, some sections of the Lower Balonne region did not experience no-flow spells that were longer than a year. As such, the mapping technique could not identify refuge waterholes for these sections of the rivers. For most of the region, however, there were no-flow spells of at least one year, and the satellite image analysis identified 10 refuge waterholes that retained water after one year without flow (see Figure 3).

Figure 3. The location of refuge waterholes mapped in the Lower Balonne. Waterhole sizes are not to scale.

Some droughts during the 28 years of the satellite era resulted in periods of no flow for longer than a year. Analysis of the satellite imagery over the 28 years showed that only five of the 10 refuge waterholes permanently held water. The other five dried out for at least some of the time.

This information is incredibly important for conserving populations of aquatic biota, as these refuge waterholes can be targeted by managers to ensure they continue to fulfil their vital ecological role. In contrast to the Lower Balonne, we found that most waterholes in the Barwon–Darling persisted for every no-flow spell over the 28-year period.

To further understand waterhole persistence, we chose sites throughout the Culgoa and Narran rivers to represent a range of waterholes covering different sizes, locations, with a mix of weir pools and natural waterholes. Sites were generally less than 3 metres deep.

In combination with the depth loss data specifically collected for each waterhole, we created and calibrated 27 individual water loss models. These models simulated that the waterholes in the Culgoa River have minimum persistence times of 236 to 587 days (with an average of 377 days) and the Narran River valley waterholes have minimum persistence times of 165 to 637 days (the average being 355 days). This means that waterholes in the Lower Balonne will generally persist without flow for about a year.

The representative waterholes we selected included a majority of locations that were identified as lasting more than 350 days with the mapping technique. Our investigation into the influence of groundwater on waterhole persistence also found that there was little groundwater input or loss to affect persistence time at these sites.

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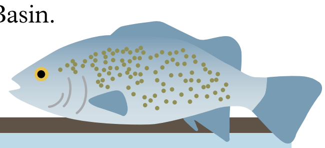
Our persistence modelling also showed there was a strong relationship between water depth in a waterhole and its modelled persistence time. Because depth is a very good predictor of persistence in the Lower Balonne, this information can be used to predict the persistence of any waterhole in the region with a single depth measurement. The relationship indicates that for every 1 metre of depth, the waterhole lasts roughly 170 days. So … to last for one year, a waterhole needs to be at least 2 metres deep when flow stops.

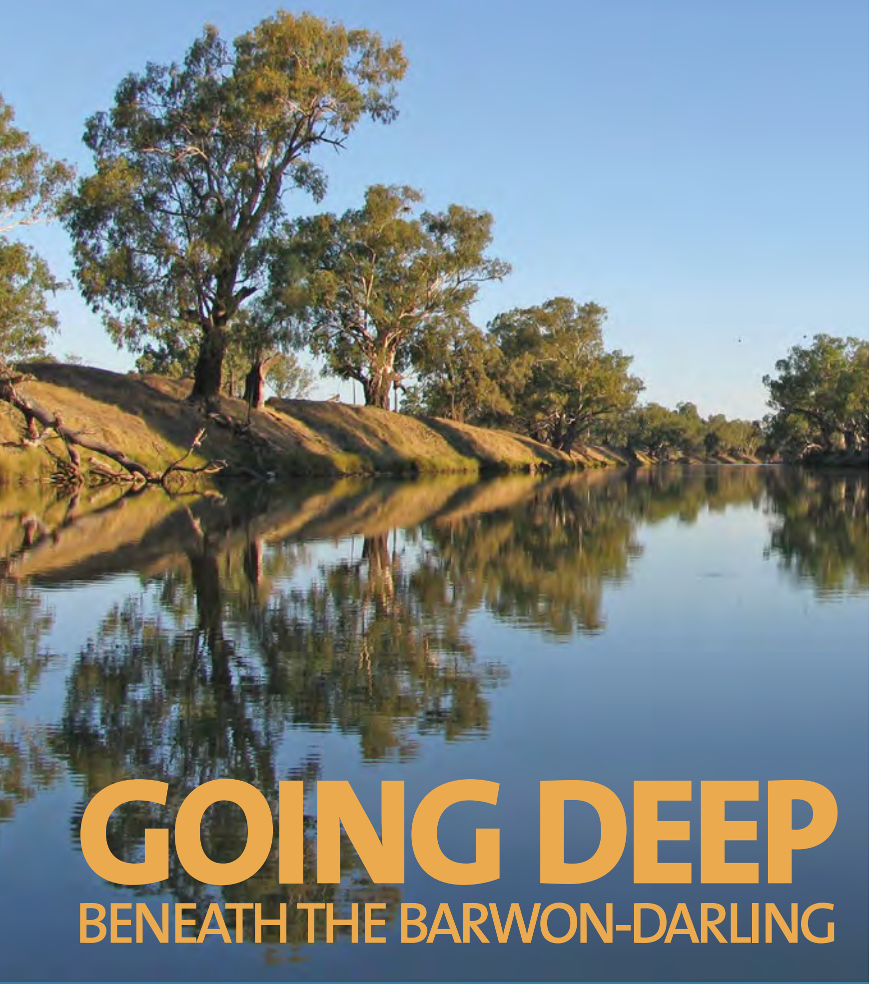
Waterholes in the Barwon–Darling were generally much deeper than those in the Lower Balonne, with some measuring up to 8 metres. Most of these waterholes have also been deepened by weirs so they can retain water longer. Depth loss data was collected, but no-flow spells were too short to create specific water loss models. Using the general persistence relationship noted earlier, it is likely that waterholes in the Barwon–Darling would last more than 1000 days, and we are confident that there is a low risk of these waterholes drying up under typical seasonal conditions.

The knowledge generated through this project has given increased confidence about the environmental water requirements needed to ensure a range of waterholes persist during drought periods. We now know there is an increasing risk to populations of aquatic biota dependent on these waterholes if a no-flow spell lasts beyond a year, and that there is high risk if spells were to last longer than one-and-half years. This knowledge also has a broad range of applications for water resource management across the northern Basin.



To read the full report:
www.mdba.gov.au/publications

ACKNOWLEDGEMENTS
Queensland Department of Natural Resources and Mines, NSW Department of Primary Industries (Water), Alisa Starkey (Ozius Spatial) and Dr Harald Hofmann (University of Queensland) assisted with this work. Complete references for all collaborators, including the development of water loss and conceptual models, can be found in the full report.



GOING DEEP

BENEATH THE BARWON-DARLING

INNOVATIVE SCIENCE USED AS PART OF THE MURRAY–DARLING BASIN AUTHORITY'S NORTHERN BASIN REVIEW HAS HELPED US 'DEEPEN' OUR KNOWLEDGE OF THE BARWON-DARLING RIVER IN THE HOPE OF REVIVING THE HEALTH OF THIS ICONIC WATERWAY. **ANTHONY TOWNSEND** SHARES THE STORY.

An early morning wake-up call from the screeching cockatoos that soar above stirs the team into action. Before too long they're at the water's edge, the reflection of the day's first light stretching in both directions ready for another day of messing about in boats on the Barwon-Darling. This scene was repeated day in, day out over a period of eight weeks for NSW Department of Primary Industries Fisheries (NSW DPI Fisheries) staff as they turned the tight bends, floated down the long straights and, when possible, went with the flow of the majestic river.

Despite how it sounds, it wasn't all fun and games. The hard working duo of Rod Price and Matt Miles from NSW DPI Fisheries mapped all that they could, and couldn't see, during an epic 1100 kilometre journey of the mighty Barwon-Darling. The team can now reveal what lies beneath. From Walgett to Wilcannia, every nook and cranny that might appeal to native fish has been recorded, including favoured haunts of Murray cod and Golden perch.

Armed with the latest technology, including a handheld recording device with GPS and GIS interface to keep track of what they saw; a side scan sonar, or fish finder, to see below the water's surface, and; a piece of equipment akin to a speed gun known as a hypsometer, which detects the height of any targeted feature above the water level, the team captured:

- the number and complexity of snags (or large wood),
- the depth and area of pools, and
- the height and size of benches in the river channel.

The numbers provide a fascinating insight into the functioning of the Barwon-Darling River. Over 48,300 snags were recorded above and below the water's surface at an average of 43 snags per kilometre. This falls just below the suggested ideal snag loading for this part of the world of 47 snags per kilometre, suggesting that this important aquatic habitat feature is

functioning well in the Barwon-Darling. If we dig a little deeper into the data, however, it shows a severe lack of the complex snags that fish prefer. This type of wood only has a loading of 17 snags per kilometre, falling well below the ideal scenario and indicating there is still room for improvement to maximise the benefits large wood provides.

Large woody habitat is a major ecological and structural element of waterways, with the complex pieces of wood providing hiding and resting places for fish, as well as spawning sites and territorial markers for several native species. Snags also assist in developing scour pools, and prevent erosion by stabilising riverbanks. As instream wood breaks down, it also provides food for algae and bugs that form a large part of the food web for fish species small and large. Put simply, the more complex native timber that is inundated frequently in our waterways, the better it is for our native fish and the health of our river in general.

This reach of the Barwon-Darling River also contained 745 benches in the lower channel, covering a total area of 111 hectares. Benches are basically islands formed within a river channel. These features enhance the diversity of habitat, and influence flow variability within a waterway. Benches also store carbon and other nutrients, which are released to other parts of the river's ecosystem when inundated, playing an important role in food production for aquatic animals and helping to make fat, happy fish.

The number and size of potential refuge pools, defined for the project as areas of water that were greater than 3.5 metres deep during low-flow conditions, were highly variable across the project reach. A total of 1069 pools were recorded, providing a combined possible refuge area of 329 hectares. Aquatic habitat that persists during periods of 'no flow' or drought, is critical for the survival of native fish. The number, size, depth and interconnectedness of refuge pools affect the resilience of fish populations in arid river systems. The series of waterholes recorded in the Barwon-Darling indicates that fish will be able to naturally recolonise when flow returns to the system, and the habitat between refuge pools is inundated and connected.

The detailed data from the study provides critical information needed to guide future management and provide a benchmark for habitat change over time, guiding the prioritisation of habitat rehabilitation projects, and improving the ability to assess the benefits of using environmental water.

The inclusion of the hypsometer in the research team's arsenal also allowed for not just the height of important features to be captured, but flow levels that would inundate the features to be calculated. From this, we know for example, that a flow of 6000 megalitres per day at Bourke, makes half of the snags in the reach accessible to fish. This helps ensure that water can be managed appropriately for fish to interact with the habitat that makes the river, and the fish, healthy.

This information has been combined with knowledge of the Barwon-Darling River's fish community and the latest thinking of their flow needs (see article page 8) to develop site specific flow indicators along the Barwon-Darling. These indicators aim to improve the availability of habitat, provide connectivity up and down the river, increase primary productivity, deliver spawning and recruitment opportunities, and enhance fish condition. These targets can be used to inform future water management actions to help restore flows in the system, and the processes they support to bring back native fish to the Barwon-Darling.

OPPOSITE PAGE
Top: The expansive river reaches of the Barwon-Darling. Photo Adam Sluggett.
Map: The focus reach investigated as part of the project.
Below: Hypsometer in action. Photo Rod Price.

THIS PAGE
Above: Gravel bars and benches are an important feature in the Barwon-Darling channel. Photo Rod Price.
Square inset: Complex snags provide great homes for fish but were few and far between. Photo Rod Price.
Inset: New habitat information can be used to help bring back the iconic Murray cod. Photo Grant Gunthorpe.

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Ready, set, swim...

THERE ARE SOME GREAT NEW INITIATIVES UNDERWAY THAT COULD HELP OUR NATIVE FISH, HOWEVER, **CRAIG COPELAND** AND **JOHN KOEHN** REMIND US THAT SUCCESS WILL DEPEND ON OTHER ACTIONS.

Two bold, major programs to redress key longstanding threats to fishes are either underway or are proposed to commence. The federal and state governments, together with the Murray–Darling Basin Authority (MDBA) have secured important improvements in river flows through implementation of the *Basin Plan*. While much of the water to restore environmental flows has now been purchased, outcomes from ongoing research, management and monitoring will lead to continuous improvements in how water is delivered and the benefits achieved. A proposed biocontrol program to reduce carp populations will address another key threat (see article on page 66).

These combined actions may well be seen as the solutions our fish need, and will enable us to restore these native fish populations. We are not convinced this is the case.

Make no mistake, these interventions are historic, monumental and are to be applauded, but there are, unfortunately, many other threats to fish that are not adequately being addressed. These include barriers to fish passage, poor water quality, unscreened pumps and diversions, and the poor condition of instream habitat and riparian zones. Any one of these may have a causal role in preventing, delaying or reducing any recovery in native fish populations. For example, improving flows to enhance recruitment may not improve overall fish outcomes, without fixing barriers to passage that allow recruits to move to other areas.

We believe that if these other issues were addressed at the same time that water is being delivered and carp biocontrol is implemented, we will gain the outcomes we so desperately want to achieve for native fish.

Such a holistic approach is neither novel nor new, and planning for these actions has already been completed. Following the success of the first 10 years of the MDB Native Fish Strategy, a new forward plan was developed that received unanimous support from regional natural resource management groups, state agencies, the irrigation industry, the conservation movement and recreational fishers. Most key threats to native fishes have been recognised for many decades with priority actions viewed by scientists and recreational fishers alike as 'no brainers'. These are summarised in Table 1.

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Community 'ownership' is an essential element of all successful ecosystem restoration programs around the world. With the demise of funding for the MDB Native Fish Strategy a community capacity that had been created, is now diminished. Unlike the delivery of environmental water or carp biocontrol, where significant community roles are less critical, participation and ongoing public ownership are important for many other rehabilitation actions. A great example of what a community can achieve has been illustrated by the Condamine Alliance and their project the 'Dewfish Demonstration Reach'. The success of this initiative was recognised by the project winning the 2012 Australian River*prize*.

TABLE 1

Theme 1: Fish friendly infrastructure and water management	• Establish a Darling River fish passage program. • Address priority instream barriers to native fish migration. • Reduce injury and mortality from weirs and irrigation infrastructure (e.g. screening of pumps). • Restore variable-flow habitats. • Address cold water pollution. • Maximise the benefits of environmental water.
Theme 2: Connecting with communities	• Build demonstration reaches, where the community and multiple organisations undertake multiple restoration actions on a local river reach. • Build partnerships and a fish supporter base.
Theme 3: Protecting the icons of the Basin	• Continue recovery of the iconic Murray cod. • Protect threatened species. • Be ready to respond in emergency situations (e.g. drought, poor water quality). • Increase resnagging effort. • Maintain the Basin's estuary fish community. • Restore aquatic plant habitats.
Theme 4: Controlling alien fish species	• Carp control (Koi herpes and other actions). • Coordinate Basin-wide approaches to alien fish control. • Prevent invasion by tilapia.
Theme 5: Building, sharing and applying new knowledge	• Monitor native fish migrations. • Continue to gather, share and apply new knowledge.

The benefits of an expanded approach to restoring native fishes, building on efforts of the past, could be fantastic for the fish themselves, as well as providing social and economic drivers for rural communities of the Basin. Recreational fishing in the MDB currently provides over 10,950 jobs and contributes more than $1.3 billion expenditure annually to the economy. A restored fish community could herald a new era for regions in the Basin and be a major tourism drawcard for international tourists. More importantly, recent work in the United States has indicated that aquatic restoration work is an economic driver all of its own, with more people employed per dollar invested, than in the oil and gas, and construction sectors.

Regional communities care greatly about native fish and 'Bringing back native fish' is a theme people identify with and want to be a part of. Native fish have even greater significance and cultural value to Indigenous Australians.

A comprehensive program involving on-ground actions would recognise that local communities want to take part in actions that improve river health generally, and fish populations specifically.

With these actions funded at the same time as environmental water is being delivered through the *Basin Plan*, our communities would feel connected and a part of what is occurring along their rivers. Just imagine what could be achieved for fish with a lot more groups like Matt Hansen's (see page 48) working alongside river managers and scientists!

Environmental flows provided under the *Basin Plan* and the biocontrol of carp represent major opportunities and significant steps toward 'Bringing native fish back'. These programs will have the best chance of success if they actively involve an informed community and are embraced within a wider, holistic program of actions to rehabilitate native fish populations.

RESTORING FISH MIGRATION

THE SEA TO HUME FISHWAY PROGRAM WAS THE LARGEST FISH PASSAGE REHABILITATION PROJECT EVER UNDERTAKEN IN AUSTRALIA. IT INVOLVED CONSTRUCTING 16 WORLD-CLASS FISHWAYS, RESTORING MIGRATION OPTIONS TO OVER 2500 KILOMETRES OF THE MURRAY RIVER. **LEE BAUMGARTNER** EXPLAINS WHY THIS ACHIEVEMENT IS SO SIGNIFICANT AND HOW THIS PROGRAM WILL CONTRIBUTE TO THE RECOVERY OF NATIVE FISHES.

