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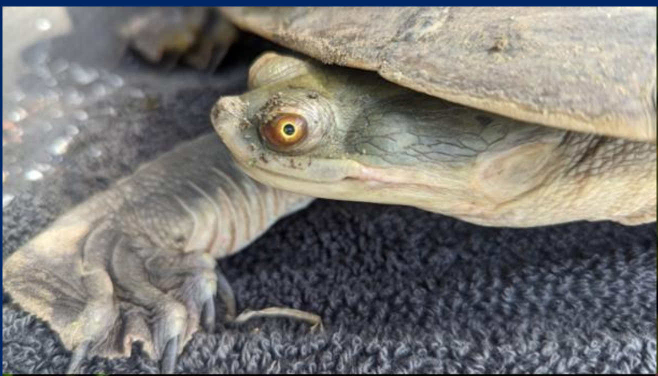
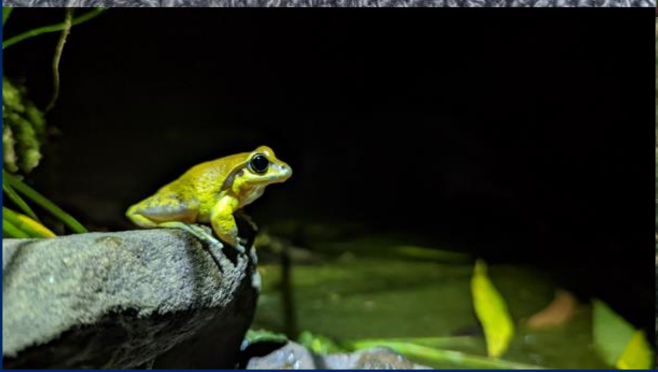
Water dependent fauna

Environmental Outcomes Monitoring and Research Program Annual Report 2021-2022






Acknowledgement of Country

The Department of Planning and Environment acknowledges that it stands on Aboriginal land. We acknowledge the Traditional Custodians of the land and we show our respect for Elders past, present and emerging through thoughtful and collaborative approaches to our work, seeking to demonstrate our ongoing commitment to providing places in which Aboriginal people are included socially, culturally and economically.

Published by NSW Department of Planning and Environment

dpie.nsw.gov.au

Water dependent fauna - Environmental Outcomes Monitoring and Research Program Annual Report 2021-2022

First published: July 2023

ISBN/ISSN: 2981-8443

Department reference number: PUB23/288

Title page image credits: Daniel Coleman, Gunther Schmida, Daniel Coleman and Bec Wood

More information

This work was completed by the Surface Water Science unit of NSW Department of Planning and Environment. Please visit our website for more information.

Acknowledgements

Our collaborators include; NSW Department of Primary Industries — Fisheries, NSW Department of Planning and Environment (DPE) Environment and Heritage Group (EHG), Local Land Services, Murray Darling Basin Authority, Australian Museum, University of New England, University of Melbourne, University of New South Wales, La Trobe University, Odonata Foundation and EnviroDNA.

Contents

Abbreviations and Acronyms

	Description
Basin Plan	Murray-Darling Basin Plan 2012
CEWO	Commonwealth Environmental Water Office
DPE-EHG	New South Wales Department of Planning and Environment – Environment and Heritage Group
DPE-Water	New South Wales Department of Planning and Environment – Water Group
DPI Fisheries	NSW Department of Primary Industries Fisheries
EOMRP	Environmental Outcomes Monitoring and Research Program
EWRs	Environmental Watering Requirements
Flow MER	CEWO Environmental Water MER program
FMP	Floodplain Management Plan
HEVAE	High Ecological Value Aquatic Ecosystems
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
MER	Monitoring, evaluation and reporting
NRC	Natural Resources Commission
NSW	New South Wales
RCI	NSW River Condition Index
WRP	Water Resource Plan
WSP	Water Sharing Plan
WOfS	Water Observations from Space

Monitoring water dependent fauna

A stony creek frog in flowing water. Photo credit: Daniel Coleman

Why are we monitoring water dependent fauna?

It is important we know how and why water-dependent fauna respond to changes in the amount of water in our rivers. This information allows the Department of Planning and Environment — Water (the department) to consider and protect the needs of animals living in our rivers when we make resource management decisions and develop plans to share water between people and the environment.

Water-dependent animals such as platypus, fish, waterbirds, turtles, frogs and invertebrates rely on healthy surface water environments to survive and thrive. An important aspect of sustainably managing these environments is understanding which river flows are critical for different animals. For example, some species of fish require increased river flows to trigger breeding, while many frog species require flowing water to breed and grow to maturity. We need to understand these various needs to address them in our water management plans.

Report purpose

The 2021-22 Annual Report for the water dependent fauna theme (this document) outlines completed works and their findings under the Environmental Outcomes Monitoring and Research Program (EOMRP) between July 2021 and June 2022.

This annual report is one of a set of 5 different themes for the EOMRP. The other themes are:

1. Floodplain connectivity and inundation
2. Ecological processes
3. Water dependent native vegetation
4. Groundwater dependent ecosystems

The EOMRP delivers information annually to meet several requirements. These include NSW reporting obligations under the Basin Plan Schedule 12, performance indicator research, data collection and analysis to inform and evaluate water sharing plans and floodplain management plans, to contribute to the NSW River Condition Index (RCI) tool, the High Ecological Value Aquatic Ecosystems (HEVAE) spatial layer, and the NSW State of the Environment Reports.

The EOMRP projects are staged over several years, building knowledge about water dependent ecosystems and their responses to water management plans, actions and decisions. For further information about the EOMRP, see the EOMRP website. Technical reports for each research project will be published separately and made available on the department's website.

The EOMRP was designed to implement the NSW Water Management Monitoring, Evaluation and Reporting (MER) framework (DPIE Water 2020) which addressed Basin Plan requirements. The EOMRP was extended in 2022 to cover coastal and non-Basin areas. A new framework designed specifically for the evaluation of all NSW Water Sharing Plans is in development. The department is completing this work in response to the Natural Resources Commission (NRC) findings and recommendations about the way we monitor, evaluate, and report information about water sharing plan outcomes.

Report structure

The water dependent fauna theme has been broken into sub-themes for the purpose of this report. These sub-themes are:

- native fish
- freshwater turtles
- frogs
- aquatic insects
- fauna diversity.

For some fauna, reporting may be restricted to one catchment only while other fauna may have reporting across large spatial regions. All reporting is restricted to the NSW boundary (Figure 1).

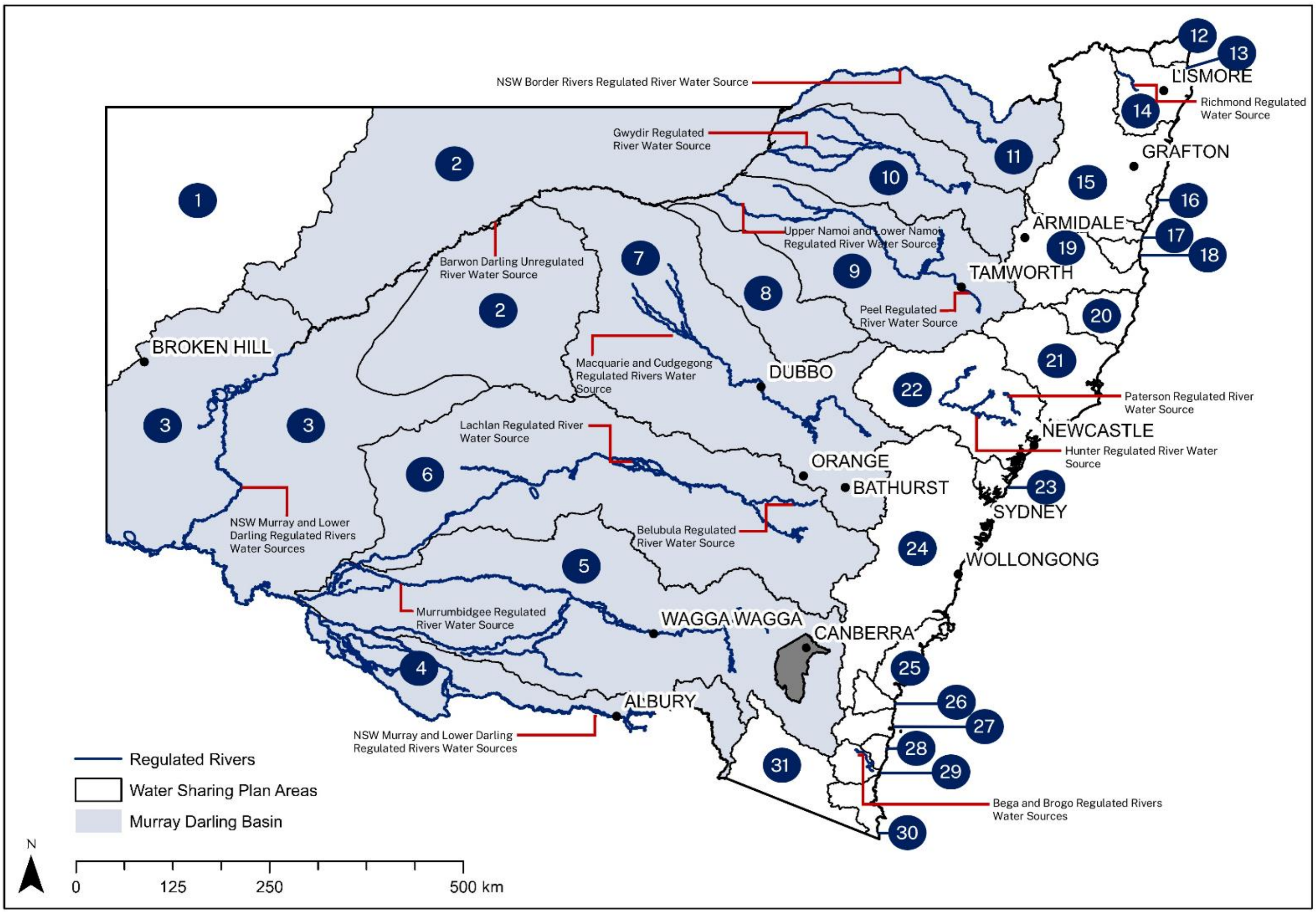


Figure 1. Map of NSW showing the Murray-Darling Basin boundaries, regulated rivers, and the NSW water sharing plan boundaries.

Water Sharing Plan Legend:

1. North Western Unregulated and Fractured Rock Water Sources
2. Intersecting Streams Unregulated River Water Sources
3. Lower Murray-Darling Unregulated River Water Source
4. Murray Unregulated River Water Sources
5. Murrumbidgee Unregulated River Water Sources
6. Lachlan Unregulated River Water Sources
7. Macquarie Bogan Unregulated Water Sources
8. Castlereagh Unregulated Water Sources
9. Namoi and Peel Unregulated Water Sources
10. Gwydir Unregulated Water Sources
11. NSW Border Rivers Unregulated River Water Sources
12. Tweed River Area Unregulated and Alluvial Water Sources
13. Brunswick Unregulated and Alluvial Water Sources
14. Richmond River Area Unregulated, Regulated and Alluvial Water Sources
15. Clarence River Unregulated and Alluvial Water Sources
16. Coast Harbour Area Unregulated and Alluvial Water Sources
17. Bellinger River Area Unregulated and Alluvial Water Sources
18. Nambucca Unregulated and Alluvial Water Sources
19. Macleay Unregulated and Alluvial Water Sources
20. Hastings Unregulated and Alluvial Water Sources
21. Lower North Coast Unregulated Water and Alluvial Water Sources
22. Hunter Unregulated Water and Alluvial Water Sources
23. Central Coast Unregulated Water and Alluvial Water Sources
24. Greater Metropolitan Unregulated River and Alluvial Water Sources
25. Clyde River Unregulated and Alluvial Water Sources
26. Deua River Unregulated and Alluvial Water Sources
27. Tuross River Unregulated and Alluvial Water Sources
28. Murrah-Wallaga Area Unregulated and Alluvial Water Sources
29. Bega and Brogo Rivers Area Regulated, Unregulated and Alluvial Water Sources
30. Towamba River Unregulated and Alluvial Water Sources
31. Snowy Genoa Unregulated and Alluvial Water Sources

Each project has key project questions that relate to water management activities. The key project questions are targeted research questions the project is trying to answer, which link to the specific strategy or water sharing plan rule that a project aims to inform.

Below is an example of how the project aims are presented for each project within this report.

Key project question(s)

- Specific question(s) that the project aims to answer.

Link to water management activities

- The water management activity the project aims to inform.

Drivers of environmental outcomes

The distribution and population structure of water dependent fauna depends on a wide range of factors, many of which are beyond the control of water resource managers. These include climatic events (droughts and flows), invasive pests such as carp, fire, disease, pollution, habitat loss and climate change. However, one of the key drivers of environmental outcomes in surface water environments is river flow, particularly the location, magnitude, timing, frequency and duration, all of which are affected by water management activities.

River flows can be broken into broad flow categories, which include cease to flows, low flows and baseflows, fresh flows, bankfull, and overbank flows (Figure 2). Each flow category can influence a range of habitats and organisms. Water management in NSW aims to ensure adequate flows of each type are provided to meet the water needs of water dependent fauna.

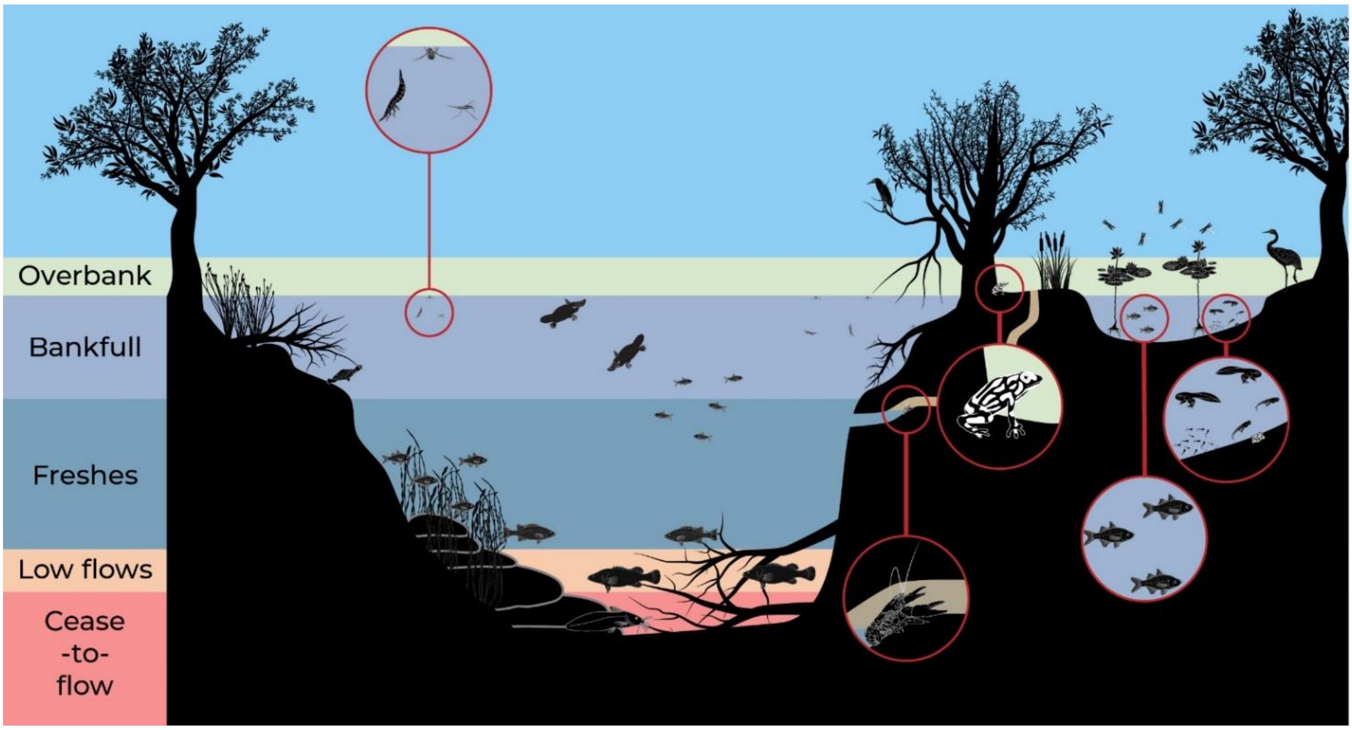


Figure 2. Conceptual model of the main flow categories and what areas of a river they influence.

In NSW, river flow is primarily managed under the Commonwealth *Basin Plan (2012)* and the water sharing plans developed under the NSW *Water Management Act (2000)*. The plans share water between people and the environment by establishing access rules and licences, protecting environmental health, and ensuring the long–term sustainability of resources by requiring water users to hold licences to take water.

This report focuses on the environmental outcomes that are influenced by river flow, and the associated water management actions in NSW, while considering other relevant external drivers.

Native fish

Native fish play an important ecological role in rivers as predators of smaller aquatic animals and as food resources for waterbirds and turtles. They also have significant cultural, social, and economic value.

NSW has a distinct fish assemblage supported by the extensive and diverse range of aquatic habitat available across the state. These fish communities are highly variable between the coast and inland areas of the Murray-Darling Basin. There are up to 50 native species in the Murray-Darling Basin and over 60 species in rivers along the coast of NSW. Understanding the response of native fish populations to flows across a range of catchments is critical for effective water management.

This section summarises projects that investigate native fish responses to flow regimes and water management decisions.

Golden perch movement in the Murray-Darling Basin

Project Team

David Ryan and Jason Thiem (Department of Primary Industries — Fisheries).

Project collaborators

This project is a collaboration with the NSW Department of Primary Industries — Fisheries and the Murray Darling Basin Authority Joint Venture.