Fishways are channels that are built to allow fish to pass a weir, lock or a dam.

The concept of facilitating fish passage at potential barriers in the Murray–Darling Basin (MBD) has been discussed since the early 1900s, coinciding initially with a Murray cod summit in 1903, and continuing following the construction of weirs along the River Murray in the 1920s. The weirs fragmented the Murray main channel, preventing fish from completing important spawning, feeding and recolonisation movements.

The first fishway built in the MDB was at Lock 6 in 1930, with another at Lock 15 in 1936. At that time, fishway designs that were doing a great job passing salmon in the northern hemisphere, were used in Australia. It was almost 50 years later that we would realise that salmon fishway designs are inadequate for Australian native fish. This led to work identifying designs tailored to the swimming abilities and behaviour of Australian fish.

The River Murray Commission's Working Group on Native Fish was convened in 1983, and during the next three years made recommendations on the construction of fishways. Research was commissioned, which culminated in the first ever design specifications for Australian native fish. These specifications were used to construct a vertical slot fishway on the Murray River at Torrumbarry Weir which was a phenomenal success, allowing year-round passage upstream for the first time in over 50 years.

Still, another 20 years passed before the implementation of the Native Fish Strategy, which, combined with a need to meet legislative requirements as part of a lock and weir upgrade, presented a once-in-a-generation opportunity to facilitate fish passage along the entire length of the Murray River. This was the genesis of the Sea to Hume Fishway Program.

In 2001, there were 20 main barriers to fish migration along the length of the River Murray, with fish passage only possible at Torrumbarry Weir, or during high-flow events when weirs were removed or drowned out. Recognising the immense scale of the job, a fish passage task force comprising engineers, fish biologists and river operators was established. These experts standardised the initial design criteria and the construction process began. It took just 12 years, and a cost of around $78 million, to construct 16 world-class fishways suitable for Australia's native fish. Fish from as small as 40 millimetres, and as large as 1 metre, can now move from the Coorong in South Australia, to the Hume Dam near Albury, a distance of some 2500 kilometres.

It was important that fishway designs were based on native fish ecology, and this proved to be an excellent opportunity to use an adaptive management approach—to build a fishway, learn about its performance, and apply successful design techniques at the next barrier.

Opposite: Fishway at Lock 6. Image taken sometime between 1930 and 1938.

Above left: Fish ladder at Torrumbarry Weir. Above right: Lock 3, vertical slot fishway construction. Photos courtesy of the author.

The performance of fishways was assessed by a unique tri-state research collaboration between New South Wales, Victoria and South Australia. While the monitoring program has now concluded, the collaboration of these researchers continues, and is another legacy of this innovative program.

The first vertical slot fishway design aimed to pass all fish species, something that no other fishway project had aspired to. Building such a fishway was costly, requiring a lot of sheet piling, excavation and concrete. The tri-state team were asked to identify an alternative more cost-effective solution. Following a series of experiments it was decided that it was more cost-efficient, and biologically effective, to build a pair of fishways targeting small-bodied and large-bodied species separately. The large-species fishway could have faster water and a steeper slope, while the small fish could pass via a lock, producing hydraulic conditions far better for their passage.

The tri-state team also developed and implemented Australia's biggest ever fish movement monitoring system. Using microchip technology, similar to those used in pet animals, listening stations were installed in every fishway constructed as part of the Sea to Hume Fishway program. The microchips, otherwise known as PIT tags (passive integrated transponder), track individual fish through the fishways. The PIT system network established by the tri-state team has since expanded to include other, non-Murray fishways, such as those on The Living Murray environmental works at Chowilla and Koondrook-Perricoota, the Stevens weir and the Edward River offtake, and a number of fishways throughout the New South Wales and Victorian areas of the MDB.

The tri-state team has implanted PIT tags in over 24,000 fish, with many more fish being tagged by other monitoring programs throughout the MDB. The PIT detection system has the ability to monitor the movement of Murray cod, Golden perch, Silver perch, Bony herring, lamprey and Freshwater catfish. A significant number of carp have also been tagged, which will inform future control efforts.

The PIT tag system has detected some long-range migrations of individual fish. Silver and Golden perch migrations have been recorded over distances of more than 1000 kilometres. Some species have also exhibited coordinated movement behaviour, with several individuals detected at fishways within hours of each other, and then detected again at the next fishway upstream. More remarkably, the system is able to be linked with flow data, enabling managers and researchers to report on the success of environmental water delivery, thus helping report on Basin Plan objectives. The legacy of the PIT reader system will be a much better understanding of the ecology of native fish, and an improved ability to measure the success of the mitigation of barriers to fish passage.

Completing the Sea to Hume Fishway Program was a significant achievement, but now is the most exciting time for fish ecologists and river managers. With over 2500 river kilometres available for fish passage, and an Australian-first PIT monitoring system in place, the activities and outcomes of the Sea to Hume Fishway Program and tri-state team, will become more and more apparent into the future.

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RETHINKING **FISH PASSAGE**

ENABLING FISH TO MOVE IS FUNDAMENTALLY IMPORTANT, AND INVESTMENTS MADE IN FISHWAYS HAVE PROVED EXTREMELY BENEFICIAL TO OUR NATIVE FISH SPECIES, HOWEVER, WITH THOUSANDS MORE BARRIERS TO BE REMOVED, **CRAIG COPELAND** AND **MATTHEW GORDOS** BELIEVE THERE IS A MORE STRATEGIC WAY TO USE OUR LIMITED DOLLARS AND STILL GET FISH MOVING FREELY.

Above: Mollee Weir, near Narrabri. Opposite top: Tenandra Weir on Marthaguy Creek, west of Gilgandra. Opposite below: Cato Bokhara near Brewarrina. All photos from New South Wales.

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Barriers to movement have been identified as a major contributor to the decline of native fish species within the Murray–Darling Basin (MDB), particularly for migrating species like Silver perch. In the late 1990s we often spoke in New South Wales about 4000 licenced weirs, and then later, after more detailed assessments and work in other states, we spoke about 10,000 barriers across the MDB—ranging from Hume Dam to small causeways across first-order streams. This produced maps like Figure 1. Any wonder fish had a problem!

Early on, federal and state governments said this should be fixed and two options were possible—removing structures and building fishways. The removal of barriers has only been feasible when structures are no longer in use, or more often superseded by others nearby. Fishways are technical structures designed to provide suitable hydraulic conditions (e.g. water velocity, turbulence and depth) so that fish can safely and effectively migrate upstream and downstream of barriers. These have been the solution most often pursued and are recognised internationally as best practice river restoration.

There has been significant investment in fishway construction along the Murray River and associated anabranches through the Sea to Hume Fishway Program, and the Living Murray Initiative. These investments have restored fish migration along 2225 kilometres of the River Murray through the construction of fishways at 15 weirs. They have attracted international recognition for their strategic approach to riverine restoration and their implementation of world-leading technology (see article page 30). Just as impressive, has been work in New South Wales where 103 fishways have been constructed, reinstating fish access to over 13,000 kilometres of priority waterway, mostly in the MDB. The bulk of these have been constructed by Water NSW (formerly State Water Corporation) under the Fish Superhighways program.

Research has repeatedly confirmed the effectiveness of these fishways in passing native fish, with the Sea to Hume Fishway Program on the Murray River passing over 80,000 fish in a single day including more than 700 Golden perch and Murray cod. Monitoring in the Nepean River at 11 vertical slot fishways constructed by Sydney Catchment Authority (now Water NSW) confirmed the successful passage of 19 species of fish ranging in size from 20 millimetres to 1.2 metres.

While this is all great news, and exciting findings of Silver perch returning to the Murray River are being reported, fishways are expensive—up to $1 million per metre of barrier height, and we believe it is not unreasonable to think that finishing the job of the remaining 9890 barriers might prove a mountain too high to climb. What if the problem wasn't that big? What if the problem was as big as the Blue Mountains not Mount Everest?

Work to be published by DPI Fisheries has tried to put the fish passage problem in perspective and analysed the barriers in the New South Wales part of the Basin. Out of over 2000 large barriers identified in the MDB, only 89 barriers to fish passage remain below the main-stem dams to the Murray River mouth. Of these, only 58 are considered high priorities due to their degree of impact on fish passage (e.g. high headloss and limited drown out frequency and duration) (see Figure 2).

So now the problem looks manageable and, at $1 million per metre, the total cost is around $177 million to provide clear fish passage to an additional 13,000 kilometres of river and help those native fish repopulate their historical distributions. Given the results of the Sea to Hume Fishway and Fish Superhighways programs, work of this nature is likely to yield large increases in numbers of migrating fish such as Silver and Golden perch and Murray cod. Importantly, if this work was to go ahead it would also boost the economies of rural and regional areas through improvements in recreational fishing and associated tourism, as well as and through direct and indirect employment in fishway construction. Let's get started!

Figure 1. Fish passage barriers across the MDB.

Figure 2. Priority fish passage barriers in New South Wales.

DIVERSION SCREENING

SIGNIFICANT NUMBERS OF FISH ARE LOST FROM OUR RIVERS ANNUALLY AT IRRIGATION DIVERSIONS AND PUMPS. FISHERIES SCIENTIST **CRAIG BOYS** DISCUSSES HOW ADDRESSING THIS ISSUE WITH PROVEN TECHNOLOGIES IS AN OPPORTUNITY TO SUPPORT NATIVE FISH AND MAKE IRRIGATION MORE PROFITABLE.

The Murray–Darling Basin (MDB) Plan is seeking to secure both the competitiveness of Australia's agricultural sector and the long-term health of river ecosystems. To this end, huge investment is being made into modernising aging and inefficient irrigation delivery systems to achieve water savings.

Improving water efficiency alone will not, however, achieve the biggest 'bang-for-buck' from either an economic or environmental perspective. In many parts of world (including the United States (USA), Europe and New Zealand), diversion screens are considered a critical component of any best-practice, whole-of-farm approach to irrigation modernisation. Diversion screens are a reliable way to prevent fish losses from rivers, as well as improving the efficiency of water delivery and profitability of irrigation.

1. Screening significantly reduces fish losses from rivers

Over the last decade, research has been underway to better appreciate the extent of fish losses at irrigation diversions, and to develop appropriate solutions. The research has shown that hundreds of fish a day can be removed from rivers by a single pump, of which there are over 4500 with diameters greater than 200 millimetres, licenced within New South Wales alone. Studies in Queensland's Condamine catchment have recorded over 12,000 native fish being removed by a single 300 millimetre diameter pump over a 9-hour period. Studies in the mid-Murray suggest that over 1 million fingerling Murray cod, Golden perch and Silver perch may be lost from gravity-fed channels.

Preliminary screen design criteria have been created for Murray–Darling fishes, with laboratory and field trials estimating that if applied correctly, screens could reduce the loss of fish from our rivers by over 90 per cent. These estimates align with the findings of fish tagging studies from the USA which have shown that diversion screens can reduce the entrainment (trapping) of salmon into diversion channels by up to 88 per cent.

Keeping things finteresting

Gravity fed canal diversions like the one shown above can remove tens of thousands of fish a day from a river system. Photos courtesy of the author.

2. Screening can reduce farm operational and maintenance costs

Electricity and fuel costs are two of the biggest expenses facing most irrigation businesses in the MDB. During recent public and private meetings with irrigators, many expressed concern about the constant need to manually deal with debris (and fish) clogging pump outlets. Clogging reduces pump efficiency and increases power consumption. Pumps need to be back flushed (sometimes daily) which adds to labour costs and, in more extreme instances, pumps or outlets would become damaged and inoperable. This is a result of the fact that rudimentary debris screens, often consisting of parallel bars, a grate, or a coarse mesh box, constantly clog and are not designed to exclude fish.

Well-tested and self-cleaning screens are currently used overseas. These use sensor technology to monitor pump performance and automatically clean debris from the screen as required. The result is a screen that does not clog and keeps performing from a pump and fish protection perspective, without the need for constant farmer monitoring and intervention.

3. Screening can improve water efficiency and quality

By reducing the entrainment of debris, screens allow less-efficient water delivery practices to be replaced by more-efficient ones. Examples include the conversion of open channels to piped systems, or the replacement of flood irrigation with centre pivots, micro sprayers or drip lines. In many instances, these upgrades are currently prohibited by the inability to deal effectively with debris.

As an example of what can be achieved, after the installation of a diversion screen comes from the Sisters Irrigation District in Oregon (USA) where 11 kilometres of open channel was replaced with pressurised pipe. This allowed individual farmers to install centre pivots and micro sprayers. As a result, the district now diverts 40 per cent less water to irrigate the same area of land. An added benefit has meant 147 pumps have been removed, at a substantial cost saving.

There are already examples of how similar improvements in water delivery practices have benefited agriculture in the MDB. By converting surface furrow irrigation to subsurface drip technology, tomato farmers have been able to reduce water application rates from 8 to 5 megalitres/hectare, doubling crop yields.

4. Screening will create new and emerging manufacturing and supply opportunities in rural and regional towns

Rural and regional towns need to be more resilient to a future of greater water scarcity. One way of doing this is to explore and invest in new markets and industries that could generate jobs. In countries like the USA a niche manufacturing sector has been established around the design, manufacture, installation and maintenance of diversion screens. It has resulted in the establishment of regional 'screen workshops', many of which offer full-time employment in the design, construction and installation industries. In addition, there are potential market opportunities to be explored more broadly throughout Asia.

> A coordinated Basin wide initiative is needed to validate the economic, social and environmental benefits that can be achieved from diversion screening.

Where to now?

By adopting diversion screens there is great potential for irrigators and other water users to be stewards for native fish recovery in the MDB and, by doing so, reduce the operational costs and improve the profitability of their businesses. Fish biologists and irrigation engineers have already completed preliminary investigations that suggest diversion screening has immense potential to deliver benefits for farmers and the environment in the MDB. The community is becoming increasingly aware of this opportunity, and there is growing interest to begin trialling self-cleaning screens as part of a Basin-wide diversion screening initiative.

The initiative would involve pilot trials of well-established technologies at select sites to validate the economic, social and environmental benefits that can be achieved. Critical to this is establishing an oversight committee whose task would be to ensure a coordinated approach to pilot projects throughout the Basin. The expert committee should include biologists, engineers, irrigators and anglers to ensure that appropriate guidance is provided into the design and operation of screens, to assist with project prioritisation, to help identify suitable funding streams, and to ensure that targeted research and evaluation is in place.

A self cleaning rotating pump screen is one of many different types of screening solutions available to keep debris and fish in the river.

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THE SECRET LIFE OF GOLDEN PERCH

BRENTON ZAMPATTI SHARES WORK HE IS DOING WITH OTHER 'FISH DETECTIVES', TO INVESTIGATE HOW GOLDEN PERCH OTOLITHS (EARSTONES) HOLD THE KEY TO UNDERSTANDING THE INFLUENCE OF FLOW AND HABITAT ON POPULATION DYNAMICS.

River regulation simplifies and fragments aquatic habitats, leading to population decline and a loss of biodiversity. Degradation of aquatic habitat is considered a primary cause of the decline of native fish populations in the Murray–Darling Basin (MDB) and habitat restoration is seen as a means of redressing this. Habitat requirements, however, are often considered from the perspectives of individual fish. For example, most anglers and biologists know that Murray cod love snags, but while specific habitats may sustain individuals, what habitats are required to sustain populations, or indeed promote population growth?

Population growth is a function of births, deaths, immigration and emigration. Fundamental to this equation is an understanding of the habitats that support these processes, the spatial scales over which they operate, and the importance of connectivity between habitats. In large and complex river systems like the MDB, specific regions may act as sources and sinks of particular life stages, and connectivity between these locations may influence population structure at discrete locations. Understanding where these locations are, and their habitat characteristics (including hydrodynamics) and hydrology, is essential to rehabilitating native fish populations.

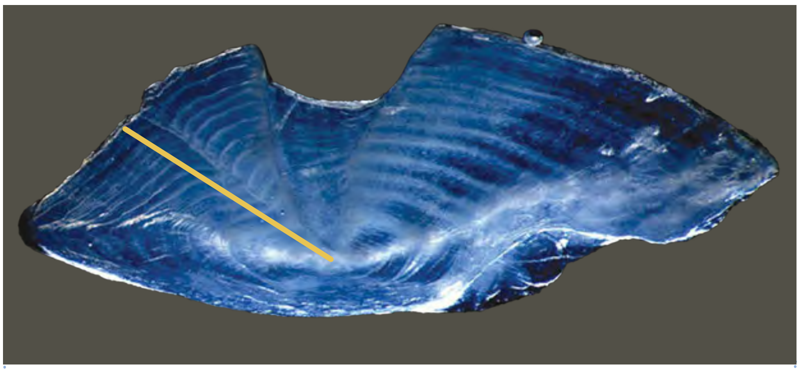
Over the past few years, researchers from the South Australian Research and Development Institute, the Arthur Rylah Institute Victoria, Fisheries NSW and Charles Sturt University have been working together to investigate the spawning, recruitment and movement of Golden perch in the southern MDB. A key question has been to understand the demographics (i.e. age structures) of populations in specific regions, and retrospectively determining where these fish were spawned and what regions of the MDB they occupied during certain life stages (e.g. juveniles).