Introduction

Some native fish need to migrate between upstream and downstream habitats to complete their life cycles and successfully breed. This means that maintaining the connection of flows along a river and between flowing habitats, such as in-stream pools, is important for their ongoing survival.

Perch can migrate from the lower parts of the Murray River into the upper river reaches of the NSW Basin and even all the way to Queensland. They can travel large distances to seek out a mate and a suitable place to spawn (Koster et al. 2017). To enable this, water must be managed so that there are adequate flows to allow freshwater fish to migrate. This requires co-operation and a coordinated effort covering many rivers and catchments across multiple water sharing plan areas.

We have used golden perch (Figure 3) in this study as an indication of the effects of water management practices on migratory fish, as they are a native fish with high commercial, cultural, social and ecological value that can migrate long distances.

Project aims

We are tracking fish movement to improve our understanding of what type of flows will prompt golden perch to move upstream, how far they travel and the timing of their movements.

Figure 3 Golden perch (*Macquaria ambigua*). Photo credit: Gunther Schmida.

Golden perch are presumed to migrate into all of the larger valleys of the Murray-Darling Basin during connecting flows. However, more information is needed to identify the size of flow events required to trigger migration events.

This project will help us determine whether all Barwon-Darling flow events need to be protected to support fish movement, or whether a rostered approach (for example one in 2 flow events) would be equally effective. Evidence of whether fish tend to move collectively on flow events, or whether different subgroups move in different events is also needed to inform flow management decisions.

The specific aims relate to the following questions:

Key project questions

- Do golden perch move in and out of Barwon-Darling tributary valleys during flow events?
- Do golden perch migrate during all flow events in the Barwon-Darling?
- How important are the flows within the A, B and C class* cease to pump for golden perch movement?

**Class licences represent the available entitlement able to extract from the lowest flows (A class), slightly higher flows (B class) and highest Cease to Pump flow class (C class).*

Link to water management activities

- Evidence of golden perch movements will refine end-of-system flow protections from the NSW Border Rivers, Gwydir, Namoi, Macquarie, and Intersecting Streams valleys into the Barwon-Darling.
- Evidence of golden perch movements during A, B and C Class cease to pump events to evaluate water sharing plan rule effectiveness.
- Evidence that flow targets for fish passages are appropriate to allow movement across key barriers in the Barwon-Darling. These flow targets are listed within the *Water Sharing Plan for the Barwon-Darling Unregulated River Water Source 2012* and summarised below:
  - *A flow of 14,000 ML/d at Brewarrina for 5 consecutive days (Sep-Feb)*
  - *A flow of 10,000 ML/d at Bourke for 5 consecutive days (Sep-Feb)*
  - *A flow of 2,000 ML/d at Wilcannia for 5 consecutive days (Oct-Apr)*
  - *A flow of 150 ML/d at Wilcannia, 280 ML/d at Louth, 390 ML/d at Bourke, 550 ML/d at Brewarrina, and 700 ML/d at Walgett.*

Methods

We began collecting information in 2018 when a fish tracking network was established on the Barwon-Darling River by the Department of Primary Industries — Fisheries. Fish tracking involves attaching small tags that generate an acoustic signal to adult fish, so that their movement is recorded when they swim past receivers mounted in the river. The transmitters in the tags are battery-operated with an approximate life span of 3 years, which means a new cohort of fish must be tagged every few years to maintain the numbers of tagged fish. A new cohort of 150 golden perch was tagged in 2021, and data is downloaded from the receivers twice a year by staff from the Department of Primary Industries — Fisheries.

This project added new tracking stations to the existing network to monitor movement into and out of major tributaries of the Barwon-Darling in the northern Basin including Bogan River, Macquarie River, Namoi River, Mehi River, Warrego River, Culgoa River (Figure 4), Boomi River, Moonie River and the Macintyre River. The Gwydir, Paroo and Narran Rivers were considered but not progressed because their confluences with the Barwon-Darling River are too broad or undefined for acoustic receivers to work successfully. Figure 5 indicates the locations of receiver stations.

Figure 4 Junction between the Culgoa River (left) and the Barwon-Darling (right). Photo credit: Daniel Svozil.

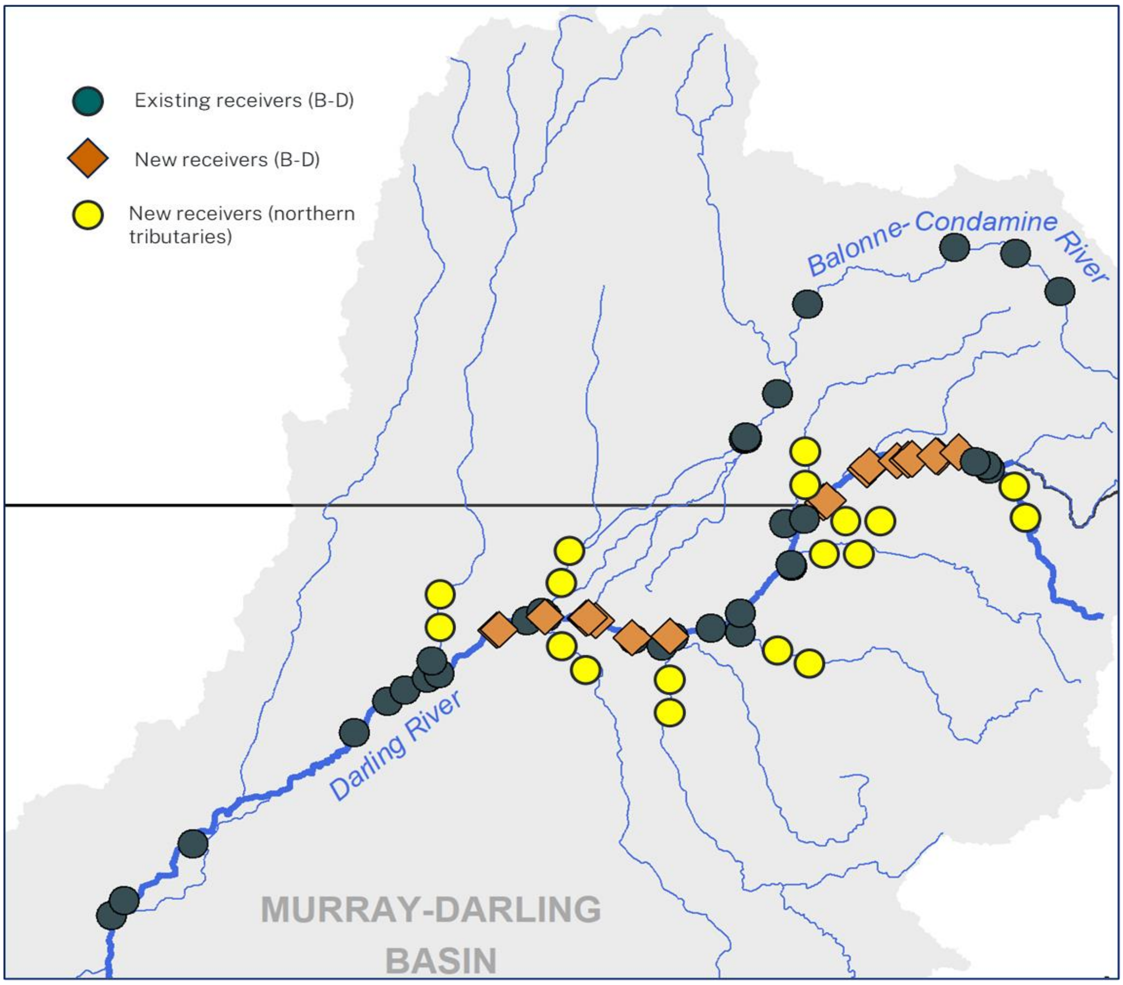


Figure 5. Map of new and existing acoustic receivers in the Murray-Darling Basin. Paired receivers have been placed on all significant tributaries so that the direction of fish movement can be recorded.

Results

Field staff have been unable to download receiver data in 2022 due to the very high flows in the Murray-Darling Basin. This is a high priority for Department of Primary Industries — Fisheries staff and the information will hopefully be collected in early 2023.

Conclusions

No conclusions can be drawn at this time.

Recommendations

No recommendations can be made at this time.

Next steps

This project is ongoing with the project due to end in June 2024. Once the 2023 dataset has been downloaded, the project team will begin analysing the movement of golden perch against different components of the flow regime. Further information on the first batch of results will be provided in the 2022-23 EOMRP theme report. The final report will be available in late 2024.

Native fish monitoring in coastal NSW

Project Team

David Ryan, Daniel Svozil, and Matt Balzer.

Project collaborators

This project is led by the department, consulting with the Department of Primary Industries—Fisheries, Local Land Services, and the Environment and Heritage Group of the Department of Planning and Environment.

Introduction

Over 60 species of native freshwater fish, several of which migrate annually, have been recorded in NSW coastal freshwater rivers (Morris et al. 2001). To effectively manage water resources, we need to know which rivers they live in, what habitats they prefer and their life-history movement patterns, so we can understand how well their water requirements are protected by current water sharing rules.

Iconic species such as Australian bass (Figure 6) and Estuary perch travel between upland streams and the ocean at different stages of their life history, and tend to return to the same rivers over time. Connectivity along river systems, which can be thought of as fish 'highways', is critical for species that need to travel between freshwater and the ocean to complete their life cycles.

Figure 6 Australian bass (*Macquaria novemaculeata*) Photo credit: Gunther Schmida.

Likewise, breeding and refuge sites are critical for the survival and dispersal of threatened species. Identifying these important rivers and habitats allows us to focus our management advice where it will have the most benefit to long-term persistence and recovery of fish populations.

Before this project, the most recent fish population monitoring on the NSW coast was completed over 10 years ago. The lack of contemporary data meant that the department was relying on predicted distributions and decades-old surveys for water sharing planning processes.

Project aims

This project will establish a comprehensive monitoring program that will collect native fish data across all of NSW's coastal water sharing plans. The monitoring is targeted at strategic water sources in each coastal plan area, based on criteria (see Site selection) that support the development of water sharing rules and state-wide condition assessments.

The project will provide crucial baseline data to improve our understanding of when coastal fish species move and how best to provide adequate flows to support their migrations. The data will be used to inform how future water sharing arrangements can support critical water requirements for threatened and migratory fish species.

The specific aims relate to the following questions:

Key project questions

- What is the current distribution of freshwater fish species in coastal NSW catchments?
- How does connectivity throughout a river catchment facilitate access for migratory and threatened species to key habitats in freshwater and estuarine reaches?

Link to water management activities

- Identify water sources where water sharing plan rules need to protect minimum flow and depth requirements for:
  a. maintaining connectivity between headwater and estuarine river reaches for migratory movements of species such as Australian bass and Freshwater mullet
  b. biologically relevant flow components such as freshes, that trigger spawning and migratory behaviour
  c. evidence that the relevant low flow cease to pump rules are protecting key fish habitats such as drought refuges during dry conditions.

Methods

Currently, this project is using environmental DNA (eDNA) sampling (Figure 7) to establish a baseline of species distribution at key sites that can be revisited over time to produce a long-term data set. While the eDNA technique currently only provides information about presence or absence of key species, long-term eDNA data sets can tell us whether populations are stable, retracting or expanding, or able to successfully migrate through coastal valleys during different flow conditions.

We are collecting eDNA from freshwater streams in coastal NSW as it is a cost-effective technique that identifies the presence of different species at a site. This is done by harvesting and analysing the concentration of DNA fragments left by fish from faeces, slime, and scales in a water body. Detections of a species' eDNA above or below certain thresholds are designated as "positive" (3 assays across all sample replicates from a site result in detection), "negative" (no assays result in a detection) or "equivocal" (at least 2 assays in an individual sample replicate resulted in detection).

Site selection

Sampling sites were selected in strategically relevant water sources (see Project aims and Appendix 1 for site locations). Water sources were selected based on the following criteria:

- Water source is rated high or medium risk (DPE Water 2023) *and*
    - either threatened species are recorded or
    - threatened species are predicted in the water source based on NSW Fisheries MaxEnt (DPI Fisheries 2016a) distribution model or expert opinion *or*
- High HEVAE value (Healey et al. 2018) is reported for the water source or it is rated as low risk and,
    - the water source occurs upstream of or between high or medium risk water sources, and
    - are likely to be characterised as key habitat for migratory or threatened species based on HEVAE ratings or RiverStyles classifications (Brierley and Fryirs 2005).
- The water source has high relative ecological value and/or a gauge and can act as a reference site for an adjacent water source with higher risk or lower ecological value.

Specific sampling sites within the selected water sources were determined by accessibility and proximity to potential fish habitat locations, refuge sites, river junctions, barriers to migration based on state-wide data of barriers to fish migration (DPI Fisheries 2016b), and other factors that might influence species distributions.

Figure 7. Environmental DNA sample collection on the Brogo River, June 2022. A backpack-mounted pump draws a predefined volume of water over a specially treated filter that is mounted on the end of a sampling pole (to the left of the operator). Photo credit: Anna Helfensdorfer.

Sample and data analysis

Water samples are collected using a Smith Root backpack eDNA sampling unit to control the volume of water sampled and prevent cross-contamination between samples (Figure 7). At each site a minimum of 3 replicate samples were collected. Each sample consists of water which is passed through a very fine (5 µm) filter using the Smith Root backpack sampling unit until a target volume of 10 L is filtered across the combined 3 samples. Where high turbidity results in rapid blockage of filters, a minimum of 2 L across 4 samples is collected and noted for analysis.

Each sample is taken by submerging the filter suction tube at varying depths below the water surface at as many different micro-habitat features as possible within the site (for example, drowned timber, submerged rocks, undercuts, and so on).

The samples are then analysed using a technique called metabarcoding. This compares the eDNA fragments to known genetic sequences for species to genetic sequences within a reference library. The metabarcoding procedure can be targeted to specific groups of organisms, and the technique we use for this project is targeted to identify coastal fish DNA.

An additional benefit is that eDNA samples can be preserved and revisited to analyse for other species. This means that samples can be re-analysed by a certified lab for presence of platypus, freshwater turtles, frogs or other biota without repeating the field sampling.

Our field sampling is focused on upland and mid-valley water sources. We are currently planning to sample 240 locations each year, covering every coastal water sharing plan area between the Tweed and Genoa valleys, as seen in Figure 1.

Results

In 2021/22 samples were taken in 5 coastal valleys: the Richmond, the Lower North Coast, Hunter, Central Coast and Bega valleys. The findings for these coastal valleys are summarised following.

Total species richness

Overall, 26 native fish species were detected throughout the sampled catchments, with average species richness varying greatly between catchments (Figure 8). The Richmond River catchment had the highest species richness, averaging 10 native species per site. The Bega valley had the lowest species richness, averaging 4 native species per site. The Hunter valley and Lower North Coast also had low diversity.

There were 4 non-native species detected throughout the sampled catchments. Average non-native species richness was much lower than that of native species (Figure 9). The Central Coast and Richmond River had the highest number of non-native species with an average of 1.4 and 1.1 non-native species per site respectively.

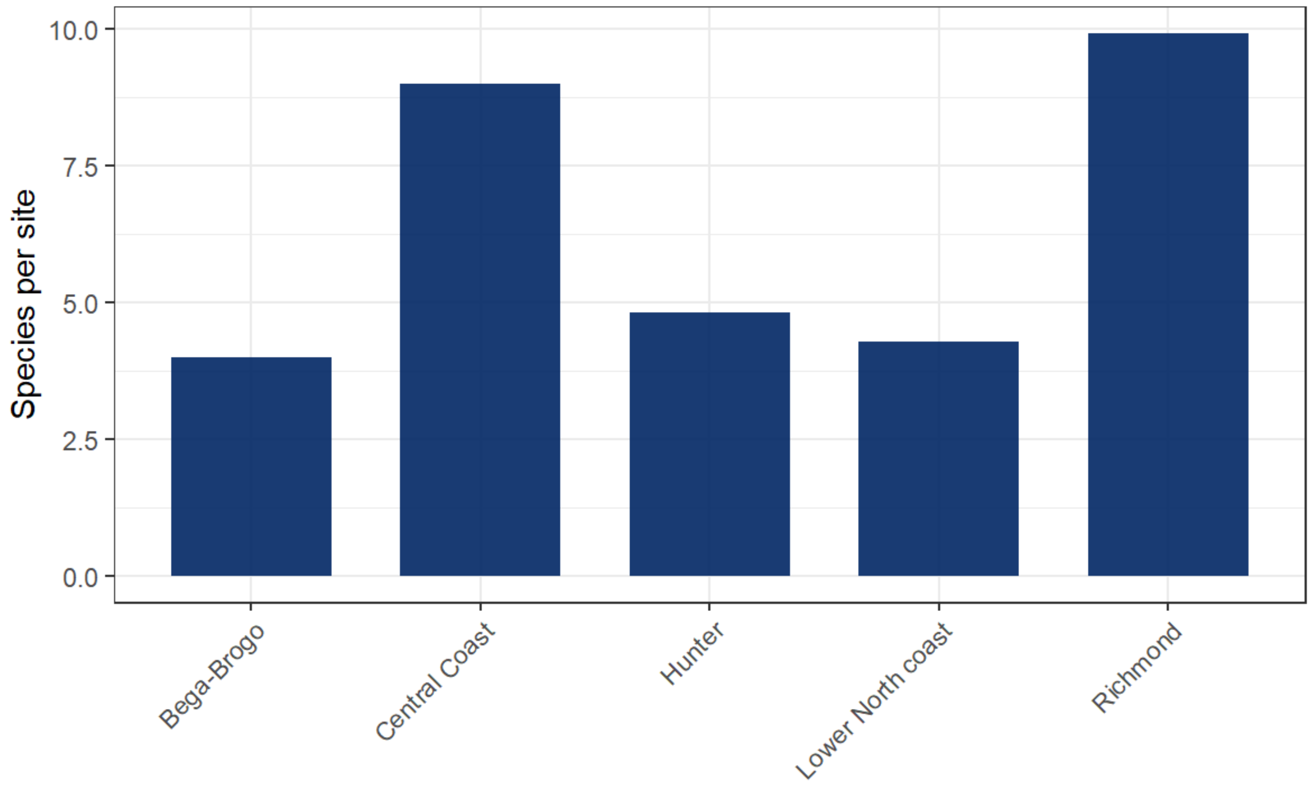


Figure 8 Average number of native species detected per site in each catchment.

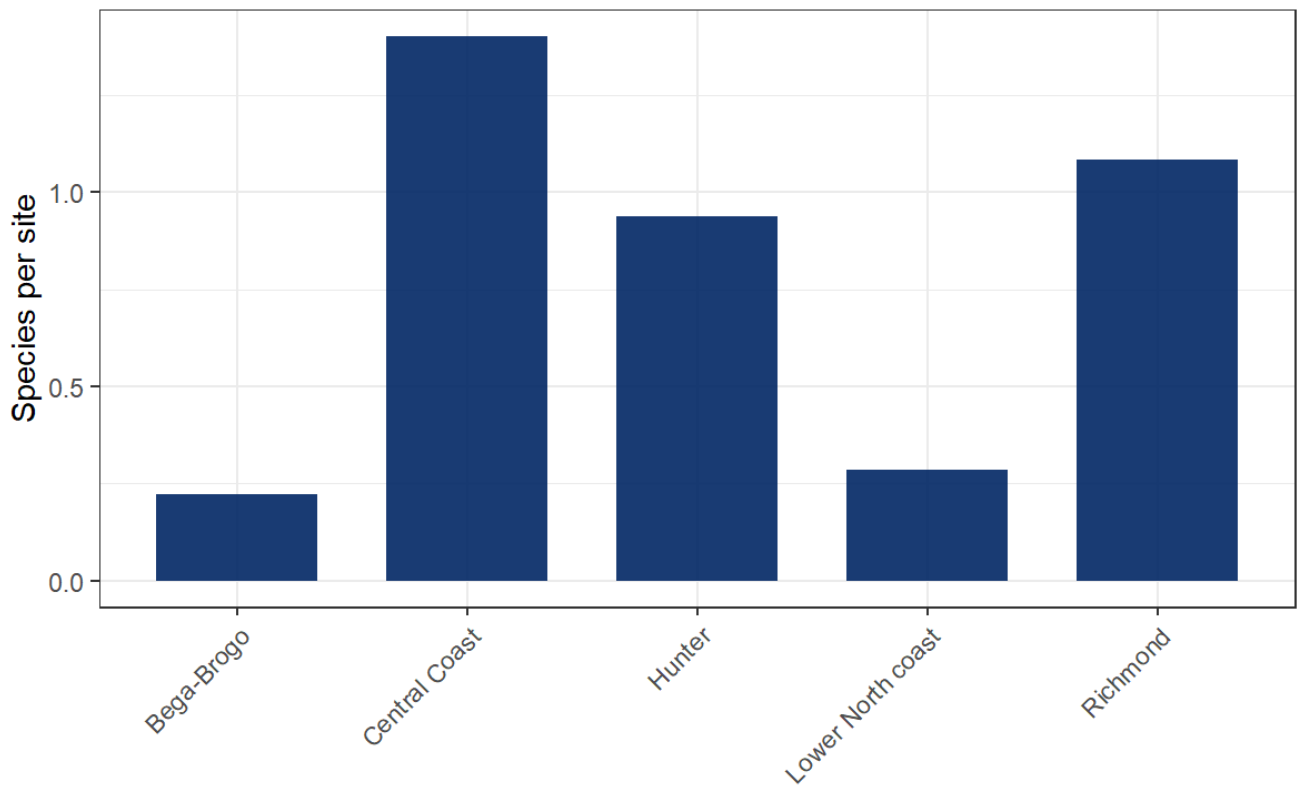


Figure 9 Average number of non-native species detected per site in each catchment.

Richmond River

The Richmond River Unregulated, Regulated and Alluvial water sharing plan area was sampled in June 2021. For this area:

- At least 3 migratory species (Australian bass, grey mullet and eel) were detected in 10 of 12 sites in the Richmond River (Table 1).
- Eastern freshwater cod was detected at one site in the Wilson River at Donaghy's bridge (Table 1).

The Eastern freshwater cod DNA was detected in only 1 out of 8 samples at the site. This result must be interpreted cautiously and any conclusions about the presence of a sustainable Eastern freshwater cod population in the Wilson River must be confirmed with further sampling. Eel-tailed catfish were also detected at all sites in the Richmond River (Table 1).

Species richness in the Richmond River was consistently high across all sites, ranging from 8 to 12 species detected within a site (Figure 10). Gradys Creek near Ford 3 and the upper Richmond River near Gradys Creek Road had the lowest recorded species richness, while the Wilson River near Binna Burra Rd recorded the highest species richness.

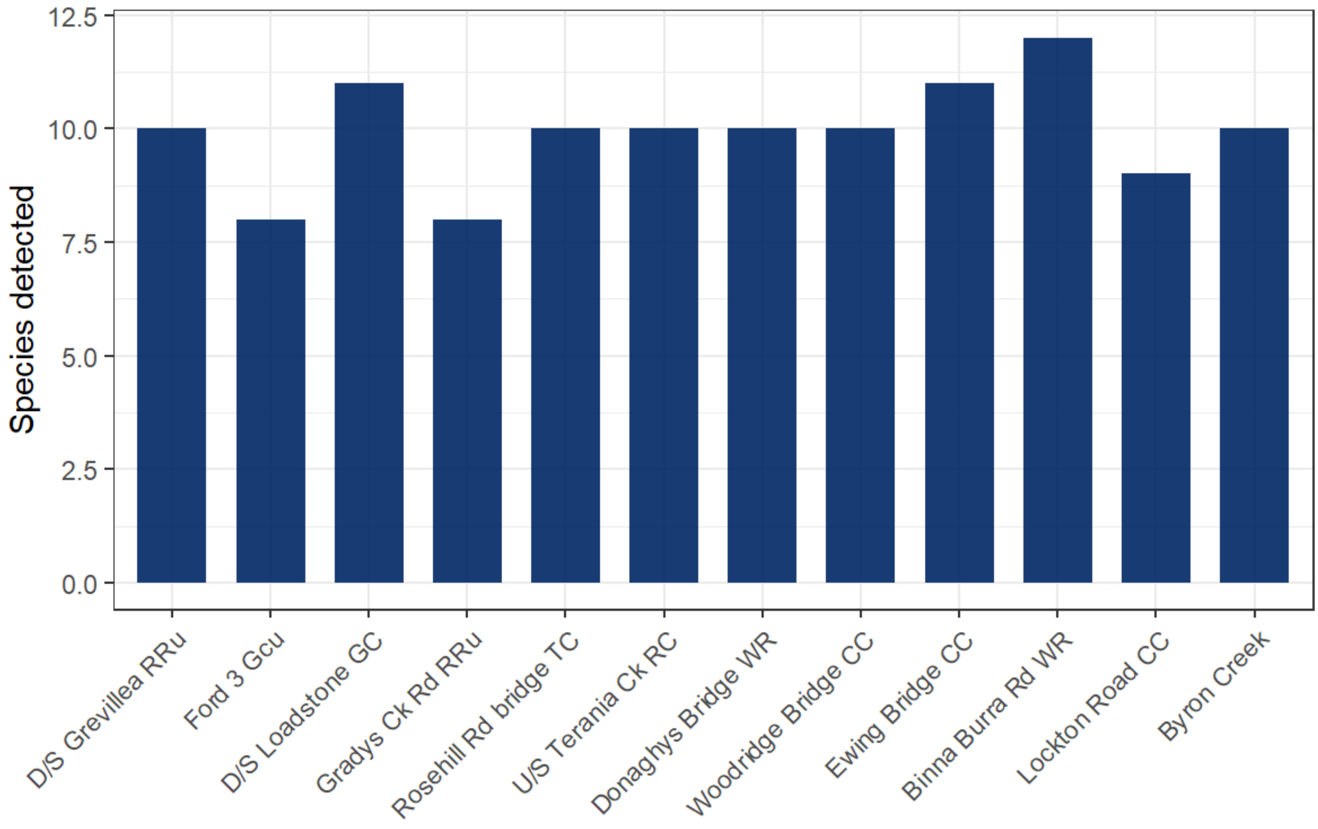


Figure 10 Number of native species detected at each sampling site in the Richmond River catchment. Sites are shown most upstream (left) to most downstream (right). Initials at the end of site names indicate water sources: RR = Richmond River, CC = Cooper Creek, WR = Wilson River, GC= Gradys Creek, TC = Terania Creek, RC = Rocky Creek, lower case u indicates upper reaches of the water source.

Table 1 eDNA detections in Richmond River Unregulated, Regulated and Alluvial WSP in June 2021. Dark blue cells with a + indicate positive detections. Red cells with a / indicate equivocal (insufficient detection rate in sample) and blank cells indicate no detections of the species at that site.

Site	Byron Creek (Booyong Rd)	Coopers Creek (Woodridge Bridge)	Coopers Creek (Ewing Bridge)	Coopers Creek (Lockton Road)	Gradys Creek Upper (Ford #3)	Gradys Creek (D/S Loadstone)	Rocky Creek (U/S Terania Ck)	Terania Ck (Rosehill Rd bridge)	Upp Richmond River (D/S Grevillea)	Upp Richmond River (Gradys Ck Rd)	Wilsons River (Donaghys Bridge)	Wilson River (Binna Burra Rd)
Agassiz's glassfish						+			+			
Genus that includes Australian eels	+	+	+	+	+	+	+	+	+	/	+	+
Carp or goldfish	+	+	+	+			+	+	+	+	+	
Eastern mosquitofish	/		+	/								+
Striped gudgeon	+	+	+	+	+	+	+	+			+	+
Sandy sprat, white pilchard							+				+	+
Empire gudgeon	+							/				/
Western carp gudgeon								/				
Genus that includes carp gudgeons	+	+	+	+			+	+	+	/	+	+
Eastern Freshwater Cod											+	
Gstuary perch or Australian bass	+	+	+	+	+	+	+	+	+	+	+	+
Genus that includes rainbowfish	+	+	+	+	+	+	+	+	+		+	+
Flathead grey mullet, sea mullet	+	+	+	+		/	+	+	+	+		+
Flathead gudgeon	+	+	+	+	+	+	+		+	/	+	+
Dwarf flathead gudgeon			/		+	+			+	+		
Pacific blue-eye		+	+			+						/
Australian smelt	+	+	+	+	+	+	+	+	+	+	+	+
Eel-tailed catfish, freshwater catfish	+	+	+	+	+	+	+	+	+	+	+	+

Lower North Coast

The Lower North Coast Unregulated and Alluvial water sharing plan area was sampled in June 2022.

For this area, eDNA indicated the presence of longfin eel at all sites, and 2 other migratory species (grey and pinkeye mullet) in the lower Nowendoc River above the junction with the Manning River (Table 2).

Native species richness in the Lower North Coast catchment ranged from 3 to 8 species detected per site (Figure 11). The Curricabark, Cooplacurripa and lower Manning rivers had the lowest recorded species richness while the lower Nowendoc River had the highest. The Nowendoc River at that site had 8 identified species present, while only 3 or 4 species were detected at the remaining 6 sites (Table 2).

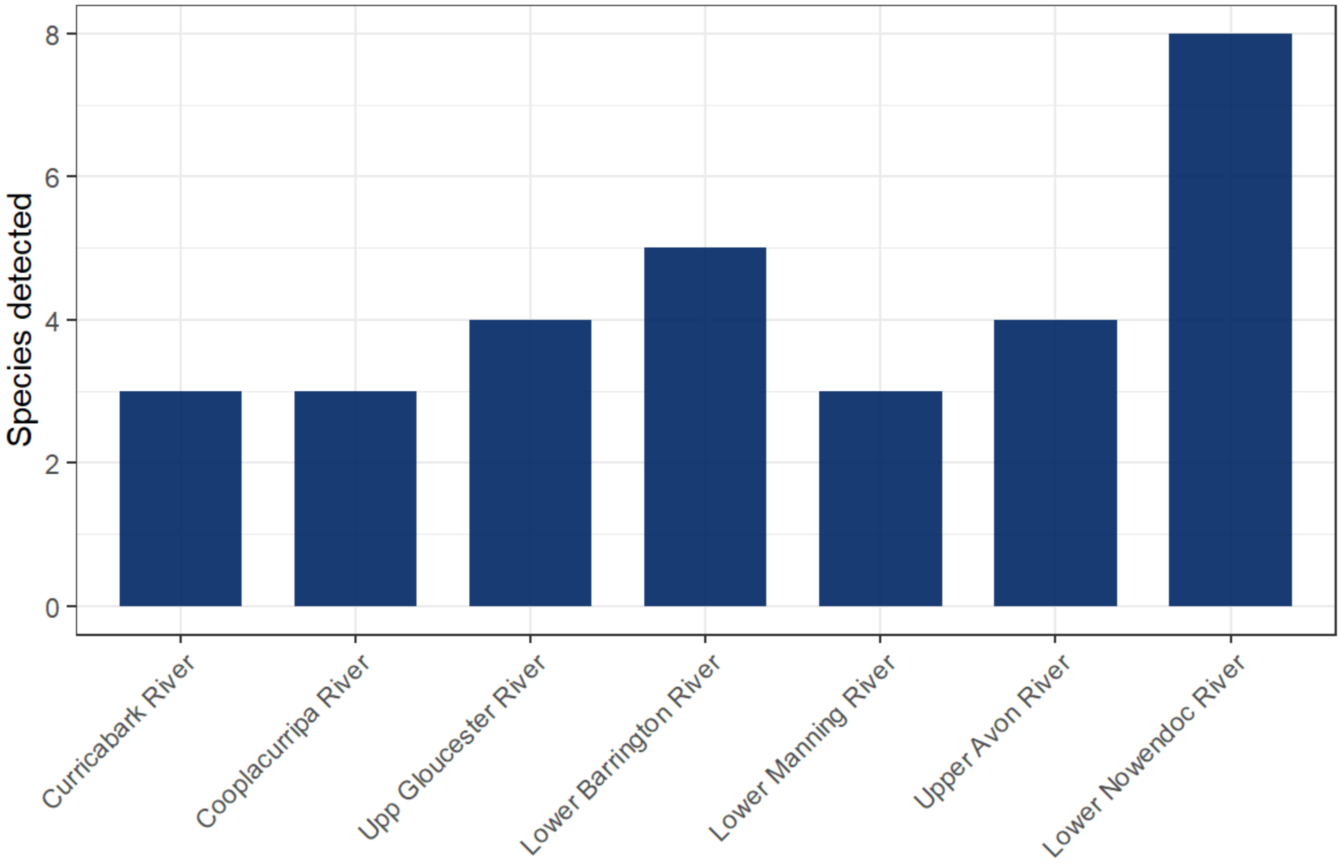


Figure 11. Number of native species detected at each sampling site in the Lower North Coast catchment. Sites are shown most upstream (left) to most downstream (right).

Table 2 eDNA detections in Lower North Coast Unregulated and Alluvial WSP in June 2022. Dark blue cells with a + indicate positive detections. Red cells with a / indicate equivocal (insufficient detection rate in sample) and blank cells indicate no detections of the species at that site.

Site	Upper Avon River	Upp Gloucester River	Cooplacurripa River	Curricabark River	Lower Barrington River	Lower Manning River	Lower Nowendoc River
Unknown Fish sp.	/	+	+	+	+	+	+
Tamar goby							
Australian shortfin eel							
Australian longfin eel	+	+	+	+	+	+	+
Common galaxias							
Genus of Carp Gudgeons							+
Flathead grey mullet, Sea mullet					/		+
Genus of salmon and trout							
Australian bass							/
Flathead gudgeon	/						/
Dwarf flathead gudgeon		+			/		
Genus of flathead							
Australian freshwater herring							
Australian grayling							
Compressed goby, Largemouth goby							
Australian smelt	+	+	+	/	+	+	+
Pinkeye mullet							+
Goldfish							+
Common carp, European carp				/			
Eastern mosquitofish							
Brown trout							

Hunter River

The Hunter River Unregulated and Alluvial water sharing plan area was sampled in June 2022. For this area:

- Australian bass were found at 6 sites (Wollombi Brook, Allyn, Paterson and Williams Rivers),
- Pinkeye mullet were present at 3 sites (Chichester and Williams Rivers) and grey mullet were found at the Lower Goulburn River, Wollombi Brook, and Paterson River (Table 3).

Native species richness was highly variable in the Hunter River catchment, with a range from 2 to 9 species detected per site (Figure 12). Several sites in the mid to upper reaches of the catchment had 3 or fewer native species detected.

Wollombi Brook and the Williams River appeared important for diversity within the catchment, with high species richness in the upper and lower reaches of both waterways. There was also a general trend of species richness increasing from upstream to downstream, towards the river mouth.