By knowing *where* a fish was, and *when* it was there, we can determine the flow and habitat characteristics of these regions.

To retrospectively determine where juvenile and adult Golden perch were spawned, and the regions of the southern MDB they have inhabited, we have used fish otolith (earstone) structure (daily and annual growth increments like the rings of a tree trunk) and chemistry. Fish otoliths are formed by the sequential addition of layers of calcium carbonate from birth to death. The chemical composition of the otolith reflects, at least in part, the chemistry of ambient water at the time of deposition. Consequently, the migration history of a fish, including its place of birth and death, can potentially be determined by comparing geochemical signatures in otoliths with ambient signatures in water. This only works when there is geographic variability in water chemistry.

Dissolved strontium isotope ratios ($^{87}Sr/^{86}Sr$) in rivers and streams are an artefact of catchment geology and can provide a geographically distinct natural marker in fish. Importantly, strontium isotope ratios are not biologically modified; therefore the values measured in otoliths are generally similar to those measured in ambient waters. As a result, spatio-temporal 'isoscapes' of dissolved $^{87}Sr/^{86}Sr$ in water can provide a template for determining the spatial origin of freshwater fish. By combining otolith chemistry and chronology a fish can be retrospectively positioned in space and time throughout its life.

Figure 1. A section of a Golden perch otolith showing annual growth increments (analogous to tree growth rings) and the plane of a laser ablation (LA-ICPMS) transect (gold line) to determine strontium isotope ratios across the fish's life time.



FOR FURTHER INFORMATION

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To determine where Golden perch were born, and the habitats they had used throughout their life, we first needed to measure strontium isotope ratios in various rivers of the southern MDB to create a strontium 'isoscape'. We have now collected these data over several years and have established that, in some rivers, $^{87}Sr/^{86}Sr$ is stable over time (for example, the Darling River, Goulburn River and upper Murray River) and in others, $^{87}Sr/^{86}Sr$ is temporally variable, particularly in rivers which have numerous tributaries and hence a constantly varying water source (for example, the mid and lower Murray River). This isotope map was then used as a basis to compare the isotope ratios in the otoliths of Golden perch sampled from locations throughout the region. Laser ablation-inductively coupled plasma mass spectrometry (LA-ICPMS) was used to measure $^{87}Sr/^{86}Sr$ along a transect from the otolith core (time of birth) to the edge (time of death), providing an environmental chronology for each fish (Figure 1).

One of the key findings from our research was that the Golden perch populations sampled in early 2014 in the lower and mid-Murray River, Darling River and Edward–Wakool system were dominated by 4-year-old fish that had otolith core strontium isotope signatures characteristic of the Darling River. This meant that these fish were spawned in the Darling in early 2010 in association with a bank-full flow. Incidentally this was during a time when the MDB was still in the grip of the Millennium drought, and flows in the Murray were at record lows. When we subsequently looked at transects of strontium isotope ratios from the otolith core to edge, we saw a transition in $^{87}Sr/^{86}Sr$ when these fish were either young-of-year (YOY, age 0+) or age 1+, as they moved down the Darling and into the Murray (Figure 2). Many of the 1-year-old Golden perch migrated down the Darling in association with widespread flooding in the southern MDB in late 2010 to early 2011.

Our recent research demonstrates that in the southern MDB, larval, juvenile and adult Golden perch move passively and actively over hundreds to thousands of kilometres, including between the lower Darling River and lower and mid-Murray River (at least up to Torrumbarry Weir), and into tributaries of the mid-Murray such as the Edward–Wakool system.

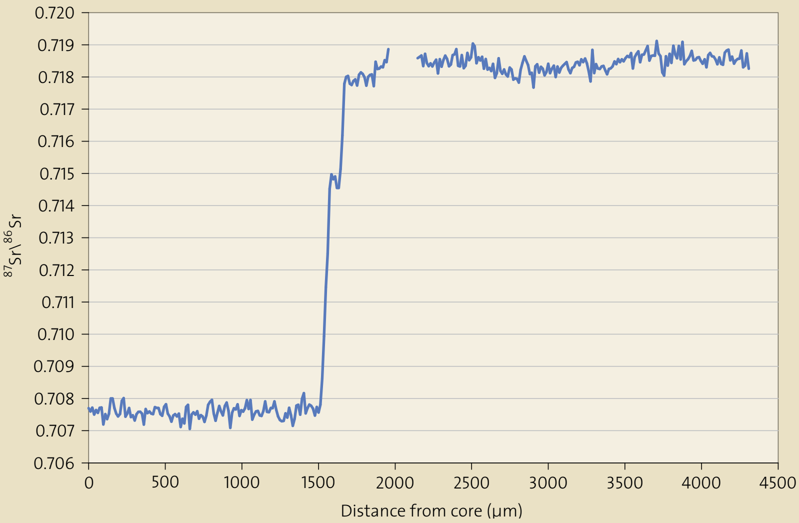


Figure 2. $^{87}Sr/^{86}Sr$ measured along a transect from the core to the edge of an otolith from an age 4+ Golden perch collected in the mid-Murray River at Cohuna. This profile shows the transition (at ~1500 µm from the otolith core) from the $^{87}Sr/^{86}Sr$ ratio of the lower Darling River (~0.7075) to the $^{87}Sr/^{86}Sr$ of the mid-Murray (i.e. ≥0.7180). This transition occurred when the fish was age 1+, in conjunction with widespread overbank flooding in the Murray and Darling Rivers in 2010–11.

Figure 3. Map of the southern Murray–Darling Basin. Blue shading indicates the spatial extent of a dominant cohort of age 4+ Golden perch (captured in 2014). Age 4+ Golden perch from across this region were spawned in 2009/10 and had otolith core strontium isotope ratio indicative of the Darling River. Gold stars indicate potential spawning regions, upstream and/or downstream of the Menindee Lakes.

We have also found that variability in within-channel and over bank flows, in conjunction with appropriate water temperature, can promote Golden perch spawning.

Nevertheless, in some regions of the southern MDB this may not lead to *in situ* recruitment of fish. For example, while Golden perch spawning (as demonstrated by the collection of eggs and larvae) may occur in the lower Goulburn River and the Murray River at Barmah, recruitment of these early life stages to YOY is uncommon, and there is emerging evidence to suggest that immigration of adult and potentially juvenile fish may have a substantial influence on population dynamics in these regions.

Golden perch age structures in any one region of the southern MDB may be dependent on spawning and movement and/or dispersal from regions hundreds of kilometres away, reinforcing the importance of hydrological and biological connectivity and the need for a river-scale perspective for the management of flow and habitat for Golden perch. Importantly, adult Golden perch may have inhabited numerous river systems and habitats, from birth to maturity, so maintaining connectivity between these habitats is essential for the growth of Golden perch populations in the southern MDB.

This novel research is now being used to guide flow management and environmental water delivery across the southern MDB to promote growth in Golden perch populations. It also forms an integral part of monitoring programs to robustly measure response to flow restoration.

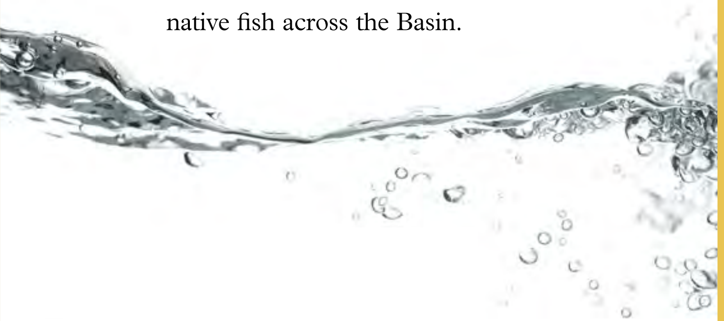
E-water success tales
IN THE BASIN

Introduction

There are many ways environmental water (e-water) can be used to benefit native fish either by delivering water from storages or putting rules in place that keeps water in the river as it flows downstream. E-water can:

- reconnect rivers, and their wetlands and floodplains, providing food, habitat and breeding opportunities for native fish,
- be sent downstream to create a new flow pulse, with the rise and fall of the water stimulating fish to move up and downstream, and into or out of wetlands,
- recreate flows that have been disrupted by river regulation, such as a winter shutdown where the tap is 'turned off' for human water supplies and the system dries, limiting native fish survival,
- be added to other water already flowing down a river to increase river heights and connect native fish with habitats off the main channel,
- protect rivers and wetlands from extraction so that drought refuges are not pumped dry, or so that the rise and fall of a natural flow event travels further downstream.

Understanding of the relationship between flow regime and the impact on the Murray–Darling Basin's (MDB) fish is still evolving, however, scientists already know a fair bit about some aspects that fish need from water and what e-water can help provide. The snapshots on the following pages have been provided by water managers and fisheries scientists from state and Commonwealth agencies to demonstrate how e-water is benefiting native fish across the Basin.



Golden Perch—a winner!

Mid-Murray River (upstream of Barmah): The period 2013/14 saw the best spawning results for Golden perch since 2005 with good spawning results again the following year.

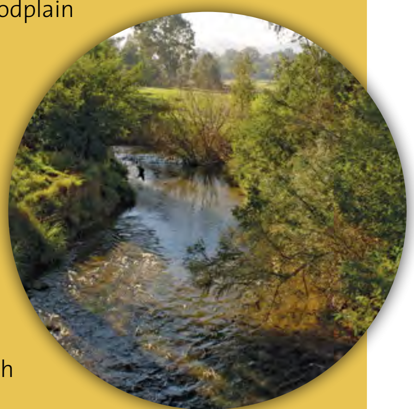
Hattah Lakes: A release of 67 gigalitres in late 2013 and 91 gigalitres between May and September 2014 resulted in:

- observation of juvenile Golden perch,
- larval and juvenile fish in return waters into the Murray River,
- Golden perch recorded moving from the lakes to the Murray at Messengers Regulator.

Murrumbidgee: Repeat Golden perch and critically endangered Silver perch spawning events were detected in 2014 along the river channel in response to the delivery of e-water.

Severn River: Six thousand megalitres was set aside for the 2015/16 season to support Murray cod and Silver perch recruitment, as well as facilitating movement, habitat access and productivity gains. Monitoring indicated good numbers of adult large-bodied native species including Golden perch and very few alien species.

Gunbower: In spring 2014 and 2015, Golden perch with acoustic tags were released into Gunbower floodplain and were tracked moving within the floodplain and back into the river with the e-water event.



Goulburn River: Golden perch exhibited a strong spawning and movement response to increased flows provided by e-water, with Golden perch spawning in numbers not seen since the 2010 floods. Silver perch also spawned in association with the increased flows.

Lower Murray: Golden perch larvae were present following a pulse in late 2012. Flow-cued spawning of Golden perch and Silver perch was also found in 2013/14.

1

Warrego/Darling 2014/15

E-water decisions prolonged the inundation of key waterholes in the Warrego from natural rainfall. The Warrego then added to the mix of water coming out of the Gwydir, Condamine-Balonne, Macintyre and Barwon to stimulate food and increase habitat access in the Darling.

2

Gwydir 2014/15

E-water travelled down the Mehi River in the lower Gwydir valley to enhance instream ecological function and provide opportunities for fish to access habitat. The event supported breeding of Carp gudgeon, Murray River rainbowfish and Bony bream.

3

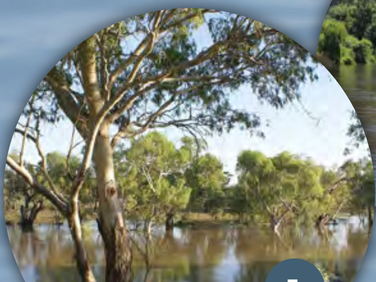
Border Rivers 2015/16

Six thousand megalitres was delivered to support Murray cod and Silver perch recruitment in the Severn River, with good numbers of large-bodied native species found and few alien species.

Macquarie 2014/15

A strong spawning response in Murray cod and Freshwater catfish coincided with an e-water flow in the Macquarie.

4



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Darling River

The lower 700 kilometres of the Darling River is a hotspot for native fish (including Golden perch, Silver perch and Murray cod), breeding good fish numbers under both natural and e-water flow events. Flows in this region are critical to protect native fish in the Basin. E-water can play a key role in protecting native fish in this reach.

6

Lachlan 2014, 2015

High rainfalls triggered a translucent dam release event in the Lachlan valley in late August 2015 'priming' the system for native fish prior to their breeding period. Larval fish monitoring in the Lower Lachlan indicated that native Murray cod, Flat headed gudgeon, Eel-tailed catfish, Australian smelt and Carp gudgeon all spawned in the system.

Lower Murray

Record numbers of the endangered Murray hardyhead were captured at Berri Evaporation Basin, with a sub-population translocated to Victoria (see story page 60). E-water is securing a water supply to maintain these fish.

7

PHOTO DENISBIN.

8

Hattah Lakes

Pumping of e-water moved juveniles of large-bodied fish into the lakes with Murray Cod, Golden perch and Silver perch taking advantage of greater lateral connectivity between the Murray channel and the floodplain.

PHOTO MDFRC.

9

Murrumbidgee 2014

E-water stimulated repeat Golden perch and Silver perch spawning events. Murray cod and Australian smelt also benefited, as well as high densities of macroinvertebrates that are important first feed prey of larval fish.

10

Yanco Creek 2015

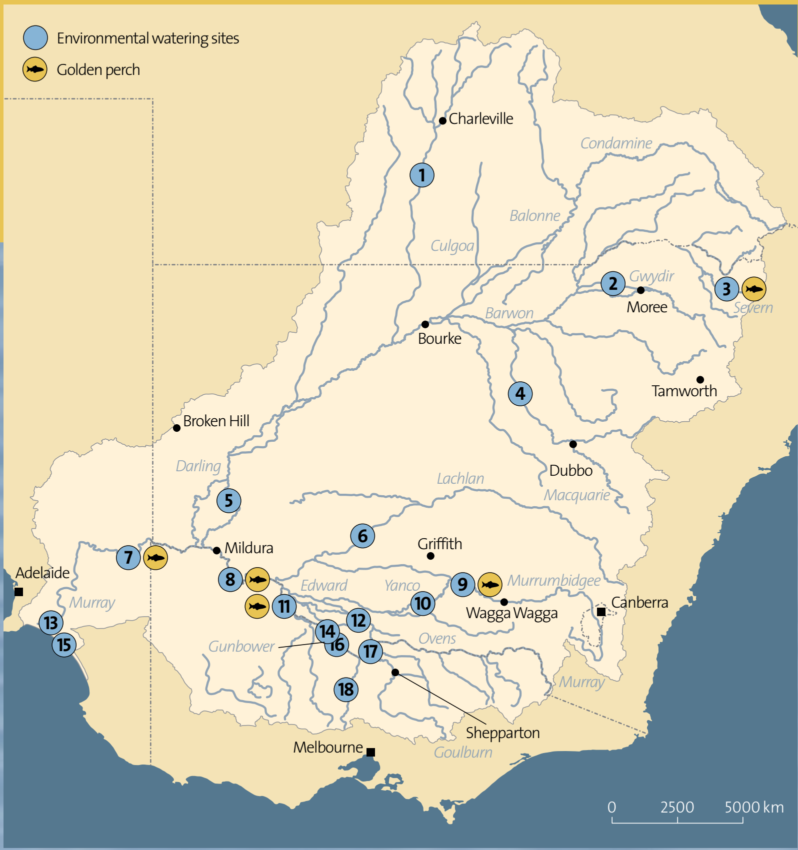
E-water was used to reduce the extreme variability in river depths that occurs due to river operations. Nesting species such as Trout cod need fairly consistent water levels during spawning and when tending their nests, and the water delivered in 2015 had positive outcomes for this species.

11

Mid-Murray River

E-water helped create the flow conditions favoured by Murray cod, Trout cod and Golden perch, with Murray cod in the Murray and Ovens rivers recorded at their highest levels in 14 years. Thousands (up to 2500 per day) of juvenile Silver perch moved upstream via the Torrumbarry fishway in May 2016 in response to variations in flows.

PHOTO MATTINBGN.