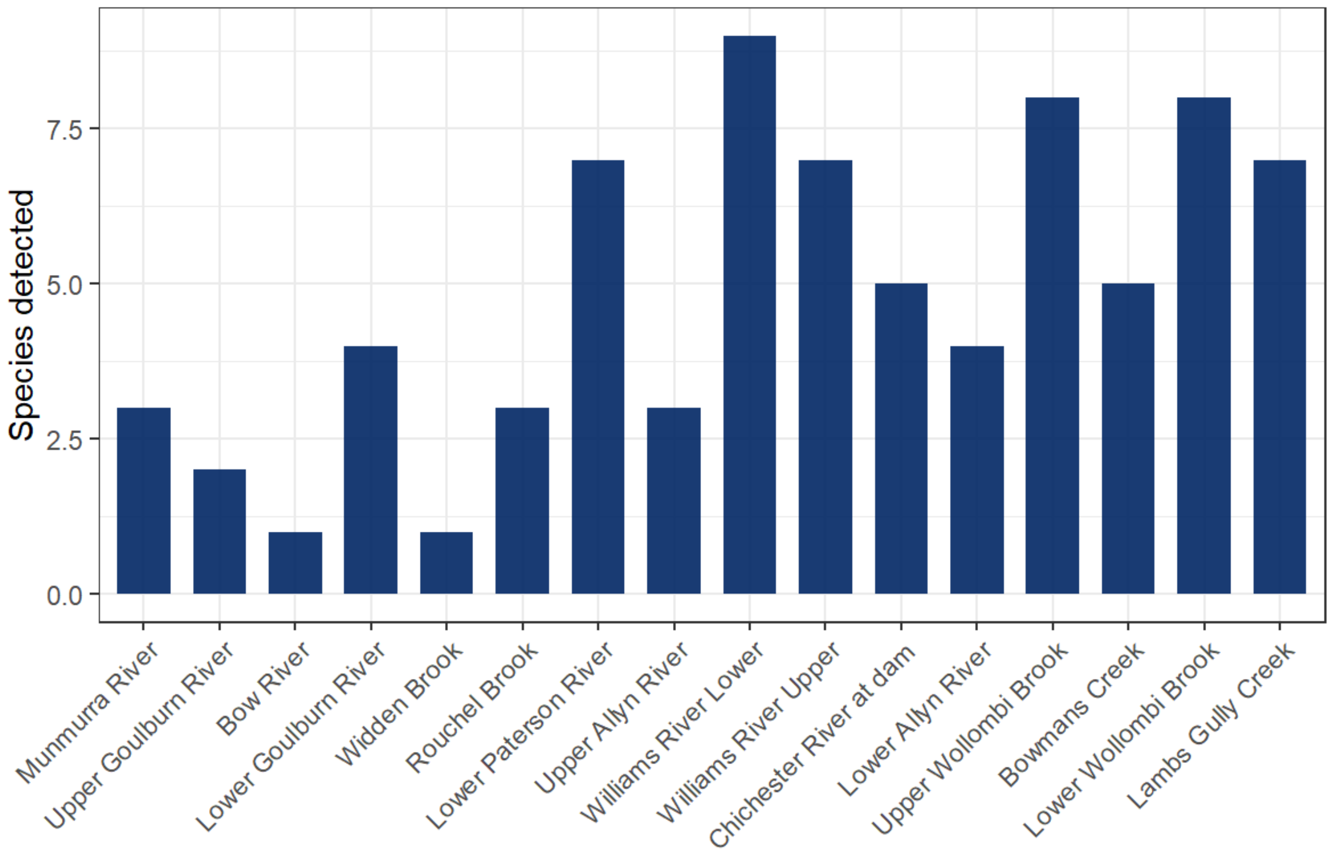


Figure 12 Number of native species detected at each sampling site in the Hunter River catchment. Sites are shown most upstream (left) to most downstream (right).

Table 3 eDNA detections in Hunter River Unregulated and Alluvial WSP in June 2022. Dark blue cells with a + indicate positive detections. Red cells with a / indicate equivocal (insufficient detection rate in sample) and blank cells indicate no detections of the species at that site.

Site	Rouchel Brook	Lambs Gully Creek	Upper Goulburn River	Lower Goulburn River	Munmurra River	Widden Brook	Bow River	Bowmans Creek	Upper Wollombi Brook	Lower Wollombi Brook	Lower Paterson River	Upper Allyn River	Lower Allyn River	Chichester River at dam	Williams River Upper	Williams River Lower
Unknown Fish sp.		+		/	/			+	/	+	/	+	+	+	/	+
Tamar goby																
Australian shortfin eel											+					
Australian longfin eel	+	/	/	+	+		/		+	+	+	+	+	+	+	+
Common galaxias																
Genus of Carp Gudgeons		+							+	+					/	+
Flathead grey mullet, Sea mullet	/			+				/	+	+	+					/
Genus of salmon and trout																
Australian bass		/						/	+	+	+		+	+	/	+
Flathead gudgeon		/							/	+	+					/
Dwarf flathead gudgeon		+						/	+	+					+	+
Genus of flathead																
Australian freshwater herring																
Australian grayling																
Compressed goby, Largemouth goby																
Australian smelt	+	+	+	+	+	+		+	/	+	+	+	+	+	+	+
Pinkeye mullet														+	+	+
Goldfish									+							
Common carp, European carp	+			+	/	/	+	+	+	+	+				+	+
Eastern mosquitofish			/	/						/						
Brown trout																

Central Coast

The Central Coast Unregulated and Alluvial water sources water sharing plan area was sampled in June 2022.

For this area, eDNA indicated the presence of Australian bass at 4 sites, grey mullet at both Mangrove Creek sites and equivocal evidence of pinkeye mullet at 3 sites (Table 4).

Native species richness in the Central Coast catchment was high at most sites, ranging from 5 to 14 native species detected per site (Figure 13). Upper Jilliby creek had the lowest richness with 5 species detected. All other sites detected 8 species or more, with Mangrove creek recording 14 different native species.

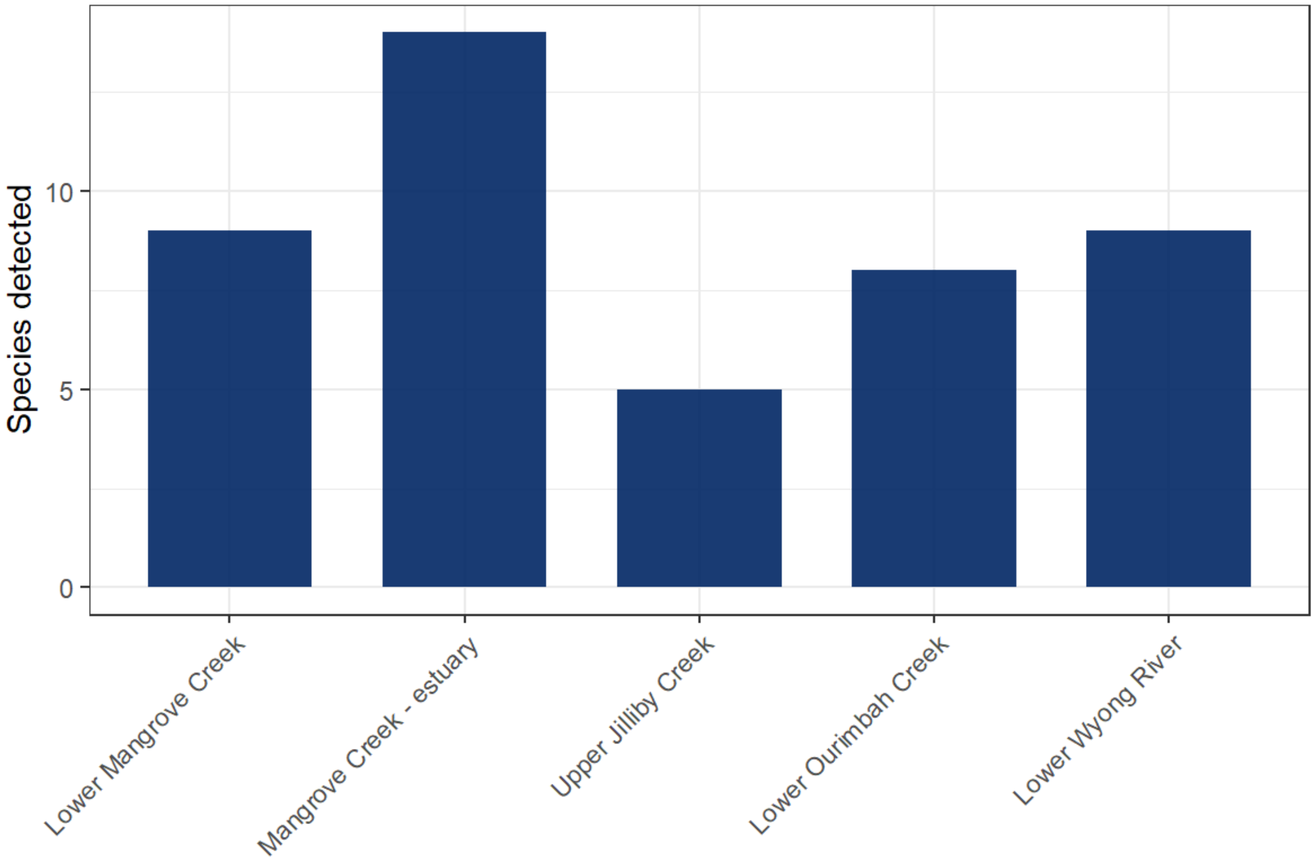


Figure 13 Number of native species detected at each sampling site in the Central Coast catchment. Sites are shown most upstream (left) to most downstream (right).

Table 4 eDNA detections in Central Coast Unregulated and Alluvial WSP in June 2022. Dark blue cells with a + indicate positive detections. Red cells with a / indicate equivocal (insufficient detection rate in sample) and blank cells indicate no detections of the species at that site.

Site	Upper Jilliby Creek	Lower Wyong River	Lower Mangrove Creek	Mangrove Creek - estuary	Lower Ourimbah Creek
Unknown Fish sp.	+	+	+	+	+
Tamar goby				+	
Australian shortfin eel					
Australian longfin eel	+	+	+	+	+
Common galaxias				/	
Genus of Carp Gudgeons	+	+	+	+	+
Flathead grey mullet, Sea mullet		/	+	+	/
Genus of salmon and trout					
Australian bass		+	+	+	+
Flathead gudgeon		+	+	+	
Dwarf flathead gudgeon	+	+	+	+	+
Genus of flathead				/	
Australian freshwater herring			+	/	
Australian grayling					
Compressed goby, Largemouth goby				/	
Australian smelt	/	+	+	+	+
Pinkeye mullet		/		/	/
Goldfish			+	/	/
Common carp, European carp			+	+	/
Eastern mosquitofish	+	/	/		
Brown trout					

Bega-Brogo and Murrah-Wallaga Rivers

The Bega Unregulated, Regulated and Alluvial water sharing plan area and Murrah-Wallaga Unregulated and Alluvial water sharing plan areas were sampled in June 2022. As of June 2022, fish were sampled for monitoring and evaluation reporting at 8 sites in the Bega area and one site in the Murrah-Wallaga area.

Our preliminary results indicate that:

- Native species richness in the Bega and Murrah-Wallaga catchments was relatively low, with 7 out of the 9 sampling sites recording 4 or fewer detections of native species (Figure 14).
- Lower Bemboka and Lower Brogo Rivers appeared important for species richness within the catchment, recording 7 species at both sites.
- Species richness appeared to increase moving downstream towards the river mouth, however further sampling is required to confirm this.

The key species of interest in the region is the Australian grayling. This is an endangered migratory species that has been detected only occasionally on the NSW south coast over the last 40 years. It has not been detected north of the Clyde River since the 1970s despite several surveys (Gehrke et al. 2002).

Environmental DNA surveys from June 2022 have indicated only minimal evidence of migratory or threatened species in the Bega and Murrah-Wallaga water sharing plan areas (

Table 5). Of the species of interest:

- There was equivocal evidence of Australian bass at 2 sites (Lower Brogo and Bemboka rivers).
- There was equivocal evidence for Australian grayling at one site (Lower Brogo) and no evidence of the 2 mullet (grey and pinkeye) species at any sites.
- Only longfin eel, which is a ubiquitous migratory species, was detected at 6 sites.

The partial indication of Australian grayling in the Brogo River suggests the species is persisting in the catchment. It is not yet clear where key habitats and drought refuge may be located and how the Bega water sharing plan may be influencing population change or distribution. Further targeted studies will be developed in consultation with the Department of Primary Industries — Fisheries and other research teams in 2023 to address this question.

Table 5 eDNA detections in Bega Unregulated, Regulated and Alluvial WSP and Murrah-Wallaga Unregulated and Alluvial WSP in June 2022. Dark blue cells with a + indicate positive detections. Red cells with a / indicate equivocal (insufficient detection rate in sample) and blank cells indicate no detections of the species at that site. Evidence for presence of Australian Grayling and other migratory species in these areas was equivocal at all sites where detections were recorded.

Site	Candelo Creek	Lower Bemboka River	Upper Bemboka River	Colombo Creek	Tantawangalo Creek	Double Creek	House Creek	Lower Brogo River	Murrah River
Unknown Fish sp.	+	+		/	+	+	/	+	
Tamar goby									
Australian shortfin eel		/			/	/	+	+	/
Australian longfin eel	+	+	+	+	+	+	/	/	
Common galaxias									/
Genus of Carp Gudgeons		/							
Flathead grey mullet, Sea mullet									
Genus of salmon and trout			+						
Australian bass		/						/	
Flathead gudgeon									
Dwarf flathead gudgeon		/						/	
Genus of flathead									
Australian freshwater herring									
Australian grayling								/	
Compressed goby, Largemouth goby									
Australian smelt	+	+	+	+	+	+		+	
Pinkeye mullet									
Goldfish									
Common carp, European carp									
Eastern mosquitofish									
Brown trout			/		+				

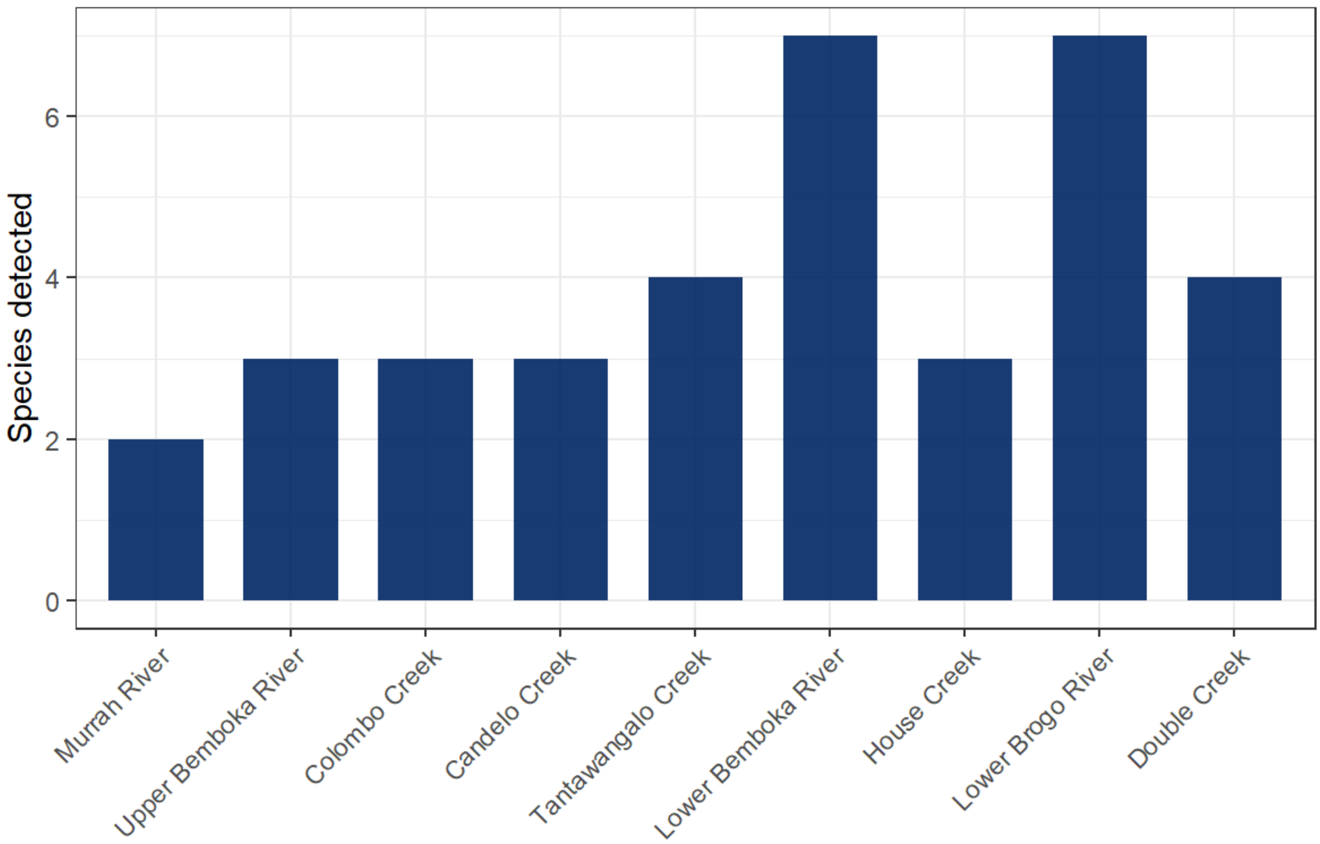


Figure 14 Number of native species detected at each sampling site in the Bega River catchment. Sites are shown most upstream (left) to most downstream (right).

Coastal platypus monitoring

The samples collected during the coastal fish monitoring, evaluation and reporting program from 2021 and 2022 were also analysed for the presence of platypus. This analysis found:

- Platypus were detected in every catchment, however the occurrence of these detections varied considerably (Figure 15).
- The Lower North Coast had the highest number of positive detections, showing platypus were clearly present at 6 out of the 7 sites sampled.
- The Central Coast had relatively low positive platypus detections at 40% of all sites sampled. However, it had equivocal detections at all other sites, suggesting platypus may have been present at every site in the Central Coast.
- The Hunter River had the lowest number of platypus detections, with positive detections at 2 out of 16 sites and equivocal detections at another 4.

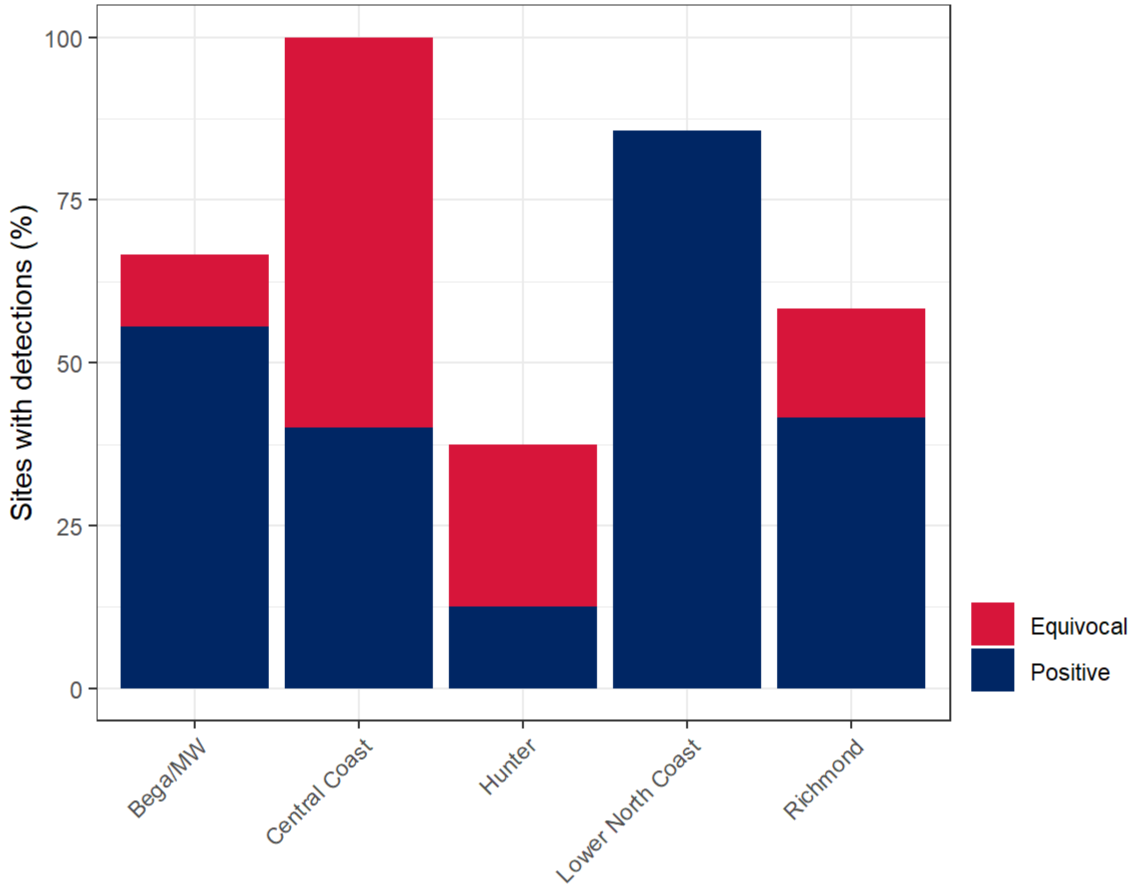


Figure 15. Percentage of sites with Platypus detections across all sampled catchments. Blue indicates a clear positive detection and red indicates an equivocal detection. MW = Murrah-Wallaga.

Conclusions

Our preliminary findings were:

- Native species richness was highly variable across catchments, with the Richmond River and Central Coast catchments having the highest average species richness.
- 26 native species and 4 non-native species were detected throughout the NSW coast.
- Migratory fish such as Australian bass and sea mullet were detected within every catchment, typically in sites located in the lower reaches of the catchment.
- There may be diversity hotspots within catchments, such as Wollombi Brook and the Williams River in the Hunter catchment, which appeared to be important refuges for native fish species.
- Endangered Australian grayling were detected at one site in the Bega catchment and Eastern freshwater cod at one site in the Richmond catchment.
- Platypus were detected in every catchment, however the occurrence of detection was highly variable.

Next steps

Our results have shown the presence of migratory fish throughout the NSW Coast and potential hotspots of diversity and potential areas of key habitat important for native fish. We are planning for annual sampling of all coastal catchments to begin in Autumn 2023.

The results from further sampling will help us to understand the flow requirements for fish movement between the lower and upper reaches of coastal river catchments. More sampling is required to identify waterways which are particularly important for native fish diversity, and to confirm the presence of threatened species such as the Australian grayling and Eastern freshwater cod.

Further detailed studies and monitoring activities, in conjunction with the Environment and Heritage Group of the Department of Planning and Environment and the Department of Primary Industries — Fisheries, will be required to identify critical trends in population structure and distribution, and how these respond to hydrological alteration. The results from this study will be used to inform coastal water sharing plans, flow management decisions and environmental water requirements, particularly during flow conditions when connectivity is most at risk.

Recommendations

No recommendations are made at this time.

Freshwater turtles

Freshwater turtles are one of the world's most threatened vertebrate groups (Lovich et al. 2018). They play an important role as scavengers in freshwater ecosystems, as they contribute to nutrient cycling and improve the water quality in rivers (Santori et al. 2020). Understanding the response of freshwater turtle populations to changing environmental conditions is therefore critical to assist in maintaining biodiversity in aquatic environments in NSW.

In NSW, there are 7 freshwater turtle species with records of at least one species in all NSW water sharing plan areas. However, to date, the flow requirements of turtles are not considered within water sharing plans or the Murray-Darling Basin Plan. This is primarily due to a lack of targeted research and monitoring on the flow-ecology of freshwater turtles (Deeth and Coleman 2022).

Detailed information on the relationship between flow and specific components of a turtle species life history is critical to improving our understanding of how water management can protect freshwater turtles. This section summarises projects that monitor freshwater turtles and identify the influence of flow regimes and water management decisions on turtle populations.

Figure 16 Broad shelled turtle (*Chelodina expansa*) from the Gwydir catchment. Photo credit: Dan Coleman

Turtle movement in response to river flow in the northern Murray-Darling Basin

Project Team

Daniel Coleman, Anna Helfensdorfer, Lauren MacRae, and Deborah Bower (University of New England).

Project collaborators

This project is a collaboration with the University of New England.

Introduction

Movement to breed, disperse and colonise new habitats is critical for most organisms. Flow has been shown to stimulate movement of native fish to breed and access new habitats. However, the influence of flow on turtle movements remains a key knowledge gap for this group of animals.

Several turtle species are widespread within the Murray-Darling Basin. Research to identify if flow is important for dispersal of these species is required to understand how water management affects turtles. This project involves tagging the broad-shelled turtle (*Chelodina expansa*) and the Murray river turtle (*Emydura macquarii*) to track movement responses to flow in the Gwydir and Barwon-Darling valleys (Figure 17).

Figure 17. The first image shows *Chelodina expansa* (broad-shelled turtle) being released into the Gwydir River after an acoustic tag was attached. The second image shows *Emydura macquarii* (Murray river turtle) with an acoustic tag being attached at the Gingham Waterhole. Photo credit: Daniel Coleman.

Project aims

This project will track the movement of turtles throughout rivers in the northern Murray-Darling Basin to identify the potential effects of water management on their population, breeding success and dispersal. The specific aims relate to the following questions:

Key project questions

- Do freshwater turtles disperse within the Gwydir and Barwon-Darling Rivers and are there specific flows required to trigger dispersal?
- Do channel dwelling freshwater turtles move between the river and floodplain under specific events or are they isolated populations?

Link to water management activities

- Evidence of turtle movements will refine delivery and evaluate the effectiveness of the Gwydir Environmental Contingency Allowance*.

**The Environmental Contingency Allowance is a volume of water set aside for environmental purposes in the* Water Sharing Plan for the Gwydir Regulated River Water Source 2016.

- Evidence of turtle movements will inform the effectiveness of the Gwydir 3 Tributary rule* and supplementary flow protection in the Gwydir.

**The Gwydir 3 Tributary rule protects combined flows (up to 500 ML/d) coming from the Horton River, Myall Creek and Halls Creek tributaries into the Gwydir regulated river. This water is protected until it reaches the Gwydir Wetlands.*

- Evidence of turtle movements during A, B and C Class cease to pump events to evaluate water sharing plan rule effectiveness.

**Class licences represent the available entitlement able to extract from the lowest flows (A class), slightly higher flows (B class) and highest CtP flow class (C class).*

- Evidence that fish passage targets are also appropriate to allow turtle movement across key barriers in the Barwon-Darling.

Methods

We are using acoustic tracking methods to document the movement of adult turtles within river systems. Up to 80 adult turtles were tagged across the Gwydir and Barwon-Darling water sharing plan areas with active flow gauging stations. Acoustic arrays are currently set up using Vemco VR2 in the Barwon-Darling and Gwydir regulated rivers (Figure 18). These receivers detect tagged turtles if they move within range of approximately 300 m.

The frequency of movement, number of individuals moving, and distance of turtle movement will be analysed against flow at the relevant gauge. This information will be used to identify if specific timing, magnitude and other flow metrics stimulate turtle movement. The utilisation of floodplain habitats (for example, wetlands) by turtles will also be investigated.

With this improved knowledge, we will better understand the environmental water requirements of the 2 turtle species. By understanding their water requirements we will be able to evaluate the adequacy of the current water sharing plan rules to protect (a) the flows required for small and large-scale turtle dispersal, and (b) the preferred habitats of these turtle species.

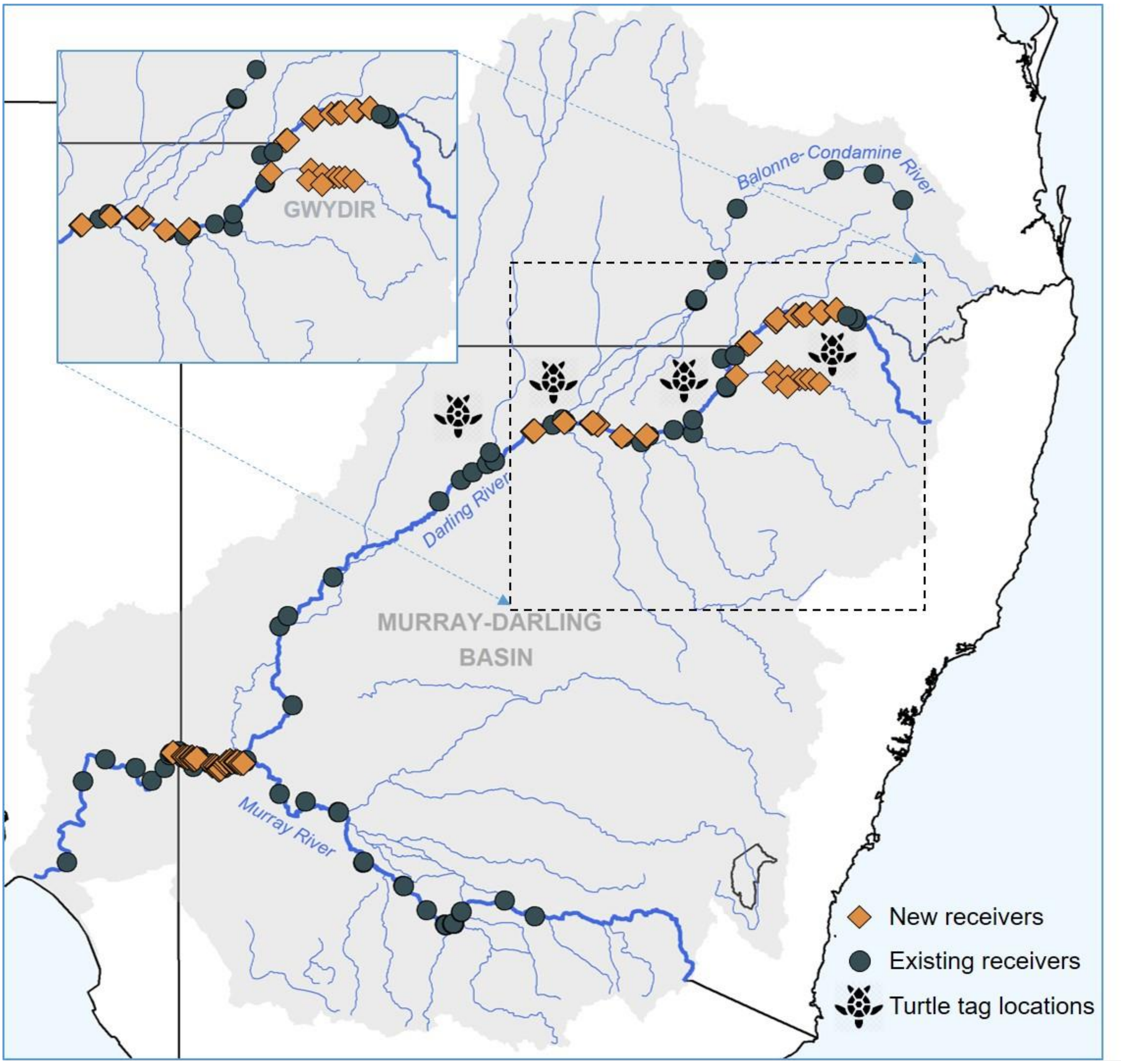


Figure 18. Map of new and existing VR2 acoustic receivers in the Murray-Darling Basin. Turtle tagging locations are identified on the map and the inset highlights the study area for freshwater turtle movement.

Results

In 2021/22 11 new receivers were installed in the Gwydir and Gingham water sources in the Lower Gwydir. In addition, 20 broad-shelled turtles and 20 Murray River turtles were tagged in April 2022. Another 40 turtles will be tagged in the Barwon-Darling in early 2023. These turtles will provide movement data for the next 5 years, allowing us to analyse movement patterns in both wet and dry years.

Conclusions

No conclusions are drawn at this time.

Recommendations

No recommendations are made at this time.

Next steps

Another 40 turtles will be tagged in the Barwon-Darling in early 2023. These turtles will provide movement data for the next 5 years, allowing us to analyse movement patterns in both wet and dry years.

The first results are expected in Autumn 2023 and will be reported in the 2022-23 report.

Frogs

Frogs have declined globally, with over 30% of species threatened with extinction. Flow alteration has been linked to reduced genetic diversity (Peek et al. 2021), population declines (Kupferberg et al. 2012), community composition changes (Wassens and Maher 2011), and is listed as a threat for numerous frog species (Gillespie and Hines 1999).

In NSW, there are at least 50 native frog species that breed and live in river and creek habitats (hereafter 'stream frogs'). Of these, 18 species are listed under the NSW Biodiversity and Conservation Act 2016 (BC Act) as at risk of extinction. Stream frogs are ideal target species for monitoring and assessing environmental outcomes from environmental water management due to their dependence on flow and their importance in aquatic ecosystems (McGinness et al. 2014). This section summarises projects that monitor stream frogs and identify the influence of flow regimes and water management decisions on frog populations.

Environmental flow requirements for stream frogs

Project Team

Daniel Coleman, Bec Wood and Michael Healey.

Project collaborators

This project is led by the department.

Introduction

Stream frogs are dependent on river flows and in-channel stream habitats for their survival. River flows support frog reproduction, juvenile development, provide food resources and maintain suitable habitats for all life stages. Until recently there has been relatively little research to understand and incorporate the flow requirements of stream frogs into environmental flows (Wassens et al. 2008, Ocock 2013, Ocock et al. 2014, Railsback et al. 2016).

Some limited effort has been made to identify and develop the environmental flow requirements (Walcott et al. 2020) needed to support the conservation of stream frogs that occupy flowing streams in coastal drainages and western slopes of the Murray-Darling Basin.

Although there is documented evidence of the significance of flows for frogs on the floodplain and in wetlands (Wassens and Maher 2011, Kupferberg et al. 2011, 2012, Hunter and Gillespie 2014, Railsback et al. 2016, Thomas et al. 2019, Littlefair et al. 2021), there has been little attempt to prioritise flow management for stream frogs which occur in in-channel stream habitats (for example, pools and riffles). This study is the first comprehensive review and development of general flow requirements for stream frogs using a traits-based analysis and systematic literature review.

Figure 19. Stuttering frog (*Myxophes balbus*), a stream breeding specialist which uses riffle and pool habitats for spawning and as a tadpole. The tadpoles can take up to 15 months to metamorphose into adults. Photo credit: Jodie Rowley.

Project aims

This project aims to develop stream frog functional groups and determine the basic flow requirements for each functional group. This will then be used to prioritise monitoring and evaluate whether water sharing plans are providing the correct hydrological conditions for stream frogs.

Key project questions

- Can stream frogs be categorised into broad functional groups based on their flow dependent traits?
- What are the flow requirements for stream frogs?
- Which species are most dependent on in-channel flows and sensitive to flow alteration?

Link to water management activities

- Determine key flow requirements for stream frogs to allow a hydrological assessment of frog outcomes
- Use frog flow requirements to test whether cease to pumps protect the low flow requirements of stream frogs in NSW.

Methods

We compiled information on 8 ecological and life history traits that we hypothesised were linked to stream flow for 50 stream frog species that occur within NSW into a species traits database. The life history and breeding habitat association traits for the frog species were used to develop flow-dependent groups (Anstis 2017). Traits included in the study were: male size, egg clutch type, egg clutch size, egg stage duration, tadpole body type, tadpole duration, stream breeding dependence and breeding habitat type.

The species traits dataset was analysed using agglomerative hierarchical clustering (AHC) using the Ward method (ward.D2) to split the species into clusters based on trait similarities. These groups were further refined and general flow requirements were established for each of the groups, using a systematic literature review to link the life history and species ecology to flow.