Coorong

E-flows in the Coorong have increased the distribution and abundance of Black bream and Small-mouthed hardyhead. With flow improving connectivity between Lake Alexandrina, the Coorong estuary and the ocean, Congolli and Common galaxias have doubled in abundance.

E-water in winter has provided flows that have brought lamprey back into the River Murray. Flows in winter allow spawning migrations of lamprey—with the greatest number of Pouched lamprey caught in 2015 since sampling began. These lamprey have now used fishways in the River Murray and are travelling hundreds of kilometres upstream!

PHOTO HULLWARREN.

Edward–Wakool River System

Instream habitat, especially plants, has improved with e-water. This provides shelter to young or small-bodied fish like the Obscure galaxias, detected for the first time in five years. E-water in the Yallakool Creek created faster flowing habitat preferred by some native fish.

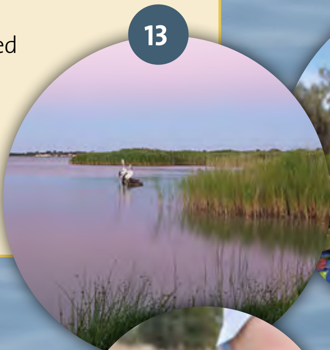
Gunbower 2013, 2014, 2015

In 2013, e-water maintained water levels for Murray cod breeding, helping to ensure spawning and recruitment for the first time in eight years. A follow up winter base flow enabled young fish to survive and grow— previously winter shutdown in this system has reduced survival of these youngsters. E-water also helped deliver the spring 2014 and 2015 floodplain inundation. Thousands of Australian smelt and Carp gudgeon bred on the floodplain and then moved back into Gunbower Creek.

Lower Lakes

Increased lake levels resulted in Murray hardyhead and Southern pygmy perch populations surviving and demonstrating successful recruitment.

PHOTO CAROLINE LLOYD.



Barmah 2015/16

Without e-water Silver perch and Golden perch would not have spawned in 2015/16, as e-water provided the right flow triggers for spawning. One-year-old silver perch are now present in the region.

Barham Lake 2015, 2016

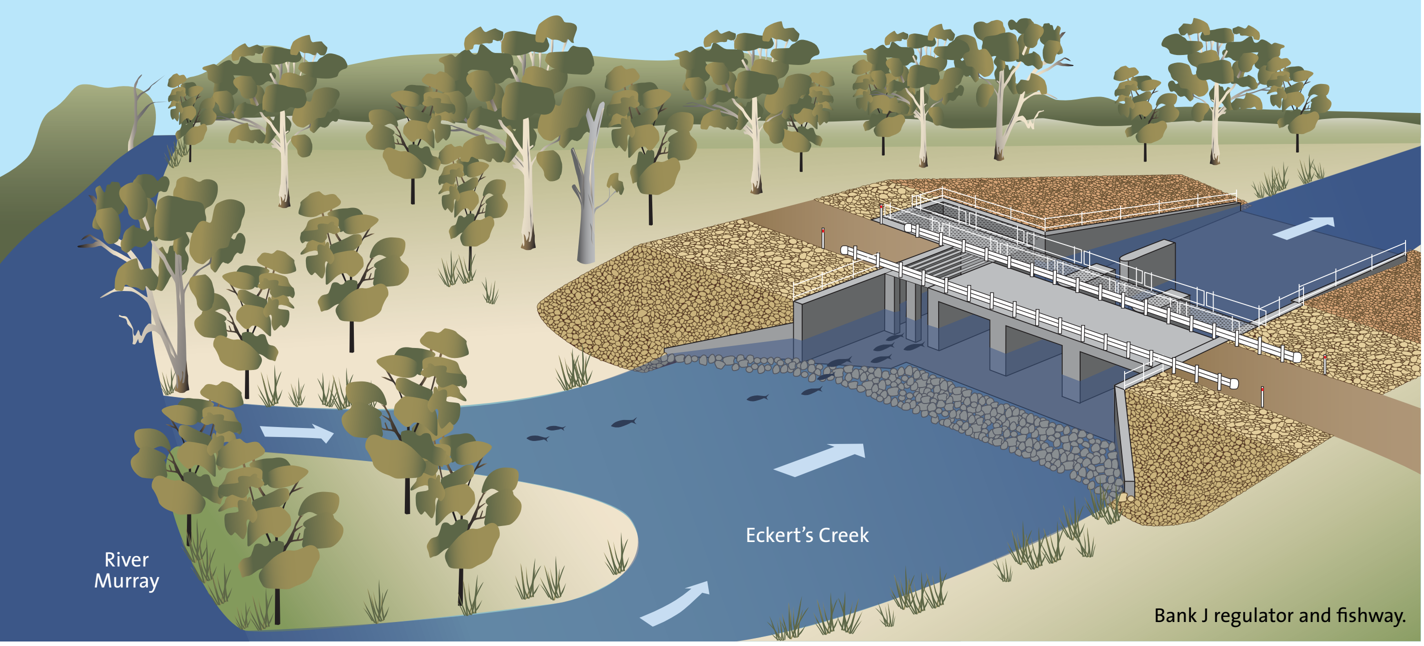
E-water provided to Barham Lake helped remnant populations of Freshwater catfish survive and enhanced their spawning/ recruitment opportunities.

PHOTO HIRAJOIO.

Campaspe 2015

Monitoring detected the presence of Murray cod and an increase in the abundance of Murray River rainbowfish which, although once widespread across the Basin, had declined in recent years in the Murray.

Fish moving freely AT KATFISH REACH



Bank J regulator and fishway.

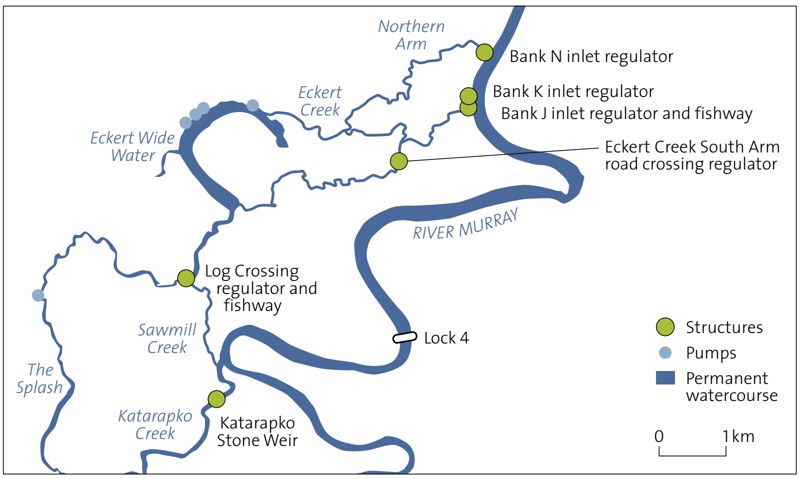
LARA SUITOR PROVIDES US WITH AN UPDATE ON THE WORKS UNDERWAY AT KATFISH REACH TO IMPROVE FISH MOVEMENT ACROSS THIS FABULOUS FLOODPLAIN SYSTEM.

The Eckert Katarapko Anabranch and Floodplain system is one of three large anabranch systems located within the lower Murray River between Berri and Loxton in South Australia. The Eckert Creek anabranch bypasses Lock and Weir No. 4, producing a head gradient of approximately 3.5 metres between the main Eckert Creek inlet, and the confluence of Katarapko Creek and the River Murray. Due to this hydrological dynamic, the Eckert Katarapko anabranch system encompasses a range of diverse aquatic habitats with permanent fast-flowing and slow-flowing creeks. Habitats with this hydraulic diversity are now scarce in the lower River Murray, and this resulted in 'Katfish Reach' being identified as a high value site for native fish. In 2007, the floodplain became part of a network of native fish demonstration reaches.

The total Katarapko floodplain area covers 9000 hectares, and traverses over 56 kilometres of creeks. The site is a South Australian River Murray priority floodplain. An Implementation Plan for the site was developed in 2008, with the Katfish Reach Steering Group playing a key role in the plan's development.

The plan identified 17 key threats across nine project site assets, with two threats standing out—the lack of environmental flows and instream barriers to fish movement.

The Katarapko and Eckert Creek system have some of the most diverse flowing habitat for native fish, however, barriers, such as pipes, roads and earthen embankments, have meant native fish are unable to follow hydrological cues and move through the system to find suitable habitat and spawning grounds. In response to this situation, a number of interventions have now been implemented to improve hydrology and fish movement, including the removal or modification of six major instream fish and flow barriers throughout Katfish Reach. This on-ground work is nearly complete, and will significantly increase water flows and facilitate fish passage.



Improving flow and fish passage

Construction of an eight-bay vertical slot fishway and a four-bay overshot regulator at the main inlet of Eckert Creek (Bank J) to replace a 900 millimetre diameter pipe and rock bank commenced April 2016.

The Katarapko Stone Weir will be lowered by 340 millimetres to allow river flows greater than 5000 megalitres/day to overtop the Weir.

Two banks on secondary inlets of Eckert Creek (N and K) have also been removed. A 300 millimetre pipe in Eckert Creek South Arm was replaced with larger culverts, and the Log Crossing structure were all completed in 2015. The new structure consists of a four-bay overshot regulator and a five-bay vertical slot fishway, with capacity to add a PIT reader in the future.

Completion of the new Log Crossing regulator and fishway, as well as the removal of associated smaller barriers in the system, allows native fish to move through the anabranch in response to changes in water level and flow for the first time in 80 years.

Monitoring results

Annual summer monitoring in 2015 recorded increased numbers of small bodied native fish species such as Unspecked hardyhead, carp gudgeon and Murray River rainbowfish. Ongoing fish condition monitoring within the Katfish Reach site will assist us in gaining knowledge on the changed hydraulic conditions due to on-ground interventions.

Recent fish monitoring results are positive, and have provided inspiration to community members involved in the project. A number of complementary projects and activities are underway within the project site including; delivery of environmental water, protection of Aboriginal cultural sites, rabbit and weed control, carp musters, bike trails and the ongoing removal of barriers to fish movement.

FOR FURTHER INFORMATION
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Building up finterest

Bank N before (above) and after

Log Crossing before (above) and after

THE PROJECT

The Katfish Reach Project is a partnership between the community and government agencies to deliver the following objectives:

- improve floodplain and wetland health,
- manage water to create wetting and drying cycles,
- increase native fish numbers,
- improve native fish movements and flows through the removal of barriers,
- improve the health of native plant communities,
- control pest animals and weeds,
- improve habitat for native animals including threatened species,
- recognise the importance of traditional Aboriginal culture and European heritage.

The new Log Crossing regulator and fishway and associated infrastructure is part of the $100 million Riverine Recovery Project funded by the Australian and South Australian Governments.

COORONG
AND LOWER LAKES

FISH FINDING THEIR WAY

JASON HIGHAM PROVIDES US WITH AN OVERVIEW OF WORK UNDERWAY IN THE COORONG AND LOWER LAKES RAMSAR SITE THAT IS TRYING TO KEEP THE MURRAY–DARLING BASIN'S ONLY ESTUARY CONNECTED TO THE RIVER FOR SOME ENIGMATIC FISH SPECIES.

The Boundary Creek fishway (inset) with its attraction flow gate open (main image). Photos throughout provided by the author.

The Coorong, Lakes Alexandrina and Albert wetland (the site) is a 'Wetland of International Importance' under the Ramsar Convention. The site is well known for its importance nationally and internationally to waterbirds, but less so for its highly diverse fish population, unique within the Murray–Darling Basin (MDB). Many of the endemic fish are species of national and state conservation significance, and are also important to the Traditional Owners of the site, the Ngarrindjeri.

The international importance of a Ramsar wetland for fish is determined by the diversity of fish species it supports (biodiversity) as well as the range of morphologies and reproductive styles (biodisparity).

In the case of the Coorong and Lakes, the site supports 43 fish species across a range of fresh water, estuarine, marine, and diadromous (fish that migrate between the sea and fresh water) species not found elsewhere in the MDB. Crucially, this represents more than 50 per cent of the fish species found within the Basin, highlighting the site's importance nationally and internationally, but also to the Basin and Australia.

Not only does the site support a high level of species diversity, fish of the region also display a range in size at maturity from 40 millimetres, to more than 1 metre. They also possess contrasting body shapes, from benthic (bottom dwelling) flat fishes to pelagic species (fish that swim in the water column and are wider in the middle and taper toward the ends of their body). This biodisparity is another example of the high ecological value of the site.

In addition to a high level of biodiversity and biodisparity, the site also provides feeding areas, dispersal and migratory pathways, as well as the spawning sites that are so critical to its diverse fish population. The site is the only estuarine habitat for the MDB and, as such, is the only access point for diadromous fish species within the Basin.

Diadromous species are those for which migration between freshwater and marine environments is required for the completion of their life cycle. Within the Coorong and Lakes, five species of diadromous fish can be found, including the Pouched lamprey, Shorthead lamprey, Common galaxias, Southern shortfin eel and Congolli.

From top: Pouched lamprey, Shorthead lamprey, Common galaxias and Congolli.

Finding this finteresting?

The Murray barrages were constructed between 1935 and 1940 to keep salt water from entering the lower reaches of the River Murray system, as consumptive demand across the Basin increased. The barrages were not originally designed with fish passage in mind, and have hindered diadromous species from completing their life cycles. Water flowing swiftly through open barrage gates presents a physical barrier to the upstream migration of fish. Similarly, when closed, they create a barrier for fish to move between the MDB and the Coorong or the Southern Ocean.

Passage through the Murray mouth and the barrages is essential for facilitating the recruitment and sustaining populations of diadromous species. This is why environmental flows and fish passage are so critical to maintain the fish community and the site's ecological character.

To address this issue, as part of a broader program to restore health to the pre-existing biodiversity of the Murray, the Murray–Darling Basin Authority (MDBA) implemented a program to reinstate fish passage along the River Murray from the sea to the Hume Dam. This saw the construction of fishways at 11 weirs along the river, together with fishways at Goolwa and Tauwitchere barrages, as well as on the mouth of Hunters Creek on Hindmarsh Island.

Building on the success of the program, six additional fishways are now being installed by the 'Coorong, Lower Lakes and Murray Mouth Recovery' project, funded by the Australian Government and the Government of South Australia, with the help and assistance of SA Water and the MDBA. Three fishways are now completed at Goolwa, Ewe Island barrage and Boundary Creek barrage, with the program to result in the construction of at least one fishway at each barrage by 2017, supporting the diadromous fish communities into the future.

Recent and previous fishway monitoring has shown how important and successful fishways, together with the provision of environmental flows, are in supporting diadromous fish populations. Monitoring has shown significant improvement in the site's fish communities since the end of the Millennium drought.

This year has seen catches of Congolli and Common galaxids at historical highs, and this can be directly linked to the fishways and continuous flows through the barrages provided through environmental water. The delivery of water ensured connectivity between the Coorong and the Lakes was maintained.

Monitoring of the fishways during winter 2015 found an increase in Pouched lampreys moving through the barrages, with scientists from SARDI Aquatic Sciences tagging 55 fish with microchips to track their movement up the River Murray. Of the 55 tagged, 25 were tracked and recorded at fishways between Locks 1 and 11. One lamprey travelled a distance of 878 kilometres to Lock 11.

Not only are fishways important for maintaining connectivity, the provision of environmental water through the fishways and barrages is vital to support the broader ecology of the region. A recent study by the Goyder Institute in South Australia, highlighted the value of environmental water to estuarine productivity and food for fish predators like larger fish and waterbirds. The fishways not only provide passage, but also the opportunity to deliver modest environmental flows for longer to the Coorong, a result that is critical to maintaining the health of the site's ecology, and which was not previously possible.

With the construction of the fishways at the Murray barrages and the ongoing provision of environmental flows through the Basin Plan, the ability to support the diverse fish communities of the region and therefore the MDB are well placed into the future.

The 'Coorong, Lower Lakes and Murray Mouth Recovery' project is funded by the South Australian Government's Murray Futures program and the Australian Government.

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MAKING EVERY DROP COUNT... TWICE!

PETER ROSE AND LOUISSA ROGERS TELL AN INSPIRING STORY ABOUT WORKING WITHIN AN IRRIGATION SYSTEM TO BRING BACK NATIVE FISH IN THE GUNBOWER AND LOWER LODDON AREA.

Since European settlement native fish populations across the Murray–Darling Basin have decreased by up to 90 per cent. In the Gunbower–lower Loddon area, nine of the 22 species once located in the system are now locally extinct. Of the 13 that are present, six are listed under national and/or state legislation as threatened.

Thankfully it's not all doom and gloom, the North Central Catchment Management Authority (CMA) has a plan to 'bring native fish back'. Our plan is not introducing any new ideas, the Murray–Darling Basin Commission Native Fish Strategy 2003–13 identified the majority of these actions over a decade ago, but the North Central CMA are applying these actions on a regional scale in a vibrant and productive irrigation area.

Above: Gunbower Creek in flood. Inset: Murray cod, one of six threatened species present in the Gunbower – lower Loddon area. Below: Kerang weir fishway in the Loddon River.

The Native Fish Recovery Plan – Gunbower and lower Loddon (the Plan), is a large scale, 20+ year plan that aims to boost native fish populations and improve river health in over 200 kilometres of streams and wetlands in the mid-Murray River system. The Plan vision is:

> *Native fish diversity in the project area will be recovered and abundance will be increased to 50 per cent of pre-European by 2035.*

The Plan takes a different philosophical approach to most others regarding flow. Instead of trying to restore streams to their natural state; it recognises the opportunities to increase native fish populations within an existing network of irrigation delivery streams in the Torrumbarry Irrigation Area. The system contains two anabranches of the Murray River, (Gunbower Creek and Pyramid Creek/lower Loddon River), which means consumptive water can be used en route to provide flows that fish and habitat needs. That is, making every drop count twice. The increase in native fish populations will support increased recreational fishing, eco-tourism and benefit the regional economy.

The Plan addresses four key factors responsible for the decline of native fish populations: alteration of natural flow regimes, loss of connectivity for fish movement and migration, degraded habitat and managing threats.

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Fixing flows

Environmental water management plans have been developed for all main waterways within the project area. These facilitate delivery and adaptive management of all water (consumptive and environmental), without compromising irrigation water delivery, to meet the needs of fish by providing cues for critical biological processes (such as spawning), driving a productive food web, and increasing the coverage and diversity of macrophytes for fish habitat.

Restoring connectivity

Fish passage will be reinstated on key barriers in the system, by the construction of fishways or the removal of redundant barriers. Fishways have been constructed on Gunbower weir in Gunbower Creek, Kerang weir, and 'The Chute' in the Loddon River. Concept design or construction is underway at six other sites throughout the Little Murray River, Box Creek, and Gunbower Creek systems. Once connectivity is reinstated, fish will have unrestricted access to and from the Murray River, as well as to a network of over 200 kilometres of rivers and wetlands, including high quality nursery habitats such as Kow Swamp.

Reinstating habitat

The Plan aims to rehabilitate fish habitat through familiar river health projects such as fencing and off-stream watering to restrict stock movement into waterways, revegetating and weed management. Instream woody habitat (snags) density has been mapped and reinstatement is occurring in priority areas to provide residential habitat for key fish species (e.g. Golden perch and Murray cod), resting points for moving fish, and sites for food production. Other key actions in the Plan are to recreate geomorphic diversity, particularly deep pools that have become infilled with silt, investigate options to increase hydro-dynamic diversity, and trial littoral habitat restoration such as transplanting macrophytes.

Bringing back threatened native species

Some locally extinct species are unlikely to recolonise in the region as they have poor dispersal capabilities and there are no nearby source populations. These will require translocation or reintroduction. Candidate species include Southern pygmy perch, Flat-head galaxias and Freshwater catfish, once habitat has been reinstated and flow requirements achieved.

Managing threats

It is well established that large numbers of native fish are lost from the system via irrigation off-takes—both channels and pumps. Once fish enter the channels they are effectively lost from the breeding population, and pumps are also causing a direct loss of fish. A key component of the Plan is to work with private industry to create irrigation channel and pump screens that protect fish and meet the needs of local farmers and irrigators. The North Central CMA will continue to work with the manufacturing and construction industry here, in Australia to develop, monitor and install appropriate screens within the project area.

Another priority action is to develop a pest management strategy that includes feasible control options and adopts new solutions (e.g. the carp herpes virus).

Working together

The Plan is ambitious and will bring together research organisations, policy makers, management agencies, and the community. The North Central CMA, in partnership with Victorian Recreational Fishing Peak Body, is strengthening links with the community through events such a forum in Cohuna that focused on irrigation channel screens, a carp management forum in Kerang, and a *World Fish Migration Day* tour that showcased the region's fishways. These have generated great interest, with over 40 people wanting to be part of a native fish habitat group to help with on-ground actions. Working with Traditional Owners, fishing clubs and community groups as delivery partners will be integral to the success of the Plan. The Native Fish Recovery Plan is being supported through state and federal government funding.

ANGLER PERSPECTIVE: MATTHEW HANSEN

Appetite for change

MATT HANSEN'S YOUTHFUL FACE GRINS OUT OF THE PHOTOGRAPH—HE IS CROUCHED NEXT TO A BRAND-SPANKING NEW PORTABLE FRIDGE AND IS SURROUNDED BY A TREASURE TROVE OF GLITTERING FISHING LURES. "THIS WAS THE START OF THE IWRA BACK IN 2008," HE EXPLAINS POINTING AT THE PICTURE, "WE JUST WANTED TO DO SOMETHING GOOD FOR THE RIVER AND THOUGHT THAT THINGS COULD BE IMPROVED WITH A BIT OF EFFORT. SO WE RAFFLED A FRIDGE FULL OF LURES AND RAISED $16,000 TO PURCHASE FISH FINGERLINGS TO PUT BACK INTO THE RIVER". **SAM DAVIS** SHARES MATT'S STORY.

Top: A captive audience, the IWRA at their annual fundraising event. Above: Where it all began, a young Matt Hansen leading the IWRA's first fundraiser in 2008.

And so began the fish habitat journey for mad-keen angler Matt, now a 30-something, highly successful realtor, business owner, family man and president of the Inland Waterways Rejuvenation Association (IWRA) from Dubbo, in the heart of New South Wales.

From that first humble raffle, fast forward eight years to the present. The IWRA was formed by a small group of like-minded Macquarie River anglers and, under Matt's leadership, has now become a tour-de-force in community-driven river rehabilitation.

When asked what the primary motivation was for forming the group Matt said "How could we not? When we learned that native fish numbers had massively declined across the Murray–Darling Basin, the alarm bells started ringing. There was nowhere near enough happening fast enough."

"At the start it was all about fish." Matt emphasised. "We were frustrated that you simply could not go out and just catch a fish any time you wanted any more. We wanted to catch more fish, and the simple solution for us was to buy hatchery-bred angling stock with the funds we raised and just tip bags of fish into the river—job done, problem solved." Or was it?

Matt continued: "We also wanted to start changing the negative culture and attitudes towards fishing and mistreatment of our local river. We were appalled and offended by the illegal fishing practices and amount of rubbish we encountered regularly when we were out on the river. The unattended set lines, the fish traps, the litter—it all has an impact."

Being a community group and not bound by the conventions that government organisations are when it comes to anglers flouting the rules, the IWRA dabbled in some colourful campaigning to shame the 'fish thieves', and injected a degree of humour into otherwise serious issues. As the group matured, they started to seek a more sophisticated approach to the recovery of native fish stocks.

"We started looking for more answers." But as Matt points out "We knew that there was some littering and fishing pressure, but they could not be the only problems affecting fish numbers. We wanted to validate what we were doing and ensure we were making a real difference where it counted."

The group's pursuit of knowledge was a major turning point, with a dramatic change in direction as they developed relationships with fisheries officers, scientists, managers and researchers, and the shift from simplistic thinking to holistic understanding was made.

"IWRA started collaborating with others and finding out all we could about what fish need and what we could feasibly be involved in. We delved into the science. We talked to fisheries managers and researchers. We wanted our dollars to work harder and go further, so we applied for some grants and were successful —in a heartbeat we doubled our money and outputs!"

The IWRA now administers a major annual fixture on the angling calendar, the Lake Burrendong Classic which attracts in excess of 1100 anglers from all over the nation, and raised $55,943 in 2015. The revenue generated at this yearly catch-and-release event is now mainly spent by IWRA on fish habitat rehabilitation works, including leveraging grant funding for large scale re-snagging projects and removal of willows, and replacing them with native trees along the Macquarie River.

While a start has been made, the IWRA acknowledge there is still a long way to go. "We think there has been a shift away from the 'kill it and fillet' attitude," Matt says with a wry smile "and we see that as a measure of success. It's so heartening now to see kids talking about catch and release and sustainable fishing, and returning breeding stock to the water. We think this is a sign of cultural change within the society of fishers."

Matt explained that changing the ingrained culture and habitat repair "Won't happen overnight, there needs to be a sustained effort to effect change. The damage is widespread and the job won't be done in our life times, but I want my kids to be in the most natural environment we can possibly maintain and create. I want them to be able to catch a fish sourced from a stable, healthy fish population, and know that the fish will be doing it naturally and supporting themselves."

Once described by a family member as an 'oversensitive dog with a bone' Matt really does wear his heart on his sleeve when it comes to native fish, but has demonstrated his capacity to convert emotion into action—he has embraced the role with determination that is inspirational. "Once you know how hard fish are doing it, how can you not want to act?" He reiterated, "Once you have an awareness of what the fishery once was and what it is today, you need to act".

While IWRA are leading the charge locally, they have also joined the new national group Ozfish Unlimited (Matt is a board director), emphasising they don't want to be the 'lone rangers' in community-led fish habitat rehabilitation "You don't have to reinvent the wheel, there's a lot of help out there." Matt continues, "Once you have the smell of success, you will want more. After the first goal is achieved, others will come and suddenly you are up to kicking your third and fourth goals, it just rolls on. We want to be an inspiration to help other groups to becoming empowered, self-sustaining entities, generating their own funds and getting good stuff done for fish."

When prompted, Matt admits he draws some of his inspiration for what a healthy fish future looks like from the diaries of our early explorers. "I would give just anything to be able to walk the banks of our rivers and see what the explorers saw—to see the shoals of fish that were described like birds in the air, that would be truly incredible."

And if Matt has anything to do with it, one day we just might.

Getting the job done with the revenue generated from the Lake Burrendong Fishing Classic is now mainly spent by the IWRA on fish habitat rehabilitation works which have included collecting rubbish from waterways.

IWRA AT A GLANCE

Founded: 2008

Vision: Working to make healthy waterways for better fishing and a better future.

Major projects: 'Making Fish Happen in the Macquarie and Macquarie Big Wood' which includes resnagging, weed removal and tree planting worth $75,000.

Finest hour to date: Recognition (and rubbing shoulders with anglers and groups from across Australia) at the 2015 National Recreational Fishing Conference.

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The IWRA committee.

THE LICENCE TO TARGET HOTSPOTS

RENAE AYRES SHARES SOME GREAT WORK SHE IS DOING WITH VICTORIAN RECREATIONAL FISHERS WHO ARE DIRECTING THEIR LICENCE FEES TO CREATING HABITAT FOR FISH.

Recreational fishing is a popular pastime enjoyed by 838,000 Victorians each year who contribute $7.1 billion per annum to the state's economy. Whether it's fresh water, estuarine or marine; boat or bank-based fishing; bait, lure, spear or fly fishing—recreational fishers are passionate about their sport, fish and the environment. They understand the interconnections between land and water, and the importance of healthy aquatic ecosystems and habitats to support vigorous fish populations.

Fish habitat: What is it?

Healthy habitats provide fish with everything they need to complete their life cycles: shelter, food, breeding areas and migration opportunities. This includes diverse and complex structures, such as plants, logs and rocks in and around the water; good water quality and the right flow regimes. Habitat connectivity is particularly important for fish species that migrate large distances, sometimes between fresh and salt water, as part of their life cycle. It also allows fish to recolonise areas after lean times such as drought.

Rock-ridge fishway improves fish passage on the Werribee River. Photo Renae Ayres.

There have been massive changes to our catchments and waterways through land clearing, urban development, water extraction, clearing riverbank and instream vegetation, barrier construction (e.g. road crossings and weirs), altered water quality and introduced species. One of the simplest, most effective things we can do to support great native fish populations and recreational fisheries, now and into the future, is to maintain areas with healthy fish habitats and improve the condition of degraded waterways. On-ground works programs are an important step toward improvements and include a range of activities from installing fishways, managing weeds, reinstating flows and cleaning up litter. These actions help improve the condition of instream and riparian habitats by increasing habitat complexity and diversity. This benefits fish by providing shelter and refuge areas, food sources, spawning and nursery areas, and markers for territorial or migratory species.

Working together for healthier fish habitats and better fishing

Victorian recreational fishers are becoming more interested, informed and active as advocates for improving fish habitat. In a 2009 survey, Victorian recreational fishing licence holders voted 'Repairing where fish live' as the most important way to improve recreational fishing. In a subsequent survey by Fisheries Victoria in 2012, many people indicated they were interested in participating in projects to improve fish habitat. More recently, 'Improved habitat' was again noted by Victorian anglers as a factor which would increase their fishing participation.

The productivity of fish populations is highly dependent on the environmental condition of waterways, so fisheries and waterway management needs to be integrated. Recreational fishers, waterway managers and other resource management agencies share mutual interests in improving waterway condition to enhance native fish populations and recreational fishing opportunities. This has led to significant investment directed towards common goals to enhance fish habitat. In 2013/14, half ($800,000) of Victorian recreational fishing licence fees funded fish habitat related projects. This was leveraged by $1.2 million in co-contributions from Victorian catchment management authorities (CMAs).

Improving fish habitat: Victorian Coastal Fish Habitat Hotspots project

In mid-2013 the 'Victorian Coastal Fish Habitat Hotspots' project was initiated to engage the community in improving fish habitat in coastal waterways in Victoria. This project raises awareness and encourages recreational fishers' involvement in improving fish habitat, while undertaking on-ground works in selected estuaries along Victoria's coast. The project fosters ownership and protection of fish habitat by recreational fishers and local communities.

Five 'hotspots' are being developed in estuaries of the Merri, Gellibrand, Werribee and Tarwin Rivers, as well as estuaries flowing into Gippsland Lakes (Mitchell, Nicholson and Tambo Rivers). Various on-ground works are being completed to benefit fish, including popular recreational species Estuary perch, Black bream, Mullet, and threatened species, Australian grayling, Tasmanian whitebait and Australian (or Tasmanian) mudfish.

In the Merri Estuary near Warrnambool, wood and rock structures have been installed in the river channel, while woody weeds have been removed from riverbanks and native vegetation is being replanted. Similarly, in the Gellibrand Estuary near Princetown, instream woody habitat has been improved by installing 35 root clusters and lattice log boxes at 10 locations. Native shrubs and trees have also been planted along riverbanks.

In the Werribee River, three new fishways have been built to facilitate fish passage. In the Tarwin Estuary and estuaries flowing into Gippsland Lakes, on-ground works to rehabilitate riparian zones has been the priority. Fencing has been erected to restrict stock access, native vegetation is being replanted and riverbanks are being stabilised with rock banking.

Linking with the on-ground works at each 'hotspot', several community events have been held to engage people about the importance of healthy waterways, as well as to learn and share knowledge and experiences in habitat rehabilitation. Recreational fishers and other interested stakeholder groups, including Landcare, Estuarywatch, Waterwatch and landowners, have participated in these events which have ranged from information nights and forums, to field visits and demonstration days. Topics have focused on local interests relating to fish or fish habitats. People thoroughly enjoy these opportunities to learn and network with others in their local region that share common interests in the environmental condition of their local waterway.

Overall, there are huge benefits from government, recreational fishers and other community stakeholders working together to improve the environmental condition of waterways—there are shared goals, shared resources, a shared workload, shared recognition and shared achievements.

Working together fosters local ownership, and shared understanding of why improvements to waterways are beneficial and what actions are needed to achieve particular outcomes. These initiatives provide an important start to strengthening and expanding such productive, working partnerships. Collaboratively, we can care for our catchments and improve the condition and connectivity of fish habitats. Healthier and resilient aquatic environments mean healthier native fish, and better fishing opportunities for the future.

Sharing information and stories about fish and their habitat of the Tarwin Estuary. Photo Diane Crowther.

This collaborative project is undertaken by the Arthur Rylah Institute; coastal CMAs; Melbourne Water; the Department of Environment, Land, Water and Planning; Fisheries Victoria; the Australian Trout Foundation; VRFish and Native Fish Australia, and is jointly funded by the Australian Government, Victorian recreational fishing licence fees and in-kind contributions by project partners.

Shared finterests

FOR FURTHER INFORMATION

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MODELLING FOR FISH POPULATIONS

FISH LIVE UNDER WATER AND CANNOT BE EASILY SEEN OR COUNTED, SO HOW MANY FISH ARE THERE REALLY? POPULATION MODELS MAY BE OUR 'CRYSTAL BALL' AS **JOHN KOEHN**, **CHARLES TODD** AND **SCOTT RAYMOND** EXPLAIN.