We reviewed the traits dataset and the literature from the systematic review to refine the original 4 functional groups produced by a clustering analysis that groups species based on their shared traits. An additional functional group, or sub-group was developed if the literature highlighted a clear distinction in the specific flow requirements of some species within the original clusters. Each available reference was reviewed to identify if specific flow characteristics were mentioned for the main life stages: breeding, eggs, tadpoles and adult habitat. The flow requirements for each functional group were then summarised to ensure they encompassed the needs of all species. We then developed a simplified conceptual model cross section to visualise what flows should support the requirements of each group.

Results

Our study shortlisted 50 stream frogs, which were broadly split into 4 traits-based groups using the clustering analysis. These groups were then refined into 2 main groups (facultative and obligate stream spawners) and 5 subgroups using the trait analysis and previous research. Facultative spawners use multiple environments (for example, farm dams), not just streams, whilst obligate stream spawners only breed in streams and can be considered heavily dependent on these habitats. We have further developed these functional groups by suggesting general flow requirements for each subgroup which can be used to guide future research and environmental flows for these stream frogs (Table 6).

We suggest that the obligate stream spawners are the stream frogs most sensitive to flow alteration due to their dependence on in-channel flow related habitats. This includes 15 species and 2 subgroups.

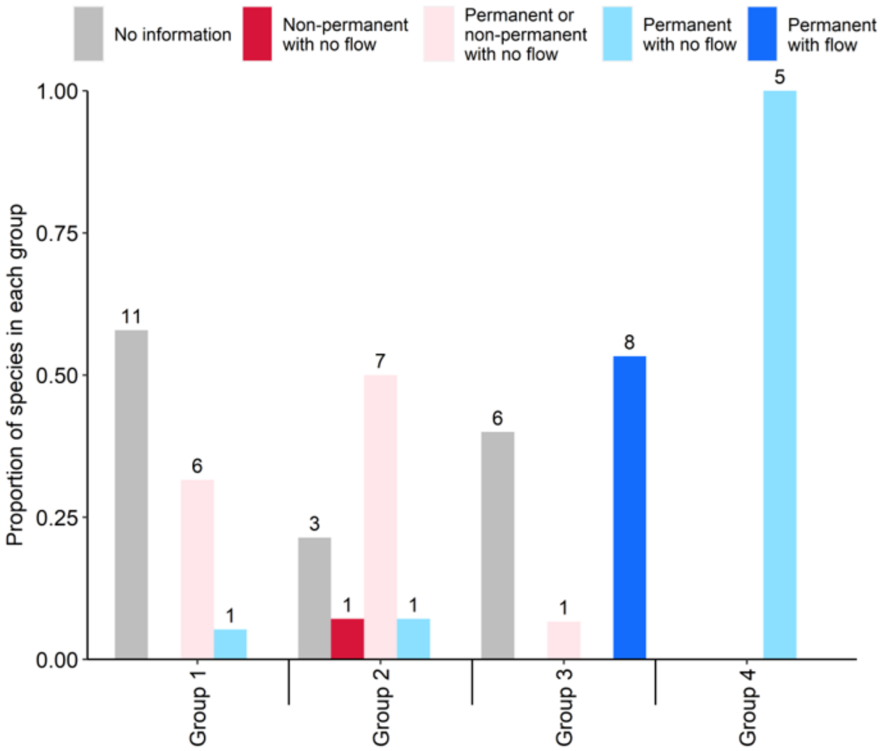


Figure 20 Summary of the systematic review results showing the proportion of species in each group categorised under the different broad flow requirements. The literature was categorised as no information, non-permanent with no flow, permanent or non-permanent with no flow, permanent with no flow, or permanent with flow. The values range from 0 (no species) to 1 (all species) within each group and the numbers on top of each bar is the number of individual literature results for that category and group.

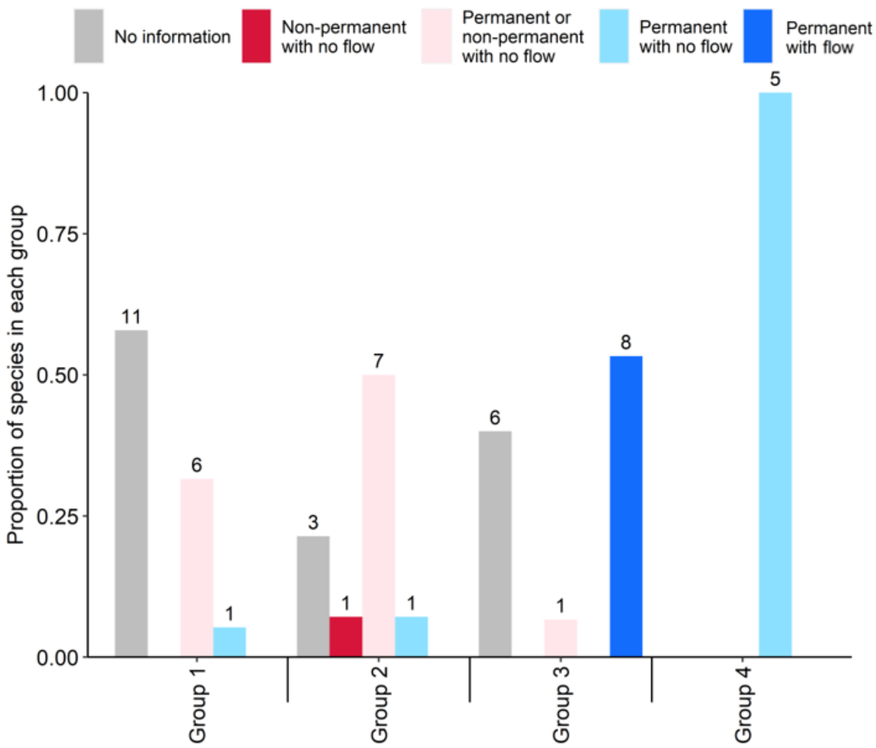


Figure 21 Summary of the systematic review results showing the proportion of species in each group categorised under the different broad flow management threats. The literature was categorised as drying, any flow alteration (not specified), flow regulation, low flow alteration, and water quality. The values range from 0 (no species) to 1 (all species) within each group and the numbers on top of each bar is the number of individual literature results for that category and group.

Table 6 Summary of stream frog functional groups, general flow requirements, and functional flows (component, characteristic and metric) for key life-history stages of stream frogs.

Flow-dependent group	General flow requirements	Flow characteristics & metric
Facultative stream spawners Subgroup 1 Tusked frog, desert froglet, common eastern froglet, knife-footed frog, wide-mouthed frog, eastern water-holding frog, rough frog, giant burrowing frog, Fletcher's frog, eastern banjo frog, giant banjo frog, striped marsh frog, red-eyed tree frog, peron's tree frog, brown tree frog, wallum rocket frog, wallum sedge frog, Victorian tree frog, southern bell frog, whirring tree frog, broad-palmed rocket frog, striped rocket frog, painted frog, ornate burrowing frog	This subgroup is associated with temporary and permanent non-flowing stream habitats. These include but are not limited to in-channel pools, chain of ponds, stream margin habitats, and flooded areas. Flow rates required to inundate breeding habitats are critical but maintaining flowing water is not.	Timing: Breeding months + tadpole duration. Duration: Number of days required to inundate breeding habitat for tadpole duration (species specific).
Facultative stream spawners Subgroup 2 Green stream frog, Littlejohn's frog, whistling tree frog, alpine tree frog	**Very low flows** This subgroup has a strong association with flowing creeks and stream habitats but can breed in non-stream habitats. Maintaining very low flows or higher is important to protect stream habitats. The importance of high flows is unknown.	Timing: Breeding months + tadpole duration. Duration: No more than the maximum number of very low flow days (location specific).
Facultative stream spawners Subgroup 3 Mountain frog, Loveridge's mountain frog, Pugh's mountain frog, Richmond mountain frog, sphagnum frog	**Cease to flow** Require moist habitat provided by seepage and flow. Minimising cease to flow periods for this subgroup is critical to avoid adult habitat drying.	Timing: All year. Duration: No more than the maximum number of cease to flow days (location specific).
Obligate stream spawning specialists Subgroup 1 Barrington tops tree frog, Booroolong frog, Blue Mountains tree frog, Davie's tree frog, stony creek frog, southern green stream frog, Pearson's stream frog, peppered tree frog, spotted tree frog, New England tree frog, eastern stony creek frog	**Cease to flow** Minimising cease to flow periods for this subgroup is critical to ensure adult habitat is protected and the reproductive life-cycle is completed	Timing: All year. Duration: No more than the maximum number of cease to flow days (location specific).
	Very low flows & Base flows Protecting very low flows and base flows are likely to be important for all life stages, but particularly breeding and tadpole development success during the reproductive period. Stream permanence is critical for all species with flowing sections required for a subset of species that use riffles.	Timing: Breeding months + tadpole duration. Duration: No more than the maximum number of very low flow days (location specific) or the average number of days at base flow magnitude or above.
Obligate stream spawning specialists Subgroup 2 Southern barred frog, great barred frog, Fleay's barred frog, giant barred frog	**Pulse flow** Peak-flows relative to channel/riffle capacity required to cause a river rise and fully inundate riffle habitat and initiate breeding activity	Timing: Breeding months. Duration is short (1-3 days) and should coincide with local rainfall.

Flow-dependent groups

Facultative stream spawners (FSS)

This flow-dependent group includes species that are capable, but not restricted to breeding in-channel stream habitats. There are 3 subgroups within the group.

FSS Subgroup 1

There are 26 species from 9 different genera within this group, with information relating to flow requirements available for only 12 of the species. The preference for standing water habitats suggests permanent flows (for example, baseflows) are not desirable for this subgroup.

In addition, there was very little information on how in-channel flows influence any life-stage for most species within this subgroup. Therefore, the basic flow requirements for stream habitats would relate to the peak rate required to inundate or maintain the breeding habitat (for example, ephemeral pools, wetlands, backwaters and so on) of each species for the duration of tadpole development. These flows would only be relevant during the active breeding period of each species and are highly site-specific.

FSS Subgroup 2

This subgroup is comprised of 4 *Litoria* (tree frog) species which are all strongly associated with in-channel stream habitats, but also breed in non-stream habitats like dams. Defining a general flow requirement for this subgroup is difficult. They are likely to benefit from higher low flows (like baseflows) but their ability to breed in non-flowing habitats suggests it is not crucial. Protecting very low flows and avoiding cease to flow conditions for the duration of the breeding, tadpole development, and adult active period may be important.

FSS Subgroup 3

This subgroup is composed of 5 species of *Philoria* (mountain frogs) which require moist and saturated environments such as seepage lines and boggy soaks within permanent headwater streams. Most tadpoles in this subgroup develop in shallow water-filled cavities which includes water draining through or pooling within burrows in stream banks and around soaks on the rainforest floor (Knowles et al. 2004, Heard et al. 2021). Based on the documented threats, habitat preferences, breeding requirements, and tadpole development of *Philoria* species, a permanent flow in headwaters is required to support the permanency of their boggy seep habitats.

Obligate stream specialists (OSS)

This flow-dependent group is composed of species with strong association with flowing streams, permanent habitats, and flow related threats. This group is considered the most sensitive to changes to in-channel flows based on the amount of literature (35 articles) on flow management threats, and the detailed literature to support the general flow requirements developed in this project.

OSS Subgroup 1

This group contains 11 tree frog species (*Litoria*). Information on life-history links to stream flow was unavailable for 6 species. Breeding activity in this subgroup occurs in or close to streams. All species have submerged eggs which are either attached to rocks or vegetation (Mahony et al. 2001, Anstis 2017)

The relatively large number of references to either general flow alteration, low flow alteration or impacts of flow regulation by dams highlights that this subgroup depends on in-channel stream flows. Based on this information, this subgroup appears to require baseflows to protect flowing habitats and minimise cease to flow periods. The significance of high flows is less clear, but this group may require higher flows to reduce sedimentation in riffles and maintain stream habitats.

OSS Subgroup 2

All 4 of the Barred frog species in this study fall into this subgroup. The obligate stream breeders Southern barred frog, Fleay's barred frog, and the giant barred frog are strongly linked to permanent streams with breeding sites in or near flowing riffles. The final species, the great barred frog, prefers breeding sites in slow flowing streams and pool habitats but has been known to breed in non-stream habitats.

Reduced flows and cease to flow periods resulting in drying out of riffle substrate during breeding and subsequently during the egg development phase would result in egg desiccation and failed reproduction opportunities. Additionally, as these species have a long tadpole phase, we expect this subgroup to require permanent streams and baseflows during the breeding period to protect riffle environments. They should also benefit from pulse events during the breeding period and higher flows to maintain clean riffle breeding habitats.

Conclusions

This is the first comprehensive examination of the importance of flows for stream frogs and has identified critical research and validation required to improve our understanding of stream frog responses to flows. This information will allow water resource managers to consider the environmental water requirements of stream frogs in their decision-making. This will help inform appropriate flow requirements are considered to support key life-stages such as breeding and tadpole development in future water management.

Recommendations

We have shown that at least 15 of NSW's stream frogs are likely to be highly sensitive to changes to low flow hydrology. We have also developed flow requirements for 50 of these species found in NSW (Table 6), which can be used to identify if water sharing plan rules are adequately protecting these flows. We suggest that the evaluation of low flow cease to pump rules at the end of a water sharing plan cycle uses the flow requirements for each species to test the effectiveness of the Plan.

Next steps

A full technical report detailing the methodology, full results and detailed flow requirements of stream frogs will be published in 2023.

Frog distribution monitoring with citizen scientist data

Project Team

Daniel Coleman, Michael Healey, Bec Wood and Jodi Rowley (Australian Museum).

Project collaborators

This project is a collaboration with the Australian Museum.

Introduction

Stream breeding frogs are dependent on flowing water during egg and tadpole stages of their life cycle. Frogs play an important role in stream food webs as both predators and prey, and are a popular and sometimes iconic components of aquatic ecosystems. Alteration to natural flow is listed as a key threat for many threatened stream dependent frogs. This makes them an ideal indicator for monitoring and assessing environmental objectives in water sharing plans developed by the department.

To date, there has been no attempt by the department to monitor and report on frog populations within a water sharing plan cycle, despite their importance in determining the risk to water-dependent ecosystems. To evaluate and guide mitigation measures within water sharing plans, the department needs better data on stream frog distributions in NSW and more information on their specific flow requirements. Without understanding the basic distribution, population status and relationship with flow, the adequacy of water sharing plan rules are difficult to evaluate for these organisms.

Figure 22. A male Southern green stream frog (*Litoria nudidigitus*) calling from riparian vegetation above a flowing stream. This species is a common stream breeding frog species. Photo credit: Daniel Coleman

Citizen science projects are becoming an important source of ecological information. The FrogID project, developed by the Australian Museum, is a national citizen science project using a free mobile app which enables anyone to monitor frogs by recording their calls.

Identification using frog calls is remarkably accurate and minimises disturbance to frogs and their habitats. FrogID helps identify frog species, record locations of frog populations, and build scientific understanding of frogs through a simple, 20-second recording. As many parts of NSW lack scientific records of frogs, particularly for stream-breeding frogs, the use of FrogID to engage the broader community in water management issues, as well as answer specific frog distribution and water requirement questions, is a major aim of this project.

Project aims

This project aims to use the FrogID media outreach and the associated FrogID data set for the purposes highlighted below.

Key project questions

- Does a strategic partnership with a citizen scientist project enhance the department's public presence and increase the data collection for frogs across NSW?
- Can the FrogID data set be used to identify if the distribution of stream frogs is protected within a water sharing plan cycle?
- What is the current known distribution of frog species relative to water use in NSW?

Link to water management activities

- This project will use the FrogID data set to provide a foundation of information to measure distribution changes within a water sharing plan life cycle.
- The distribution of stream frogs will be used to test the hydrological requirements of key species using the flow requirements developed in the stream frogs environmental flow requirements project (as described in Frog Project 1 above). Specifically, whether:
  a. Inform whether water sharing plan low flow cease to pump rules protect very low flows and baseflows to support breeding opportunities
  b. Inform whether water sharing plan low flow cease to pump rules protected stream frogs by preventing enhanced drying and cease to flow events
- The enhanced dataset for stream frog distribution will be used to update the HEVAE and River Condition Index spatial layers.

Methods

This project used the extensive dataset already available from FrogID and collected additional data on stream breeding frogs across NSW in the 2022 calendar year.

Monitoring stream frog breeding responses on the scale provided by FrogID is not feasible with the resources available to the department. Strategic partnerships between various government agencies are becoming a common occurrence. They also provide excellent community engagement tools as FrogID has a large community following.

Using citizen scientists and the high quality FrogID dataset enables a much broader spatial coverage which can be used to document frog diversity and links to flow regimes. This can then be used to evaluate and where possible provide relevant information for water management decisions.

The project will investigate the link between frog breeding occurrence and flow regimes by using the 5 years of FrogID data to:

- Select data points within 5 km of a flow gauge and no major tributary input.
- Calculate antecedent hydrology metrics (peak, minimum flow, mean daily flow, and flow percentiles related to long-term percentiles) for each sample time.
- Calculate similar metrics for rainfall, temperature and other available abiotic variables
- Investigate the relationship between these metrics and a breeding response using modelling techniques (boosted regressions and random forests analysis).
- Using the flow requirements developed in the Frogs and Flows project, evaluate the water sharing plan rules in a priority water sharing plan area using the frog occurrence dataset provided by FrogID.
- Document frog breeding responses and overall diversity changes within a water sharing plan period.

Results

This project is in progress. The final data set will be provided in March 2023 and the key project questions addressed in the 2022-23 theme report.