Figure 1: Mathematics can help manage fish populations.
Ponder the structure of this 30-year-age-class model for Murray cod.

$$N_i(t+1) = Bin\left(N_{i-1}(t), dens(t) \times s_{i-1}(t)\right), \qquad i = 3,\ldots,30$$

$$N_2(t+1) = Bin\left(N_1(t), s_2(t)\right),$$

$$N_1(t+1) = Poisson\left(RF \times s_0(t) \times s_l(t) \times s_e(t) \times 0.5 \times Eggs(t)\right),$$

$$Eggs(t) = \sum_3^{30} F_i(t) \times N_i(t)$$

$$dens(t) = \begin{cases} CC \Big/ \sum_3^{30} N_i(t), & \text{when } \sum_3^{30} N_i(t) > CC \\ 1, & \text{when } \sum_3^{30} N_i(t) \le CC \end{cases}$$

$$F_i(t) = \exp\left(f_c \times \log\left(MaxL \times \exp\left(-y_1(t) \times \exp\left(y_2(t) \times i\right)\right)\right) + y_3(t)\right)$$

Flows for fishes

Native fishes of the Murray–Darling Basin (MDB) have suffered substantial declines and, overall, populations are considered to be at about 10 per cent of levels prior to European settlement. Delivering environmental water under the Murray–Darling Basin Plan is a key action to restore river health and fish populations. When we deliver water for environmental purposes, however, there is a need to demonstrate the potential benefits for fish and other biota.

Predicting fish responses using population models

To get an estimate of how many fish we have under different management scenarios, we need to undertake serious monitoring. As of now, if monitoring is undertaken at all, it costs time and money, and can often only provide answers after the management action has occurred.

Often, there is a need to quickly indicate the likely benefits of a management action, so that comparisons and decisions can be made about which actions will deliver the greatest benefits. If only we had a crystal ball to foresee the likely outcomes…

Well, this is where population models can help. Using our best available science and knowledge, ecological models can be developed that are simplified representations of what we believe happens in the real world. Combining knowledge of fish reproduction, survival and movement with some nifty mathematics (see Figure 1), allows models to be developed that represent the dynamics of populations for a particular species, under different conditions or management options.

Models can predict likely outcomes from particular management scenarios which then allows those outcomes to be compared. Traditionally, most modelling for fishes has been used to predict commercial catches, or to test the viability of threatened populations. By extending these concepts, predictions can be made for any management action. Population models have recently been used to determine stocking regimes for restoring Trout cod populations, and for improving size restrictions for the recreational harvest of Murray cod.

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Different fishes or life stages: different responses

How do fish respond to flows? Well, this depends on the life history stages and strategies of the fish species in question, as well as the specific flow attributes. Fish populations include a variety of life history stages from eggs, larvae, juvenile and sub-adults, through to mature breeding adults; with each stage responding differently to flows. For example, some species have drifting egg and larval stages with large-scale juvenile and adult migrations, compared to benthic (bottom dwelling) species that lay adhesive eggs, exhibit parental care and are relatively sedentary. Consequently, each life history stage must be managed separately, and different flows may be required to support spawning, migrations to inundate banks or instream benches to boost river productivity (food for young fish), or to enhance egg or larval drift.

Making a population model for fish in the MDB

Developing fish population models and modelling a range of flows allows for many management options to be compared and the benefits to fish to be maximised. A new project 'Native fish population models' funded by the Murray–Darling Basin Authority and being undertaken by the Arthur Rylah Institute for Environmental Research will do just that. The models being developed are based on the best conceptual understanding of the species' ecology and life cycle needs, with knowledge drawn from literature reviews and expert workshops. This work is being closely undertaken with waterway managers to ensure the scenarios used are realistic and practical. The models will include options for assessing the impact of a range of other threats such as alien fish and instream barriers affecting different fish species.

Using the models

Species' population responses to a range of flow scenarios, including in-channel and over-bank inundations, both natural and managed flow events will be modelled. This will include watering options across the whole MDB; importantly taking into account any regional ecological differences, especially between the northern and southern Basin.

The outputs of the modelling will assist the development of practical water management recommendations that maximise environmental flow benefits to a range of fish species. It is anticipated that these models will be important tools to assist native fish management at multiple scales; for both annual and longer-term planning into the future, at both individual sites and across the MDB. As a useful communication tool, the models will also help to demonstrate the potential benefits of environmental water management for fish to a range of community and government audiences.

Which fish species?

Population models are currently being developed for eight different MDB native fish species: Golden perch, Silver perch, Murray cod, Trout cod, Macquarie perch, Southern pygmy perch, Olive perchlet and Murray hardyhead. These species have been selected to represent a range of habitats and different flow requirements, (e.g. in-channel, wetland specialists; flow-cued spawners), sizes and different management needs (e.g. threatened species or angling species). In addition, a population model has also been developed to assist with the management of introduced carp.

WHO'S INVOLVED

This project is funded by the Murray–Darling Basin Authority and undertaken by the Arthur Rylah Institute for Environmental Research (DELWP, Victoria) in partnership with a wide range of experts from the South Australian Research and Development Institute, NSW Fisheries, Kingfisher Research, Murray Local Land Services, Griffith University, University of Canberra, La Trobe University/Murray–Darling Freshwater Research Centre, University of Melbourne, Fisheries Victoria, University of Canberra, Charles Sturt University and several consultants. These models will be completed by mid-2017 so stay in touch via the Finterest website—**finterest.com.au** to find out the results.

TITLE IMAGE BACKGROUND FRANK KOVALCHEK.
OTHER IMAGES COURTESY OF THE AUTHOR.

MACCAS IN THE MURRUMBIDGEE

PRUE McGUFFIE HAS BEEN KAYAKING UP AND DOWN RIVERS FOLLOWING MACQUARIE PERCH TO LEARN MORE ABOUT THEIR HABITAT REQUIREMENTS AND LIFE CYCLE.

Worldwide freshwater habitats are under threat and so are the species that inhabit them. One such species is the Macquarie perch, a native Australian fish once found throughout the Murray–Darling Basin. Due to factors such as loss of instream habitat, barriers such as weirs and dams, and overfishing, Macquarie perch now only occur in a small number of locations. One of the most important strongholds left is the upper Murrumbidgee River, part of the Rivers of Carbon and Upper Murrumbidgee Demonstration Reach initiative—a vitally important reach that we are working hard to conserve.

Since the 1970s several hatcheries have been trying to breed the fish to bolster wild populations. Unfortunately until recently, attempts have been futile and even now only very small numbers are produced. There is a secret to the Macquarie perch reproduction habits that we need to unlock and understand for future breeding and conservation efforts.

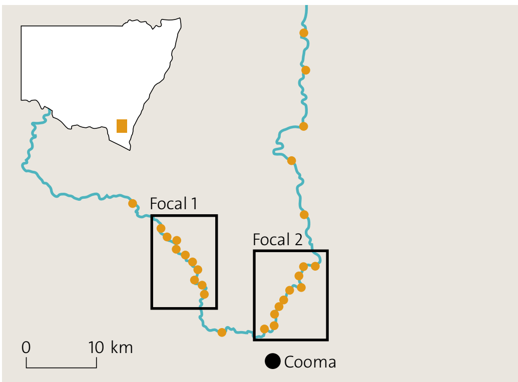
My work aims to unlock this secret life to understand the environmental factors that drive their spawning and everyday activities such as feeding and habitat use. Over the last three years I have been tracking 74 adult Macquarie perch using acoustic telemetry in the upper Murrumbidgee from the Adaminaby area to Michelago.

Most recently I tracked adults to an area within the Cooma reach during the 2015 spawning season. Macquarie Perch like to spawn in riffles, and these riffles were validated using fyke nets set below each in a 4-kilometre section of the river. Eight riffles were monitored between 20 October and 27 November 2015, and of those that were sampled, three were used by Macquarie perch for spawning.

During the first sampling event a school of 50 adults were observed on one of the spawning riffles performing courtship behaviour. This was taking place in a pool of slow water within the riffle, before pairs were seen moving into the faster shallows and spawning was observed. For all sampling events, the highest egg count was recorded after this event. Variables such as egg densities, flow, water quality and rock size were looked at within two of the three spawning riffles.

The tracked fish exhibit a core home range of less than 2 kilometres, except for in the spawning season where one individual clocked 32 kilometres! On average, most fish moved 8–12 kilometres to spawn, with individuals completing their spawning run within a couple of days, and then returning to exactly the same patch of river they call home for the rest of the year.

This information is important, because it tells us that Macquarie perch are particular about where they like to call home, and that conservation efforts need to conserve and create stable habitat. Further analysis is currently underway and more information will be available soon.



The 100-kilometre study reach for this project is on the upper Murrumbidgee River, 30 kilometres above Cooma towards Michelago.

FOR FURTHER INFORMATION

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1. Adult Macquarie perch were caught using an electrofishing boat.
2. To prepare for surgery fish were placed in a bath with clover oil to anaesthetise them.
3. A surgical incision was made into the gut cavity.
4. The acoustic tag was placed into the gut cavity.
5. The wound was sutured or stitched together.
6. Fish received a dose of antibiotics.
7. Patients recovered in a large tub with flow through until they gained equilibrium and swimming ability.
8. Fish are released and acoustic receivers or listening stations are placed into the river to track the adults.
9. Seine netting for young of year.
10. Fifty were kept each year for daily aging to back calculate birth date.
11. Acoustic receivers or listening stations are downloaded via Bluetooth on the river to gather the adult movement data.
12. Adult movement data is analysed to work out where the fish go in the river during the spawning season and spawning riffles were validated using fyke nets set below riffles in a 4-kilometre section of the river.
13. Fyke net set below a riffle.
14. Haul of Macquarie perch eggs from a fyke net.
15. The only way to get to the spawning sites is to paddle.
16. I was very lucky to have a Department of Primary Industries team come out and help me measure variables such as egg densities, flow, water quality and rock size within two of the three spawning riffles.
17. Young of year Macquarie perch were caught in fyke nets towards the end of sampling.

IMAGES COURTESY OF THE AUTHOR.

Keeping common fish common

WITH MANY FANTASTIC RESULTS BEING ACHIEVED BY HABITAT REHABILITATION PROJECTS ACROSS THE COUNTRY **LUKE PEARCE** THINKS THAT SOMETIMES WE MAY FORGET THAT THE PRIMARY OBJECTIVE OF THESE PROJECTS IS TO RESTORE AS MANY COMPONENTS OF THE AQUATIC ECOSYSTEM AS POSSIBLE.

Now we all know that we cannot go back to pre-European conditions, but it is difficult to restore full ecosystem function when key components of that ecosystem are missing and cannot return under their own steam.

What I'm referring to are locally extinct fish species. These may not necessarily be rare or threatened species, they may be species that are widespread and common elsewhere, however, for some reason, they have become locally extinct in a particular part of their historical range. Quite often these species once locally extinct cannot recolonise naturally due to barriers to their movement; road crossings, dams and weirs, natural waterfalls, sand slugs or dry sections of stream.

Australian smelt (above) and below Dwarf flathead gudgeon, both photos Gunther Schmidt. Opposite page: Yass River Haydn Burgess; River blackfish MDBA.

Often we embark on stream or river rehabilitation projects with limited or little knowledge of the current fish community, or what it was historically. Usually we focus on the main recreational species that, if they aren't present, are stocked from hatchery-reared fish, and we often forget or ignore some of the other smaller and less conspicuous species. This is particularly true for rehabilitation projects on smaller streams that have limited, or no monitoring for fish.

One example that is fresh in my mind is the great work being done by various groups along the Yass River. The years of combined effort are achieving simply stunning results in what was a severely degraded system. There has been an incredible transformation in some sections of the stream from a willow clogged, stagnant mess, to a wonderful looking natural Australian river system, complete with large complex wood debris, fantastic riparian vegetation, pools, riffles, cobble beds, fringing and submerged aquatic vegetation—ideal habitat for all manner of native fish.

FOR FURTHER INFORMATION

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Like many smaller projects, there has been limited monitoring for fish because of funding constraints. Recent fish surveys, however, funded through the Rivers of Carbon initiative, have shown some very interesting results in both the abundance and distribution of Golden perch and Murray cod. These fish were identified at sites where they had never been previously recorded, along with increased numbers at other sites. Both species are stocked into the system by local fishing groups, so it is good to see this investment is resulting in fish surviving through to adulthood. The only other native species detected during these, and previous surveys within the Yass River, is Carp gudgeon, which also showed an increase in abundance and distribution.

While these results are encouraging and show a positive response from native fish to improved habitat, diversity is extremely low. Due to a number of large weirs downstream that prevent fish movement, this situation is unlikely to improve. Unless there is greater diversity within the system upstream or in tributaries, it is virtually impossible for the fish community to recover on its own, despite the recovery of ideal habitat through riparian and instream habitat restoration.

Conservatively, this section of the Yass River is within the historical range of at least nine, and possibly more fish species. Many are now listed as threatened, and some may even be locally extinct from the Murrumbidgee catchment. There are some fish in neighbouring catchments like the River blackfish, Flathead gudgeon, Australian smelt (main image) and Mountain galaxias that are abundant, and it is almost certain they once existed in the Yass River. Rather than just focusing on a few iconic fish, should we move some other species back into the Yass River and boost its diversity?

Before going any further we need to investigate local Yass waterways to see what species exist elsewhere in the system. We then need to think about what strategies might encourage fish to spread into newly rehabilitated areas. If they are indeed absent from the system, then we can investigate options to re-establish some species back into the Yass River. This may be via direct translocation, a process that would have to be strictly managed to avoid impacting donor populations.

One opportunity that may resolve this issue is direct translocation from irrigation systems. There has been a body of work looking at the large numbers of fish diverted into irrigation systems, where many die when the channels are drained or dried during the winter draw down period. These systems present a huge potential source for a number of species, provided they are of the same genetics with River blackfish, Australian smelt, Flathead gudgeons and freshwater mussels all found in irrigation areas. This could be a great resource to repopulate areas where particular species are absent, and can no longer return on their own.

There is currently a push in the terrestrial domain to look at translocating less mobile species into rehabilitated habitats which they can't reach under their own steam. This is being done under the banner of 'keeping common species common'. Why should native fish be any different when we happily restock common recreational species, without considering what else may be missing from the system.

If we are serious about rehabilitating our rivers then we need to have a broader focus on rehabilitating as much of the aquatic ecosystem as possible. Having large components of the ecosystem missing has to have major consequences on the function and resilience of that particular ecosystem. Let's look at 'keeping common fish species common' too!

Ideal River blackfish habitat restored in the Yass river but can they return?

Two Southern pygmy perch eaten by a Redfin perch.

Pygmy fish inspiring goliath action

THE SOUTHERN PYGMY PERCH MAY BE SMALL, BUT AS **LUKE PEARCE** DISCUSSES, A GREAT DEAL OF ACTION IS UNDERWAY BY LOCAL COMMUNITIES TO SAVE THIS SPECIAL SPECIES FROM EXTINCTION.

Southern pygmy perch were once widespread throughout the southern Murray-Darling Basin (MDB). Within New South Wales (NSW) the species has now been reduced to three small remnant isolated populations, with a total distribution of less than 45 kilometres of stream. These remaining populations are in small tributaries in the upper catchments of the MDB, with the species now appearing to be locally extinct in the regulated sections of the Basin within the state.

Like all our native fish, there is a long list of causes for the decline of Southern pygmy perch, but the most significant of these is the loss of habitat and impacts from alien species.

FOR FURTHER INFORMATION
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Habitat loss

The primary habitat for Southern pygmy perch is aquatic environments with water plants such as milfoil, ribbonweed, pondweed and phragmites. This is where they live, breed, feed and lay their eggs. So… if we do not have aquatic plants, we do not have pygmy perch.

We are seeing the continued loss of aquatic vegetation because of erosion, flooding, sedimentation and the feeding habits of carp, that uproot vegetation and increase water turbidity. This reduces light penetration making it difficult for plants to grow. In some areas where aquatic plants have disappeared (due to extreme events such as a large flood) they are not re-establishing or recovering due to the activities of carp. This leaves the banks and bed of a stream bare, susceptible to erosion, and with nowhere for small fish to feed, hide from prey and complete their life cycle. It also results in little or no shade over the stream, further increasing water temperatures.

Alien fish impacts

Apart from carp, the remaining populations of Southern pygmy perch are also being significantly impacted by other alien species such as Redfin perch.

The invasions of carp and redfin into habitats previously free of these pest species, is having devastating results. Redfin have recently invaded the population of Southern pygmy perch in the upper Lachlan and have been decimating them as they progress upstream. Sections of Coppabella Creek in the upper Murray were recently invaded by carp and since then, there have been no pygmy perch recorded in this section of the creek, nor has the aquatic vegetation recovered from the 2010–12 flood events.

A barrier is currently keeping carp and redfin out of the upper reaches of Coppabella Creek, and we have seen a good recovery in the pygmy perch population and aquatic vegetation in this area. Through my research, I believe that such barriers are warranted because we can show a direct correlation between the presence of Southern pygmy perch and the abundance of carp. Basically… you only get pygmy perch where there are no carp (or very low numbers of them).

We know we need to restore habitat for the Southern pygmy perch, but it is very difficult to restore aquatic plants in the presence of carp. This is a classic example of what comes first, the chicken or the egg! We need the plants for our pygmy perch, but the plants cannot be re-established with carp present. The solution: eliminate carp or identify where they have not yet reached.

So what is being done?

In NSW we have been taking several approaches, including:

- undertaking works to maintain existing areas so they remain free from alien species,
- investigating the creation of new areas free from pest species,
- restoring habitat,
- creating refuge populations of Southern pygmy perch,
- identifying new habitats free from alien species and establishing new population in these areas.

Right: One of the rock barriers built to exclude carp and redfin. Images courtesy of the author.

We have constructed two barriers to fish passage to keep the upper reaches of the Urumwalla Creek in the Lachlan catchment free from alien fish, as well as repairing a barrier on Coppabella Creek in the Upper Murray catchment. A joint project between Murray Local Land Services (LLS) and Fisheries NSW is looking to potentially reinstate another barrier in the lower reaches of Coppabella Creek, with the subsequent removal of alien fish above it so that Southern pygmy perch can recolonise this waterway.

A joint project between Albury City Council, Murray LLS, Fisheries NSW, the Commonwealth Environmental Water Holder and the Office of Environment and Heritage (NSW) is investigating draining Norman's Lagoon near Albury, along with installing carp screens on the inlet in an attempt to remove and exclude this pest species, and restore habitat for our pygmy perch.

Fisheries NSW is also working to establish refuge populations within farm dams in the Upper Lachlan catchment. These would act as a back up and could potentially be a source for further translocations to other areas.

We have established another population of Southern pygmy perch in Pudman Creek near Boorowa which is currently free from alien species (see *RipRap*, edition 34). Gunning District Landcare is keen to identify sites where other new populations may be established.

The evidence is showing that to maintain and retain Southern pygmy perch we need to provide good habitat free from alien fish species, particularly carp and redfin. These efforts will hopefully enable us to save this little fish in habitat that is free from the negative impacts of introduced pest species.

Habitat and homes for hardyheads

LARA SUITOR ON BEHALF OF THE MURRAY HARDYHEAD RECOVERY TEAM SHARES THEIR WORK TO CREATE HABITAT AND NEW HOMES FOR THIS SPECIAL LITTLE FISH.

The Murray hardyhead is a small fish endemic to the Murray–Darling Basin that have suffered a significant decline in distribution and abundance due to the combined impacts of drought and human processes which affect their habitat (river regulation, altered water quality, isolation of wetlands, and competition or predation from introduced fish). Murray hardyhead are incredibly salt-tolerant, and have been recorded in water ranging from 250 to 110,000 $\mu S.cm^{-1}$. Today, remnant populations are generally only found in habitats of elevated salinity (>4000 $\mu S.cm^{-1}$), due to the lack of dispersal mechanisms (for example, floods) and the availability of suitable habitat.

Currently, there are eight known sites within South Australia and Victoria where populations of Murray hardyhead persist. Unfortunately, the fish are likely to be extinct in New South Wales waters, as they have not been detected in the state for over a decade. The species is listed as endangered under the *Environment Protection and Biodiversity Conservation Act 1999*, and the International Union for the Conservation of Nature Red List. It is also listed as threatened under the *Victorian Flora and Fauna Guarantee Act 1988*, and critically endangered in South Australia.

Members of the project team seine netting in the Berri Basin. Images throughout courtesy of the author.

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A Murray hardyhead Recovery Plan has been developed with cross-jurisdictional and federal support with the following objectives:

1) protect, maintain and monitor known populations, and
2) increase the area of occupancy of the species.

One option for increasing the area of occupancy is to translocate fish from existing populations to sites with favourable conditions, consequently spreading the risk of extinction. Ideally, these sites will be floodplain wetlands which are close to water sources for environmental water delivery to enable natural dispersal in future flood events.

Disher Creek and Berri Basin are Murray River wetland systems used for saline water disposal in the Riverland region of South Australia. In recent decades, Murray hardyhead at these wetlands persisted in very small pockets (less than 1 hectare) of the available habitat.

Work has now been undertaken to create and construct additional habitat for the fish at both Disher Creek and Berri Basin. At Disher Creek a range of infrastructure has been used to create an additional 17 hectares of habitat by making the best use of saline drainage and environmental water.

At Berri Basin a 3-kilometre long channel along its western edge captures and corrals irrigation drainage entering the site. Salinity and water levels are now managed to provide suitable habitat and breeding conditions for Murray hardyhead by the operation of flow control structures and environmental water delivery.

Monitoring of Murray hardyhead at these sites has recorded a steady increase in relative abundance since 2013 when the works were undertaken. During February 2015, monitoring of both Riverland populations captured high abundances of the fish. These results reflect a positive response to the habitat recovery efforts by the Department of Environment Water and Natural Resources, using water supplied by the Commonwealth Environmental Water Office (CEWO).

New homes of Murray hardyhead

Brickworks Billabong, in the Victorian Mallee has been prepared by the Murray–Darling Freshwater Research Centre and the Mallee Catchment Management Authority as a potential translocation site for Murray hardyhead through the delivery of water from the CEWO in 2014–15. The recovery of the Berri Basin and Disher Creek populations presented an ideal opportunity to translocate a sub-population of the fish from these South Australian sites to Brickworks Billabong. This interstate translocation addressed objectives under the National Murray hardyhead Recovery Plan.

Subsequent monitoring of Brickworks Billabong detected juvenile Murray hardyhead —evidence that the translocated fish had survived the move to a new home and subsequently bred. Monitoring in 2015 and 2016 demonstrated additional breeding success for a second successional year. To the best of our knowledge this is the first official interstate translocation of threatened fish between South Australia and Victoria.

A Murray hardyhead Recovery Team forms the centrepin of a collaborative network which responded rapidly in facilitating this cross-border translocation process. The ability to act swiftly and take advantage of windfall situations (like the population booms detected in Disher Creek and Berri Basin) is a key quality that all threatened species managers and researchers should be striving for.

This inter-jurisdictional collaboration has successfully coordinated strategic conservation actions for this species in the last decade, and is a blueprint for success in the field of freshwater fish conservation. The approach is paving a path for the streamlining of threatened freshwater fish recovery processes, and we welcome the opportunity to share what we know with others.

PROJECT COLLABORATORS

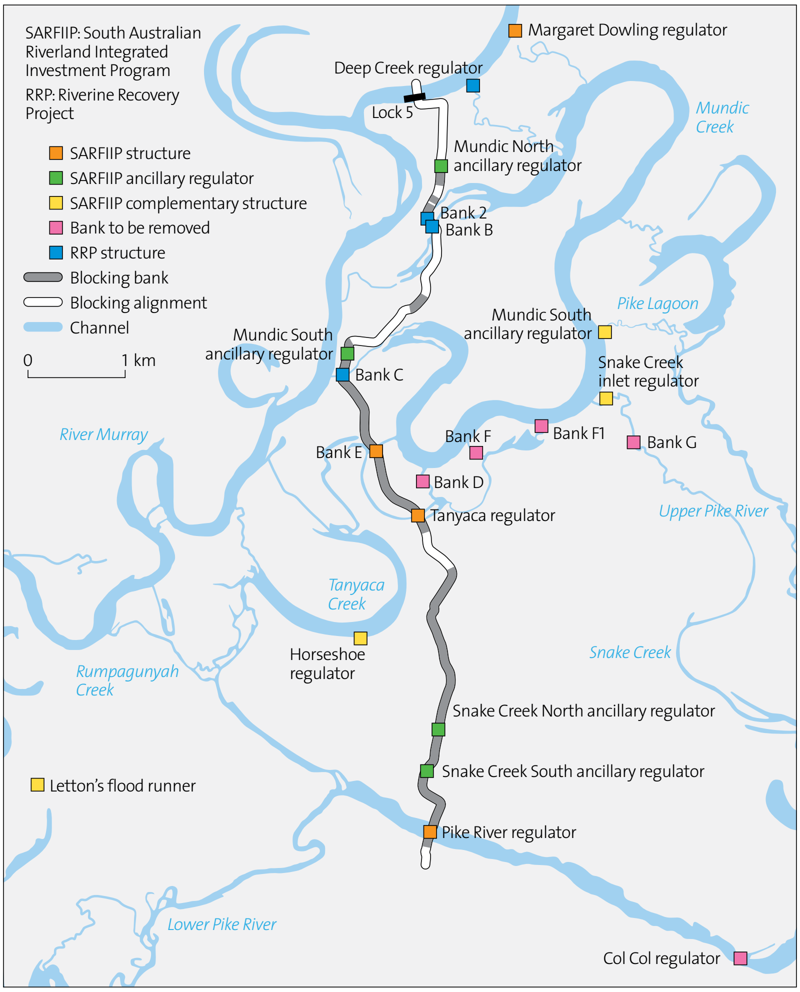
Victorian Department of Environment, Land, Water and Planning (DELWP Regional Services and the Arthur Rylah Institute), Murray–Darling Freshwater Research Centre, South Australian Department of Environment, Water and Natural Resources, Mallee Catchment Management Authority, Commonwealth Environmental Water Office, Parks Victoria, Victorian Environmental Water Holder.

Lara Suitor, Iain Ellis (Murray-Darling Freshwater Research Centre/Fisheries NSW, Department of Primary Industries) and Scott Huntley (Murray-Darling Freshwater Research Centre) developed this article for *RipRap*.

Some of the Disher Creek catch in March 2015.

Pike's position scores a 10

BRAD HOLLIS AND **CHRIS BICE** SHARE AN INSPIRING STORY ABOUT RESTORING CONNECTIVITY TO THE AMAZING PIKE ANABRANCH AND FLOODPLAIN COMPLEX.



The Pike floodplain and anabranch, located near the town of Paringa, is the second largest floodplain complex on the lower River Murray in South Australia, spanning ~6700 hectares. The floodplain comprises a range of vegetation types and habitats including River red gum and Black box woodlands, lignum shrublands, chenopod shrublands, herblands and dunes. The anabranch system bypasses Lock and Weir 5, creating a head difference between inlet and outlet creeks, a unique hydraulic condition within the anabranch. Consequently, the site is characterised by a diverse mosaic of aquatic habitats including permanent fast and slow flowing anabranches, as well as permanent and temporary wetlands. Although the Pike floodplain could be considered degraded at present, it still retains significant ecological character and attributes, including a diversity of terrestrial and aquatic habitats, and populations of rare, endangered and nationally threatened species.

FOR FURTHER INFORMATION

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A total of 16 fish species have been sampled from the Pike anabranch complex, comprising 11 native and five non-native. This assemblage represents a range of life histories, sizes and conservation/economic importance from the small-bodied generalist Carp gudgeon to the large iconic Murray cod. While habitat and hydrological requirements vary, populations within the Pike anabranch have been impacted by habitat fragmentation and flow alteration within the system. Several barriers to fish movement are present, while the original inlet structures were crude, with little capacity to vary flow volumes.

In 2009, SARDI fish ecologists conducted the first assessment of fish and aquatic habitats within the Pike anabranch complex, concluding that while the riparian habitat was generally in poor condition, the instream habitat was deemed to be relatively good. It was considered that the Pike anabranch system provided a good template for habitat restoration to facilitate instream connectivity and enhance permanent flowing habitats.

The Pike ecological restoration project has been improving the condition of the anabranch and associated floodplain. Actions have involved removing barriers to fish and flow at Banks B1, B3, C, H, Snake Creek Stock Crossing and Coombs Bridge. Further barrier removal is scheduled once the new Tanyaca Creek environmental regulator and fishway is constructed and commissioned (Banks D, E, F, F1 and G will be removed).

In 2014, a new regulator and vertical slot fishway was installed at Deep Creek (one of two primary inlet creeks), making it possible for small-, medium- and large-bodied fish (25–800 millimetres) to migrate from the Pike anabranch complex to the river upstream of Lock 5, under non-flood conditions, for the first time since the 1930s. Further, the flow capacity into the anabranch complex has been substantially increased from 150 to 800 megalitres/day as a result of this new structure. This increased capacity to vary flow brings with it the opportunity to not only protect the existing fast flowing habitat within the anabranch complex, but to also extend it. Fast flowing habitat is under-represented within the Lower Murray, so any action to increase the extent of this is considered to be particularly important for large-bodied native fish, like Murray cod and Silver perch, which prefer these hydraulically complex habitats.

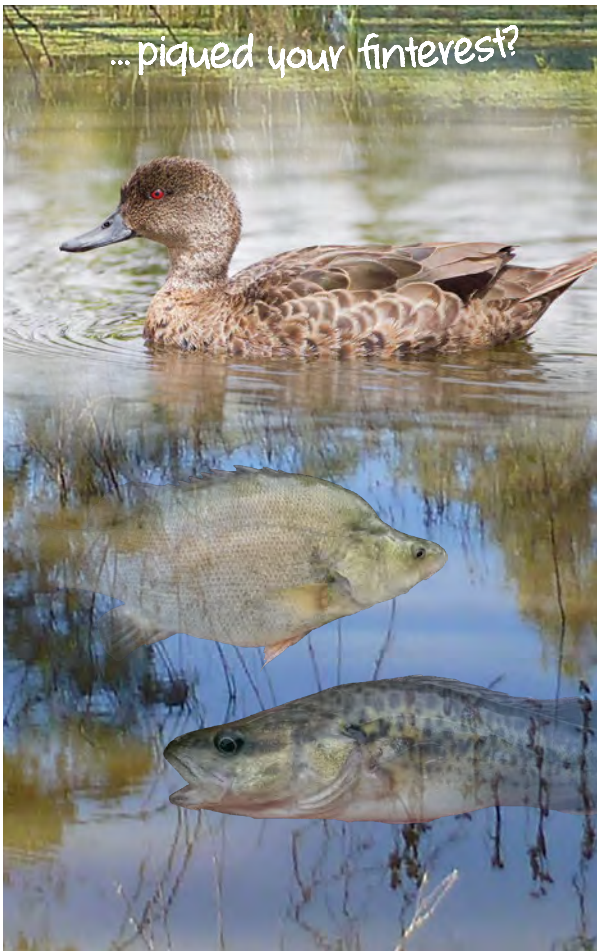
In 2015, new fish friendly regulators were also installed on inlet creeks downstream of Lock 5; at Bank B, Bank B2 and Bank C regulators. These inlets activate under higher flows to South Australia (>40 gigalitres/day). Before the upgrade, under a flow to South Australia of 50 gigalitres/day, approximately 100 megalitres/day flowed from the river into the Pike anabranch complex via Banks B, B2 and C. After the upgrade, under the same flow to South Australia scenario, approximately 3000 megalitres/day will enter the Pike anabranch complex via these creeks. The substantial flow increase and improved connectivity between the river and anabranch complex is expected to benefit a range of instream biota including native fish.

In 2016, Margaret Dowling Creek inlet structure and bridge is scheduled for replacement (the second primary inlet creek to the system). The current structure provides no fish passage, cannot be easily operated and significantly restricts flow. The new structure will include a regulator which takes advantage of the full cross-section of the creek, and will improve the capacity to introduce ecologically appropriate water regimes and incorporate a vertical slot fishway. The new structure will increase flow capacity from 150 up to 600 megalitres/day, with the flow-on effects expected to be significant to a range of flow dependant biota including the nationally-listed Murray cod.

Recently SARDI fish ecologists tested the performance of the new Deep Creek fishway using entrance and exit trapping. The trapping confirmed the functionality of the fishway, as well as providing an opportunity to optimise the gate configurations to improve attractant flows. Eight fish species and more than 20,000 individuals were recorded using the fishway over four weeks of sampling. The fishway designers and ecologists were thrilled with the performance of the Deep Creek fishway, with individuals as small as 29 millimetres able to successfully ascend the structure.

A third and final year of a concurrent fish assemblage and habitat monitoring project was also conducted by SARDI fish ecologists in April 2016. Whilst the data is yet to be fully interrogated and interpreted, it is exciting that juvenile Murray cod were sampled for the second consecutive year within the Pike anabranch complex. Other large bodied native fish species detected include the state-listed Freshwater catfish, Silver perch and Golden perch. It is hypothesised that post instream infrastructure upgrades, fish populations within the Pike anabranch will improve. If you're a fish in the Pike anabranch complex your future is certainly looking up!

BELOW: CHESTNUT TEAL PHOTO JJ HARRISON. GOLDEN PERCH AND JUVENILE MURRRAY COD PHOTOS COURTESY OF THE AUTHOR.