The current results include communication material, FrogID week outreach statistics and the number of data submissions (Table 7). The outreach of FrogID week (11-20 November 2022) included more than 190 pieces of communication material across different types of communication mediums (social media, TV, radio, and so on). These subsequently resulted in more than 17,000 records submitted with over 16,000 verified frogs. Data submissions are still being processed, with the number of verified frog data points likely to exceed 20,000. There was also a significant uptake of the FrogID app, and more than 20,000 new registered users.

Whilst FrogID is a national citizen scientist project, approximately 47% of all records are from within NSW. Therefore, assuming this trend was consistent during the 2022 FrogID week, approximately 50% of all data would be for NSW and of value to the department.

Table 7. Summary of outcomes from the strategic partnership between DPE Water and the Australian Museum during the 2022 FrogID week (11-20 November 2022).

Metric	Metric details	Value
Media coverage	Number of individual media pieces for FrogID week. This includes TV, radio, print and social media	190
Frog data submissions	Total number of records submitted	17,545
Verified frog data points	Total number of verified frogs as of 29 November 2022	16,653
Verified species found	Total number of species detected	96
FrogID app downloads	Total number of FrogID app downloads	19,900
New registered users	Total number of new users registering with the FrogID app	20,000

Conclusions

No conclusions can be drawn at this time.

Recommendations

No recommendations are made at this time.

Next steps

The FrogID dataset for the 2022 calendar year will be provided to the department in April 2023. This will include 5 years of data, which will allow further analysis of frog distributions and the links between river hydrology.

We will also develop a water source level database which will allow reporting of frog species occurrence within water sharing plan periods. This will be used as a source of information to evaluate NSW water sharing plans.

Aquatic invertebrates

Aquatic macroinvertebrates are water-dependent insects that can be seen by the naked eye. Of the 126,000 faunal species that inhabit freshwater ecosystems globally, the majority are invertebrates (insects), accounting for 60% of the total (Balian et al. 2008).

Macroinvertebrates play critical and varied roles within freshwater ecosystems by processing organic matter and mediating the transfer of carbon through food webs and nutrient cycling (Covich et al. 1999, Collier et al. 2016). They provide a crucial trophic link between primary producers and aquatic and terrestrial predators as a food source for fish, birds and turtles (Chessman 1984, Covich et al. 1999, Tran et al. 2015, Twining et al. 2018). River regulation and water extraction are the most prominent threats to the global decline of freshwater ecosystems, affecting 26% of threatened freshwater invertebrate species (Darwall et al. 2012).

This section summarises the department's projects that monitor macroinvertebrates and identify the influence of flow regimes and water management decisions on these communities.

Figure 23. A flow-sensitive coloburiscid mayfly which occurs within flowing water habitats like riffles. Photo credit: Daniel Coleman.

Macroinvertebrate responses to flow in NSW: modelling the effects of low flows on macroinvertebrate community trait composition

Project Team

Andrew Brooks and Tim Haeusler.

Project collaborators

This project is led by the department.

Introduction

The aim of this project is to develop relationships between antecedent low flow conditions and changes in invertebrate community composition, focussing on flow sensitive (rheophily), temperature sensitive (thermophily), and oxygen sensitive (hydroaerophily) taxa in riffle and pool-edge habitats across NSW.

It is difficult to assess the biological effect of extraction from unregulated streams in Australia because extraction-induced changes to the in-stream environment mimic natural drought processes. An additional challenge is to separate the effects of modified flow regimes from confounding factors such as land-use effects.

In this project we will model the relationship between the changes in macroinvertebrate communities and flow while accounting for the effect of geographic location, long term flow regime and catchment influences. Developing these flow-ecology relationships will allow water management strategies to be evaluated, by predicting macroinvertebrate responses to hydrological regimes under different low flow access rules.

Project aims

Key project questions

- What is the relationship between antecedent low flows and the composition of macroinvertebrate communities?

Link to water management activities

- Developing these flow-ecology relationships will allow water management strategies to be evaluated by predicting macroinvertebrate responses to hydrological regimes under different low flow access rules.

Methods

This project will use existing data collected between 2004 and 2015 across NSW by state government agencies and partner organisations as part of the Murray-Darling Basin Authority's

(MDBA) Sustainable Rivers Audit (SRA) (Figure 24). Relationships between antecedent flows and changes in macroinvertebrate communities will be developed using boosted regression trees.

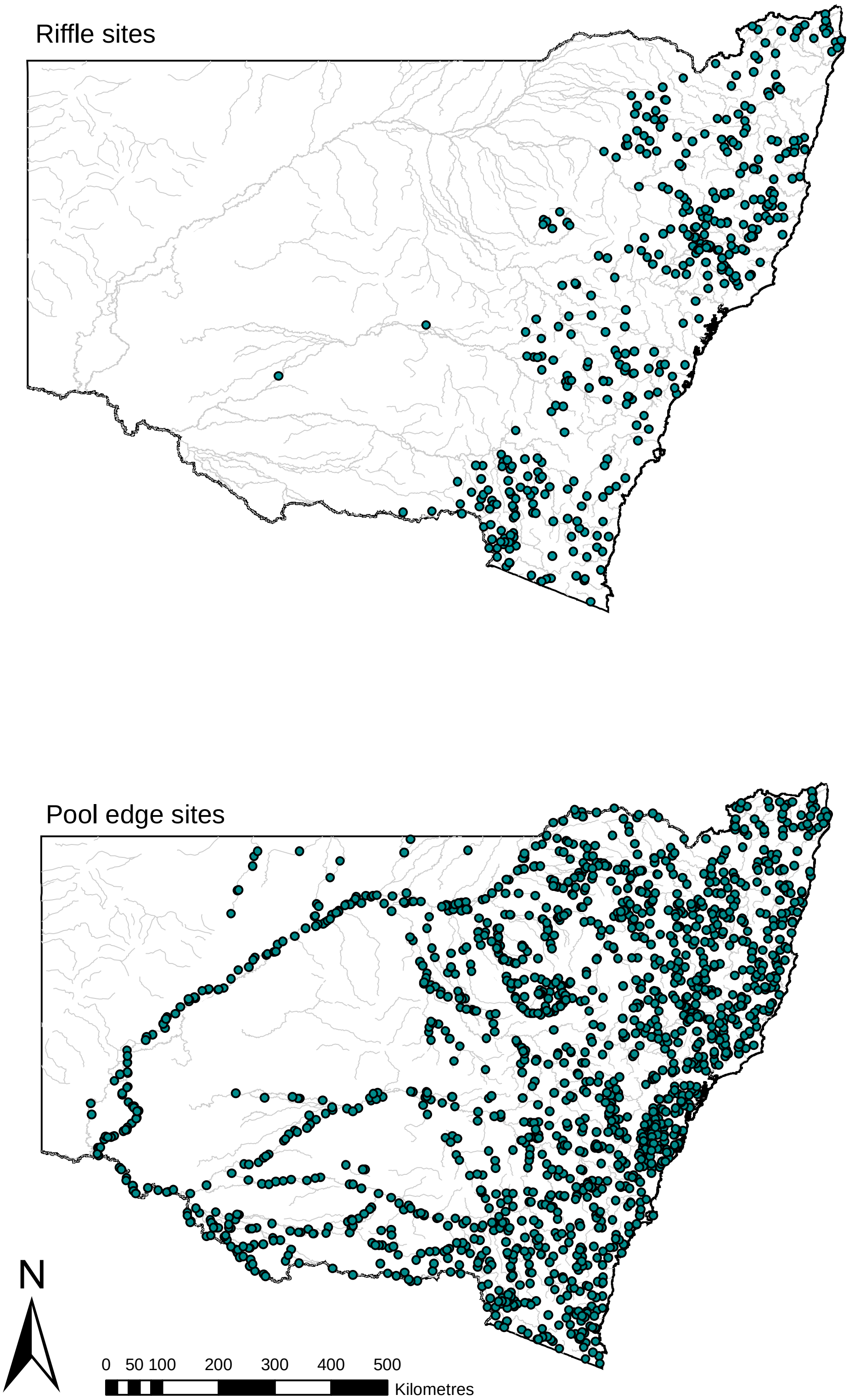


Figure 24. Location of macroinvertebrate sampling sites in riffles and pool-edge habitats. Note that only sites within 5 km of a hydrological gauge will be used in model development.

Results

We have collated biological and hydrological data and are in the analysis phase of the project. The outcomes of the project will be reported in the 2022-23 theme report.

Conclusions

No conclusions are drawn at this time.

Recommendations

No recommendations can be made at this time.

Next steps

This project will provide information for the future development of HEVAE assessments and Basin Plan monitoring and evaluation. This will be provided through assessing risk to ecological functions from water extraction in rivers where there is no biological information, supporting the development of water resource plans and water sharing plans.

The role of low flow access rules in protecting macroinvertebrates

Project Team

Andrew Brooks, Tim Haeusler, Dane Parsons and Daniel Coleman.

Project collaborators

This project is led by the department.

Introduction

In unregulated streams, water is pumped for town water supplies, irrigation, farmstead use, livestock watering, and other purposes. The hydrological effect of diversions from unregulated streams is usually greatest during periods of naturally low flow. Therefore, high levels of abstraction can increase the frequency and duration of low flows, accentuate the effects of natural droughts, and create artificial droughts that degrade water quality and reduce habitat diversity (Stanley, Fisher & Grimm, 1997; Mérigoux & Dolédec, 2004; Finn, Boulton & Chessman, 2009).

Low flow access rules are the main water sharing plan mechanism for managing water extraction in unregulated rivers and limiting impacts on low flow habitats. This project will measure antecedent flow conditions and changes in riffle macroinvertebrate assemblages in the unregulated areas of the Murrumbidgee water sharing area. This information will be used to develop a flow-ecology model that will allow water management strategies to be evaluated, by predicting macroinvertebrate responses to hydrological regimes under different low flow access rules.

Project aims

This project collected macroinvertebrates in riffles across 7 unregulated perennial river sites in the Murrumbidgee catchment. The aims of this study are highlighted below:

Key project questions

- Is there a relationship between antecedent flow conditions and changes in riffle macroinvertebrate assemblages?
- Can we predict changes to macroinvertebrate assemblages by estimating the different hydrological regimes at a location with and without low flow access rules?

Link to water management activities

- This project will be used to test different low flow access rules and guide water sharing plan evaluations and rule development in unregulated rivers.
- This project provides on-ground monitoring data for the Murrumbidgee Unregulated water sharing plan.

Methods

Every 12 weeks from February 2019 until 2021, macroinvertebrates were collected from riffle habitats at 7 sites in tributaries of the Tumut and Murrumbidgee Rivers (Figure 25). The sites selected were adjacent to flow gauges, allowing flow conditions between sampling times to be directly linked to changes in macroinvertebrate communities. The sites represent a range of hydrological conditions (that is, some sites are perennial and have high baseflows, while others regularly experience no flow periods). On each sampling trip and at each location, water quality was also measured.

In this study we will quantify the macroinvertebrate community composition in terms of:

- taxonomic composition to genus level, and
- biomass and nutritional composition (for example, amino acids).

This will allow us to determine both the taxonomic changes associated with low flows and water extraction and how these changes alter the nutritional landscape of the stream.

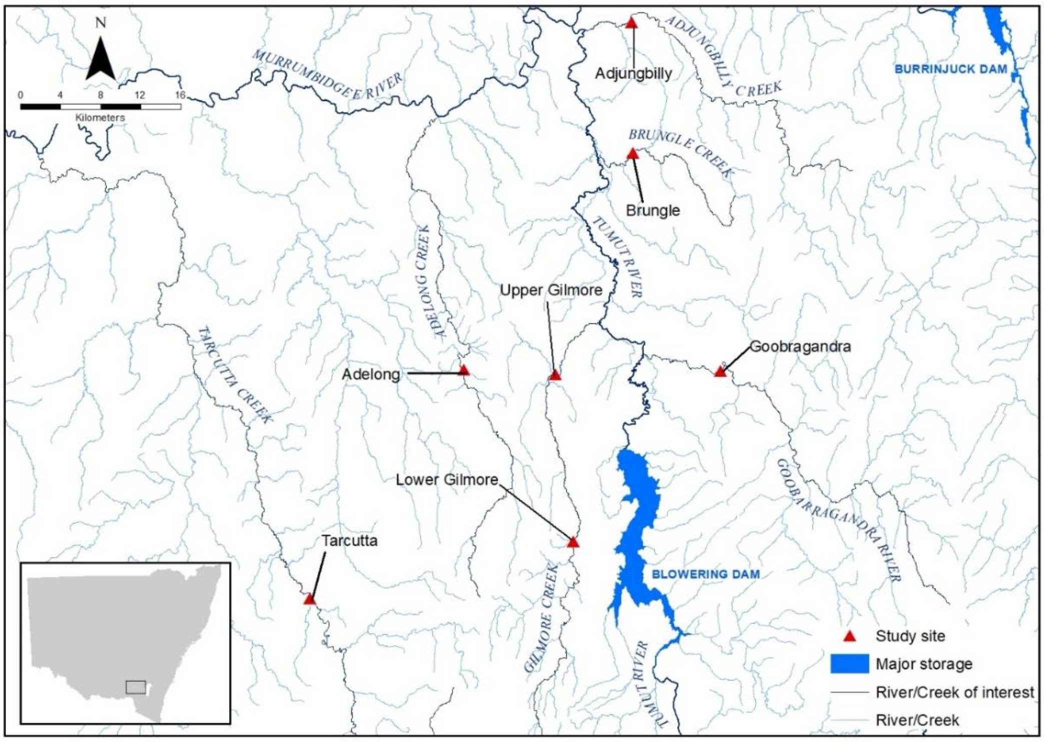


Figure 25 Map of the study sites in the Tumut and Murrumbidgee tributaries.

Results

The project is ongoing, at present we have collected all samples and are in the process of analysing the data.

Next steps

The department will begin analysis of the hydrological and macroinvertebrate data to identify the influence of low flows on macroinvertebrate assemblages. This will be reported in a peer-reviewed article and within the 2022-23 EOMRP theme report

Snowy River environmental flow monitoring

Project Team

Andrew Brooks, Daniel Coleman and Tim Haeusler.

Project collaborators

This project is a collaboration with the Environment and Heritage Group of the Department of Planning and Environment.

Introduction

The Snowy Water Initiative provides for environmental water releases. These flows aim to improve the health of rivers affected by the Snowy Hydro-electric Scheme. This project monitors the responses of freshwater invertebrate communities to environmental flows in the Snowy River below Jindabyne Dam (Snowy River Increased Flows - SRIF) and Snowy montane rivers (Snowy Montane Rivers Increased Flows - SMRIF).

Project aims

This aim of these projects was to determine whether macroinvertebrate communities were restored after an environmental flow regime was introduced to the highly regulated Snowy River below Jindabyne Dam and Snowy montane rivers.

Key project questions

- Do freshwater invertebrate communities benefit from environmental water releases from Jindabyne dam?
- Do freshwater invertebrate communities benefit from environmental water releases from weirs in the Snowy montane rivers?
- Did the increased flow from the tributaries affect the invertebrate community in the regulated river sections?

Link to water management activities

- The project will provide information with which to develop the SnowyHydro Annual Water Operating Plan for environmental flows and will help inform the SnowyHydro Licence review.

Methods

Snowy River below Jindabyne Dam

Benthic macroinvertebrates were collected from 4 sites in the Snowy River below Jindabyne Dam and from 2 sites in nearby unregulated rivers which were used as reference sites (Thredbo River and

Mowamba River) (Figure 26). At each site, macroinvertebrates were quantitatively sampled from riffles (areas of shallow fast flowing water), and pool – edges (areas of slow flow). Samples were collected in spring and autumn from 2000 – 2009 and in autumn only from 2010 onwards.

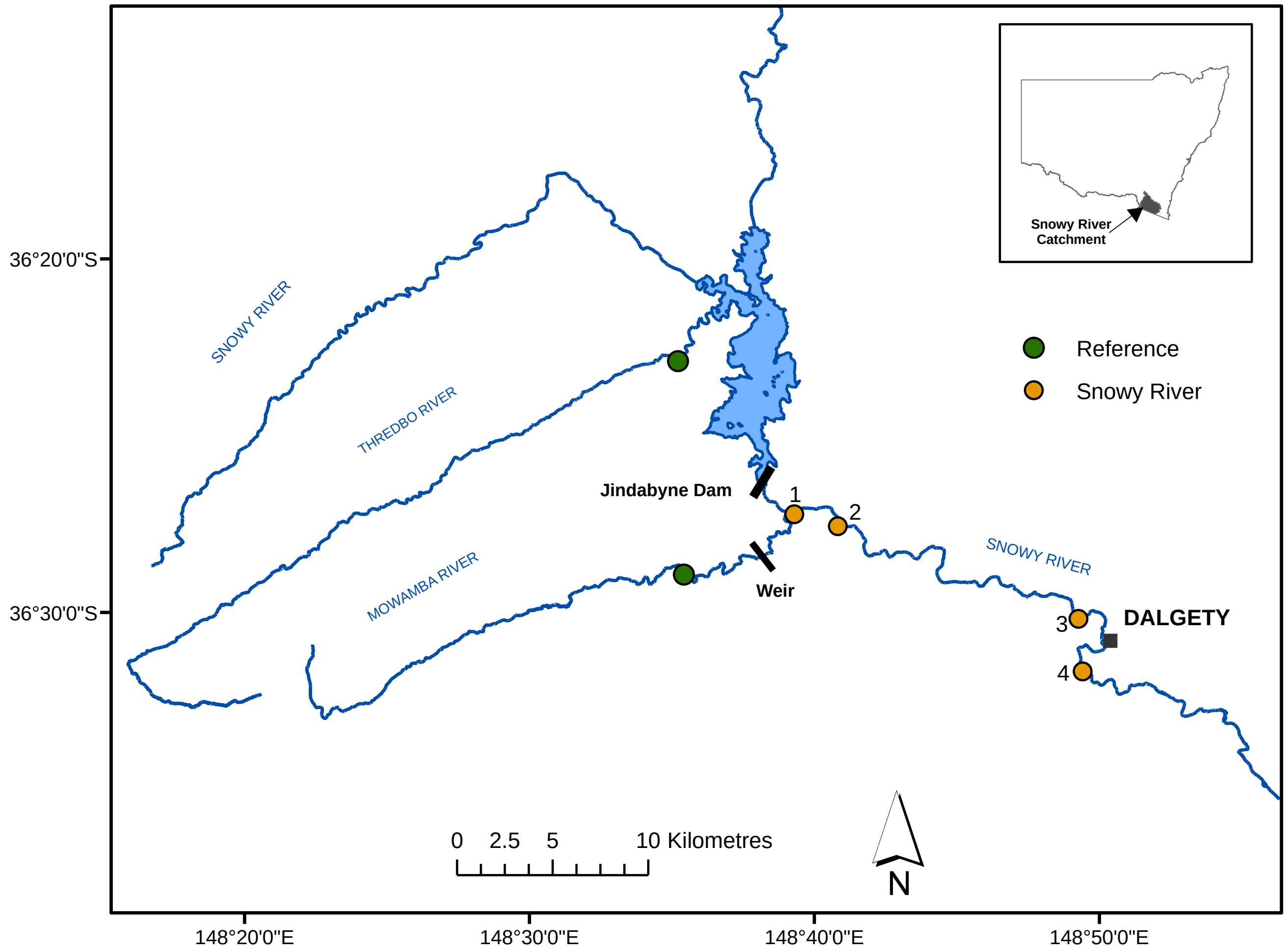


Figure 26. Map of study sites in the Snowy River.