Fish River lives up to its name

CLARE KERR PROVIDES US WITH AN UPDATE ON HABITAT RESTORATION WORK FOR FISH IN THE CENTRAL TABLELANDS OF NEW SOUTH WALES.

Since the formation of the Central Tablelands Local Land Services, our natural resource management teams have continued to focus on improving aquatic habitat by delivering incentives and targeted projects across the region. Activities have included community education, re-snagging, and riparian restoration following willow removal. Focusing on riparian zones has multiple benefits, rehabilitating waterways and associated vegetation, and helping to protect populations and habitat of threatened species such as the Purple spotted gudgeon, Silver perch and the Booroolong frog.

Our largest riparian initiative was the Fish River Project, a three-year investment funded through the Australian Government's Biodiversity Fund completed in June 2015. The Fish River is a large freshwater sub-catchment located south-east of Bathurst, with tributaries running west from the Great Dividing Range down to the confluence with the Campbells River, which is the start of the Macquarie River system. This project focused on improving riparian condition, water quality and aquatic habitat, as well as increasing landscape connectivity across the catchment.

Private landholders within targeted areas of the Fish River catchment were offered financial incentives and technical support, to protect and enhance ecologically sensitive areas, and to control invasive species that threaten biodiversity. Revegetation activities were undertaken to build landscape resilience and establish wildlife corridors, linking high conservation value riparian lands to significant remnant areas and public reserves. A series of workshops detailing specific riparian management issues were also held to educate land managers and local groups.

During the first year of the project there was a focus on the removal and management of willows along 20.3 kilometres of stream, mainly on key reaches of the Fish River. Subsequent years focused on preparing and restoring the riparian zone through stock exclusion, installing alternate watering points (dams and troughs), fencing, weed and pest animal control and, finally, revegetating with native endemic species.

The project achieved outstanding results, with 30 landholders undertaking activities on their properties, and over 38.6 kilometres of aquatic habitat being improved. Another positive aspect was the momentum it gained throughout its duration, with many landholders joining in. Success stories spread through the catchment by word of mouth, especially from those involved in the initial stages of the project.

A protected stretch of the Fish River where willows have been removed and stock have been excluded. Images throughout courtesy of the author.

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> "The key achievement of the project from our perspective is how quickly the natives have started to generate naturally when not having to compete with noxious weeds. It was very exciting and reassuring that the action we had taken was beneficial. This is magnified by the rest of landholders who have signed up to the Fish River Project—our efforts will improve the health of the Fish River and return it to having more native flora regenerating and providing habitat for native fauna."
>
> REBECCA WELSH, FISH RIVER PROJECT PARTICIPANT

Above: Water quality testing during a workshop.

Below: Community planting day on the banks of the Fish River.

Overall the project was a great success although, inevitably, it was not without its challenges. In its early stages when willow management was a key focus, there were concerns raised by members of the public who preferred the willows were left in place. This issue was addressed by discussion on impacts of willows during field days and demonstrations of best practice restoration. We demonstrated the importance of minimal disturbance to the riverbank during willow removal with root balls left in place to reduce erosion and damage to the stream bank. An experienced rehabilitation specialist planted local riparian species within all zones of the riverbanks, including the water's edge, using a mix of native groundcovers, shrubs and trees, all chosen to mimic the natural riverbank vegetation community.

In some cases, getting 'buy in' from landholders on both sides of the river was not possible, however, the few that chose not to get involved were outnumbered by the many neighbours who worked together to connect sections of aquatic habitat along the Fish River—a fantastic result for the waterway!

Protection of swampy meadow (valley fill) systems to maintain and improve water quality and base flows downstream was another focus of the project, but unfortunately, there was little interest from landholders. It seems they are not overly familiar with the terms 'valley fills', 'chain of ponds' and 'swampy meadows', and the importance of these systems. This has been identified as an area for further work through on-ground and capacity building activities.

Since the completion of the Fish River project, the Central Tablelands Local Land Services has continued to work to improve aquatic habitat, with our Ecosystem Enhancement and Improvement projects achieving over 64 kilometres of streambank enhancement or rehabilitation. We have also protected 200 hectares of native riparian vegetation with fencing. These projects involved incentives very similar to the Fish River project, but expressions of interest were opened to landholders across the whole of the Central Tablelands.

A number of other projects are also being planned and undertaken to improve the region's waterways. These include habitat mapping to identify areas with low instream habitat for fish, along with a Saving Our Species project in partnership with the NSW Office of Environment and Heritage to improve rocky crevice habitat along local creeks for the threatened Booroolong frog. We are also collaborating with others to re-snag a small section of the Abercrombie River to improve instream woody debris for fish habitat. More information about these projects can be found on our website.

No quibbling about carp

CARP CURRENTLY MAKE UP A HUGE PERCENTAGE OF THE FISH BIOMASS THROUGHOUT THE MURRAY–DARLING BASIN. IN THEIR RECENT BUDGET THE FEDERAL GOVERNMENT ANNOUNCED THAT $15 MILLION WOULD BE ALLOCATED TOWARDS PLANNING TO ENABLE CARP IMPACTS TO BE REDUCED THROUGH BIOLOGICAL CONTROL USING A SPECIES-SPECIFIC VIRUS. **MATT BARWICK** GIVES US AN UPDATE ON THE VIRAL BIOCONTROL AGENT, AND WHAT IT MEANS FOR THE CONTROL OF THIS INCREDIBLE ECOSYSTEM ENGINEER.

Like many Australians, fishing was a big part of my childhood, and I have two vivid memories from my first fishing trip to the Murray River at about five years of age. I remember being so excited at the possibility of catching a Murray cod… I was entranced by the size and power of this giant enigmatic native and wanted in! My first memory from that trip was of sitting on a bank of this wide, lazy river under a big old red gum, and wondering why the water was so muddy… there had been no rain recently. I assumed that maybe our big rivers had always been muddy, for reasons I didn't understand.

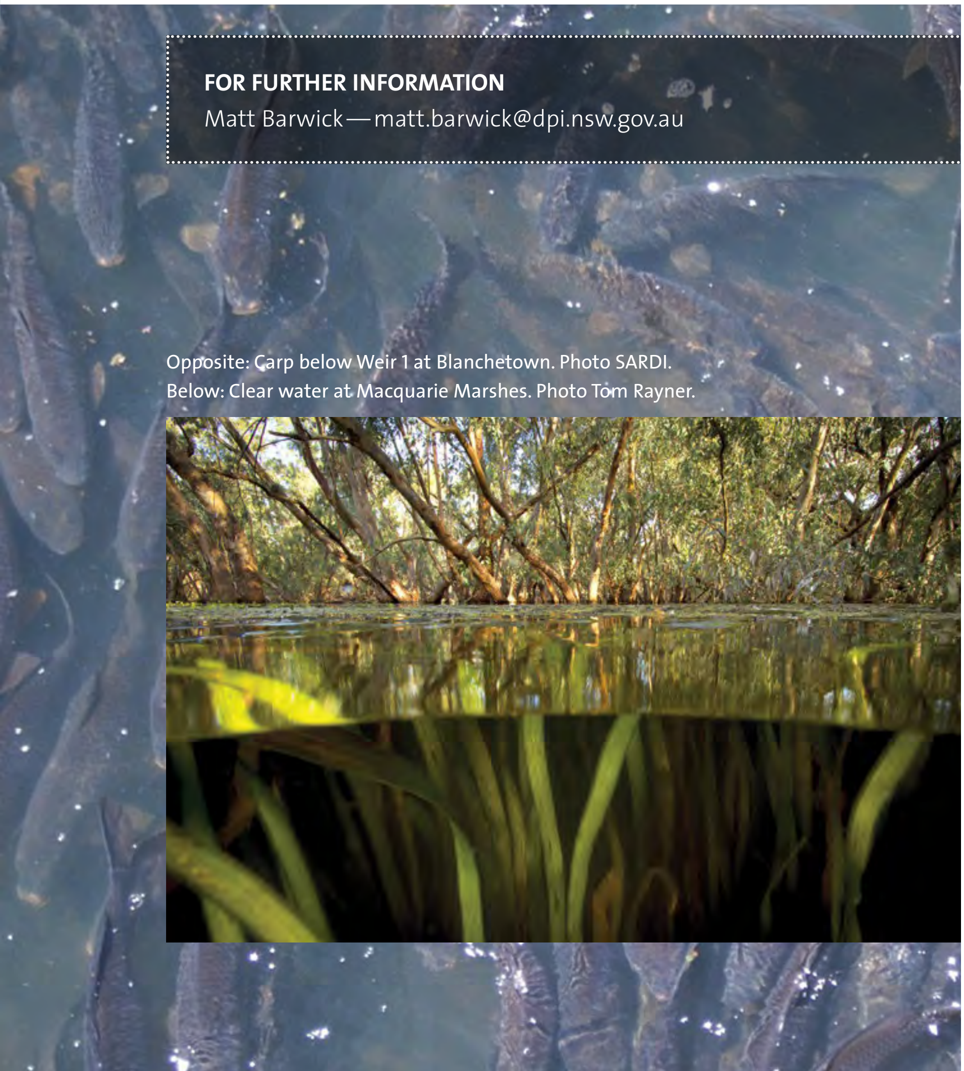
My second clear memory from the trip was later that afternoon when after a long wait my rod buckled and I felt the weight and tail beat of a big fish. Excitedly I shouted "It's a cod! I've got a cod!", and my family came down from the campsite to watch the tussle. After some time the big fish came to the surface and rolled in the muddy water, flashing golden in the sunlight. I remember my stomach lurching and a feeling of disgust and embarrassment washing over me. It wasn't a cod at all… It was a stinking carp.

I've reflected back on that day many times since. Mostly because I'm intrigued by my strong response on seeing that fish, before I think I even knew what a carp was. It's like I was hardwired to dislike that whiskered, golden invader. I also reflect on my assumption that our big rivers were always muddy, because I now know that our big rivers aren't naturally highly turbid systems—they used to flow deep and clear. Older farmers have since shared stories with me of being able to walk the river bank and spot cod sitting on snags in 6 feet of water, and being able to spear crayfish, such was the water clarity. I, and those I work with, believe our big rivers can be clear again, but for this to happen, we must take action on carp.

It turns out I'm not alone when it comes to a sense of disdain for this piscatorial pest, in fact, according to a recent survey it's a bit of a national hobby. The Australian community rank carp among the top four most disliked and significant invasive species in Australia, along with cane toads, rabbits and feral pigs. So why the national repulsion?

There are probably a few reasons. Firstly, there are just so many of them! A single female carp can carry over 1 million eggs, and under the right conditions a small number of fish can result in a dense infestation. Unfortunately that's exactly what you can see today throughout much of our largest river system—the Murray–Darling Basin (MDB). Carp currently make up more than 80 per cent of the fish biomass throughout the MDB, and up to 93 per cent in some places. Carp impact on the health of our waterways too; they can shape their surrounding ecosystem, changing it in ways that suit themselves, and disadvantage our native species. They do this primarily through the way they feed: they are largely bottom feeders, and so mooch around taking big mouthfuls of mud, eating the invertebrates hiding in amongst it, and then spit the mud back out. In this way, they contribute to the muddy condition of our rivers which, in turn, degrades the health of aquatic vegetation by reducing the light penetrating down to the riverbed. This then influences the types and abundances of invertebrates that are present.

The ecological impacts of carp translate into social and economic impacts too. One report estimated that the economic cost of having carp in our waterways at around $500 million per year. Much of this impact was due to the fact that carp reduce the quality of recreational fishing opportunities, which is a huge economic driver for rural and regional communities in the MDB. In fact, there are places where recreational fishes rarely go any more because all they are likely to catch is carp.



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Opposite: Carp below Weir 1 at Blanchetown. Photo SARDI.
Below: Clear water at Macquarie Marshes. Photo Tom Rayner.

Fortunately, the CSIRO have been researching a potential tool for the biological control of carp over the last eight years, with funding through the Invasive Animals Cooperative Research Centre (CRC), and the results are promising. Their research shows that a naturally occurring virus called Cyprinid herpesvirus 3 (more commonly known as the carp herpesvirus) has the key characteristics of a good biological control agent: it is extremely effective in killing the target species (carp), and it doesn't affect other species. Most importantly, international experience has demonstrated that it is safe for humans too.

The level of public interest on this issue became apparent in January 2016, when over 250 media outlets, as far afield as the United States and China ran stories on the potential to control carp in Australia through biocontrol, which resulted in over six million tweets on this topic over a two-week period. It seems the collective imagination of the Australian public has been activated by the potential to address issues caused by the worst freshwater pest species our nation has seen.

Though biocontrol gives new hope to those wishing to see carp disappear from our waterways, and the recent announcement of federal investment will provide significant assistance at the perfect time, it is important to recognise that there is much yet to do.

First, there is a need to complete a detailed legislative approval process, which will take up to two years. There is also a need to complete a thorough risk assessment and undertake public consultation on this issue to ensure the views of the Australian community are well understood. There is a need to undertake monitoring activities before and after release of the virus, so we can document how our aquatic ecosystems and fisheries respond to carp reduction and, of course, there is a need to implement an effective clean-up program to remove dead carp from our waterways and ensure native species and water quality is protected.

If you would also like to keep up to date on progress with this exciting initiative, 'like' the Clearer Waters Facebook page, visit www.agriculture.gov.au/carp-plan, or the Invasive Animals CRC's Pestsmart website at www.pestsmart.org.au/pest-animal-species/european-carp.

...in the national finterest

THE END OF A GOLDEN ERA?

FREQUENTLY ASKED QUESTIONS

How can we be sure that the virus will only affect common carp?

Over the last eight years Dr Ken McColl from CSIRO and his colleagues have been tirelessly testing the carp herpesvirus on a suite of fish species, as well as examples of bird, mammal, reptile, amphibian and crustacea species. This research has demonstrated that the virus only replicates in Common carp. This is perhaps not too surprising, as herpesviruses are generally specific to a single host species, but it is reassuring to see the research confirm this.

Importantly, the work by Ken and his colleagues has also shown that carp present in Australian waterways are extremely susceptible to the virus, and international case studies have demonstrated that under the right conditions, the virus will kill 70–100 per cent of carp in a population that has not been exposed to the virus before.

Will the carp herpesvirus eradicate carp from Australian waters?

It is important to ensure we have a shared idea of what success looks like in terms of carp control in Australia. Total eradication of carp is implausible. Once a pest species is introduced, it is extremely difficult to remove that very last one. It is entirely possible, however, to significantly reduce the impacts of a species by dramatically reducing their numbers—and this has always been the objective of Australia's carp biocontrol program. For this, it will be important to combine implementation of the carp herpesvirus with the strategic application of a range of measures to control carp and promote recovery of native fish communities.

How do we know that carp won't just become immune and repopulate our rivers again?

To overcome the possibility of carp slowly repopulating after the virus is released, it will be important to target the wetlands which contribute the vast majority of juvenile carp to the MDB. Releases of the virus in these areas just after the spawning season will hit them when they are most vulnerable, thereby preventing successful carp recruitment.

Work to investigate a more virulent strain of the virus will help to overcome any future immunity. The release of the carp herpesvirus will also provide an opportunity to simultaneously restore native fish habitats, improve water quality and restore migratory pathways for native fish, to help ensure that carp numbers do not recover.

Can't we just keep using the control methods that we have been using to control carp?

Over the last two decades there has been millions of dollars and many hours invested exploring an exhaustive list of measures to try and control carp in Australia. These include: commercially fishing for carp, installing screens to exclude them from areas containing their preferred types of habitat, trapping them, using sex pheromones to improve the effectiveness of traps, targeting our control efforts on carp 'hotspots' and fitting individual fish with radio transmitters so they can lead us back to their school, enabling us to efficiently target aggregations.

Large accumulations of carp in dense aggregations in deeper holes have been targeted, and technology such as the daughterless carp genetic construct is being trialled which would shift the sex ratio of carp populations by reducing the number of females present in the population.

Despite significant investment in these control measures carp persist as a dominant force in the aquatic landscape. The carp herpesvirus offers the most promising option at this time for the control of carp due to the fact that it is highly effective in killing carp, and is safe for non-target species, including humans.

If the virus is released it will kill a lot of carp. Won't that impact on water quality, and so risk our native fish species?

It is vitally important to ensure that we protect water quality so as to prevent negative impacts on our native species and to ensure ongoing access to clean water for human use. This will be managed by resourcing the job sufficiently and by using appropriate methods to effectively remove dead carp from the waterways.

Detailed research and modelling is currently being undertaken in collaboration with researchers from Water NSW to inform planning for the clean-up strategy. This work will identify carp biomass thresholds that impact on water quality, which can then be used to work out how much carp needs to be removed from the system to prevent negative impacts.

International case studies from places like Japan and North America where large-scale clean-up efforts have been successfully employed have also been investigated to help with formulating our approach.

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 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.

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