Snowy montane rivers

This study is centred on 2 cobble-bed creeks in the montane area of the Snowy Mountains, Middle Creek and Diggers Creek. These creeks are tributaries of the regulated Geehi River (regulated by Geehi Dam) and Snowy River (regulated by Island Bend Dam), respectively, and are situated in different catchments approximately 16 km apart.

As part of the SMRIF, a decision was made to decommission the aqueducts on the weirs of these tributaries. This allowed all flows to overtop the weirs and provide water to the previously dry riverbeds of the tributaries, and additional flows to the main-stem regulated rivers further downstream (Figure 27).

Figure 27 Study weirs. a. & c. – Middle Creek. b. & d. – Diggers Creek. Photo credit: Andrew Brooks.

Results

Snowy River below Jindabyne Dam

There were 2 distinct changes to the flow regime (hydrology) after the environmental flow releases began in 2002. Between 2002 and 2010, environmental water releases increased median daily flows from 39 megalitres per day (ML/d), to 90 ML/d during releases from Mowamba weir and 115 ML/d during releases from Jindabyne Dam (measured at Dalgety; Figure 28).

The larger environmental flow releases between 2010 and 2016 further increased median daily flows to 320 ML/d and the number of days of high flow events (flows > 1000 ML/d) per year increased from 0 – 10 to 18 – 67 after 2010 (Figure 28). The annual peak flow also became much greater during the post-2010 high flow environmental flow release period. Notably, there was a peak flow of almost 40,000 ML/d in 2012, which was caused by a natural catchment-wide rainfall event. All Snowy River sites and reference sites were affected by this rare flow event.

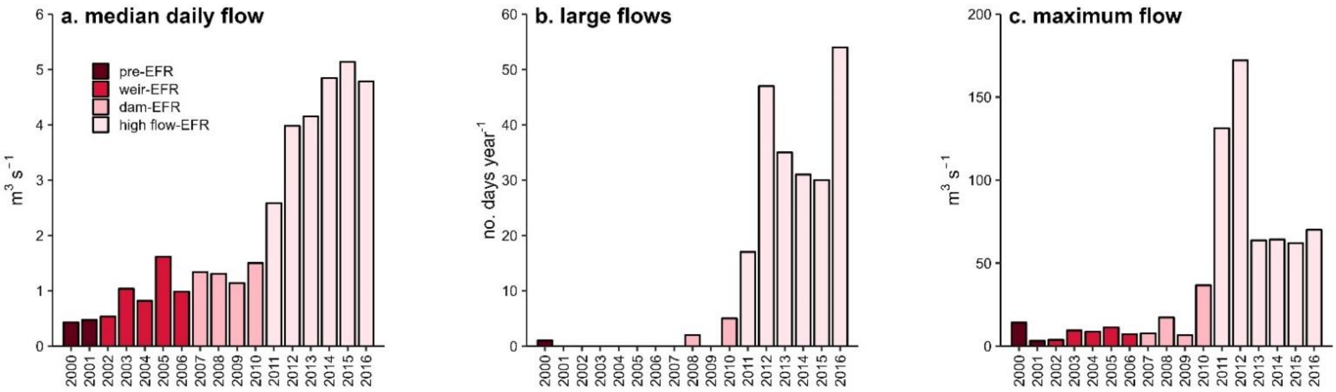


Figure 28. Changes to a. mean daily flows (ML/d), b. frequency of large flows (> 1000 ML/d) and c. the annual peak flow after the provision of increased baseflow environmental flow releases and high flow environmental flow releases. Flows were measured at Site 4 (Dalgety; gauge no. 222026).

During the period of increased baseflows and high flows to the Snowy River from Mowamba weir and Jindabyne Dam, the composition of the benthic macroinvertebrate communities at all riffle sites became more similar to reference communities in nearby unregulated reference rivers (Figure 29). These community changes were significantly associated with the improved environmental flow releases in the Snowy River, particularly the increases in daily flows and high flows (both large and peak flows).

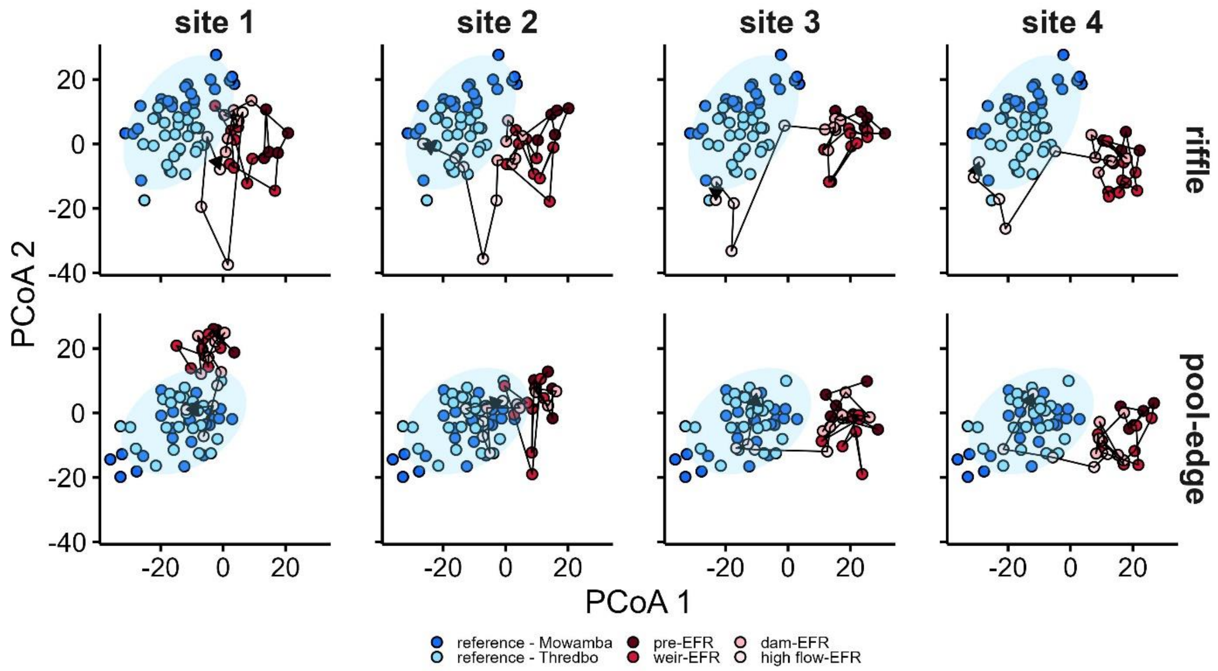


Figure 29. Changes in community composition between invertebrate communities in the Snowy River and the reference sites (Thredbo River, Mowamba River). Sample points that are close together in the ordination indicate they possess similar invertebrate communities. Light blue ellipses show the 95% confidence limits of reference samples over the period of study.

Snowy Montane rivers

Within the tributaries, benthic macroinvertebrate communities that formed after the release of water into the previously dry streams rapidly resembled reference sites after 2 years. This pattern was consistent between the rivers.

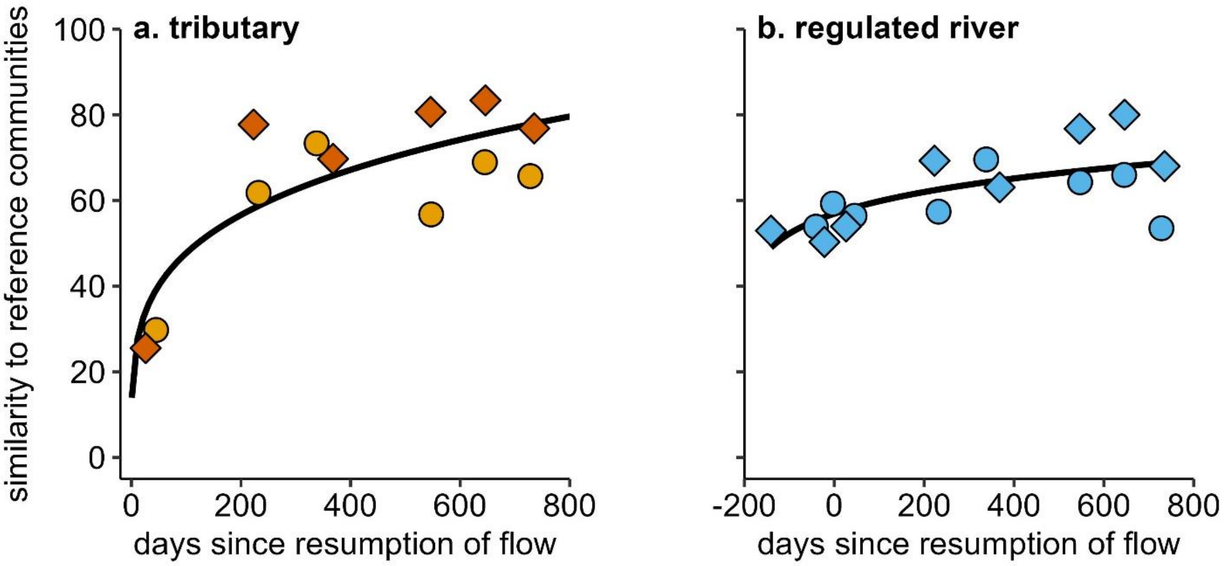


Figure 30. Invertebrate community similarity to reference communities after flows were released from the weirs. Invertebrate communities in a) tributaries and b) regulated rivers. Circles = Middle Creek / Geehi River, diamonds = Diggers Creek / Snowy River.

The new invertebrate communities in the tributaries increased the numbers and diversity of colonists arriving via drift to the regulated river sites, but this boosted dispersal had no strong effects on existing communities. Rather than causing changes across the whole regulated community, there was only an increase in the densities of filter feeders, leading to a limited increase in community similarity to reference sites.

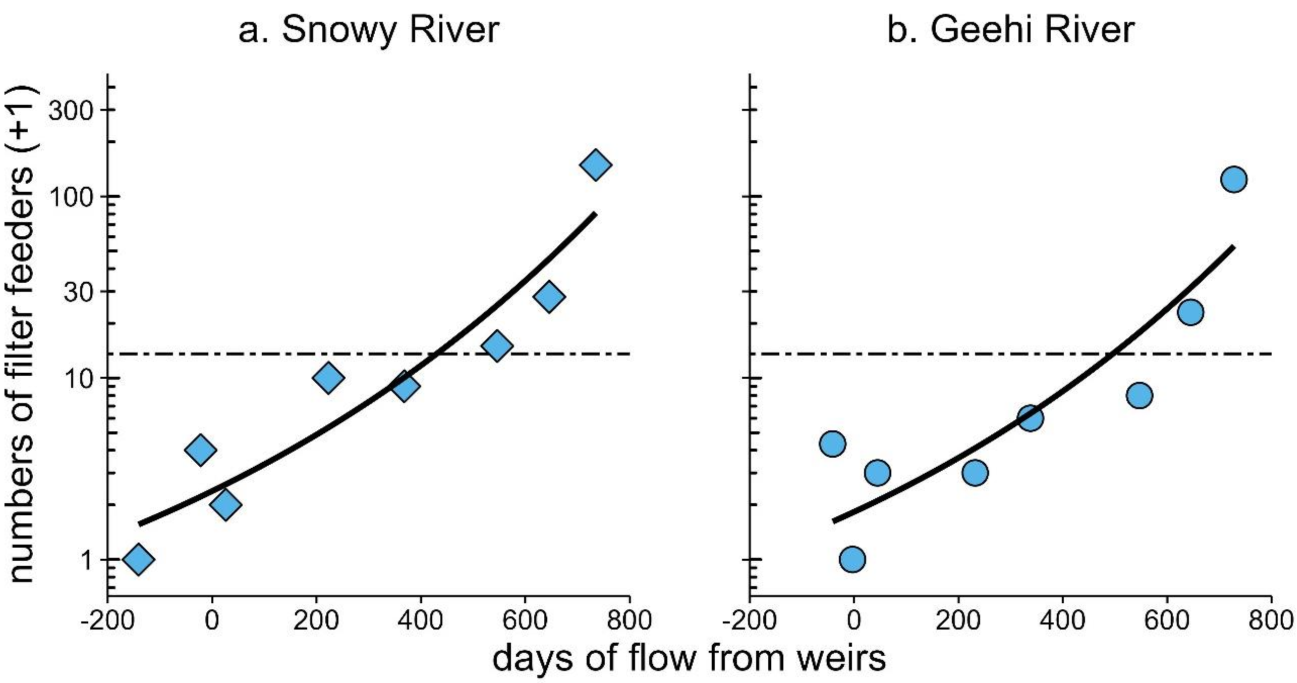


Figure 31. Response of filter feeding invertebrates in the regulated rivers after increased flow from the tributaries. a) Snowy Riverand b) Geehi River.

Conclusions

Snowy River below Jindabyne Dam

The patterns of change in macroinvertebrate community composition and trophic structure in the Snowy River show that environmental flow releases have improved communities. They now resemble those found in nearby unregulated reference rivers.

Snowy Montane rivers

The study found that water releases from weirs allow invertebrates to disperse from undisturbed locations above weirs. Macroinvertebrates dispersed and colonised downstream tributary riverbeds that had been dry for 50 years. These newly formed communities quickly resembled those in free flowing rivers. This demonstrates that water releases can restore degraded river ecosystems.

Invertebrate communities in the main-stem of the Snowy and Geehi regulated rivers received significant increases in flow. The new invertebrate communities in the tributaries increased the numbers and diversity of colonists arriving via drift to the regulated river sites. Increase in densities occurred only in a single feeding group (filter feeders), not the whole community.

Recommendations

Snowy River below Jindabyne Dam

High flows are required to alter habitat and food resources which lead to alterations in community composition. This suggests that the high flow environmental flow regime used in the Snowy River is critical to maintaining habitats and food resources for the macroinvertebrates within the system. These improvements took over 15 years to achieve, which suggests that recovery processes in highly regulated rivers may be slow and long-term monitoring is essential to establish the success of such environmental flow programs.

Snowy Montane rivers

Environmental flows from tributaries to main-stem regulated rivers may have limited benefit to invertebrate communities. Large environmental releases may be required to improve or restore highly regulated rivers in the Snowy Montane system. This would provide a greater diversity of microhabitats and create disturbances to help colonisation of new taxa. The result would be a more natural community.

Next steps

This part of the project is complete, these results are being used as evidence of the environmental outcomes of flow management and advise ongoing environmental water delivery to the Snowy River and Snowy Montane rivers. Monitoring of macroinvertebrates will continue annually in partnership with the Environment and Heritage Group of the Department of Planning and Environment.

Impact of climate change on flow and temperature regimes – effects on alpine freshwater ecosystems

Project Team

Andrew Brooks and Ben Kefford (University of Canberra).

Project collaborators

This project is a collaboration with the University of Canberra.

Introduction

Climate change is predicted to increase temperature, and the frequency and intensity of extreme events such as droughts. These changes will create challenges for the management of water in NSW.

Project aims

The aim of this project is to determine whether increases of water temperatures and reduced flow from climate change and water regulation affect benthic (bottom dwelling) invertebrate communities in the alpine rivers of Snowy Mountains.

Key project questions

- How does reduced flow regime and increased temperature affect instream primary production?
- How does reduced flow and increased temperature affect alpine invertebrate community composition?
- How do invertebrate communities respond to the changes in primary production?
- What are the impacts of reduced flow and temperature on invertebrate mediated ecosystem function?

Link to water management activities

- Answering these questions will aid in the development of the SnowyHydro Annual Water Operating Plan for environmental flows. This data will be critical in low water allocation years when environmental flows are significantly reduced.

Methods

The project will primarily use a stream mesocosm (contained and small-scale) system representing 16 independent channels located adjacent to Pipers Creek in Kosciuszko National Park (Figure 32) to investigate the key project questions. This will be constructed at the Australian Mountain Research Facility (https://www.amrf.org.au/).

The Australian Mountain Research Facility is an Australian Research Council funded collaboration between leading institutions and researchers across 4 states and territories to produce world-leading ecosystem, evolutionary and biophysical science to guide adaptive management of high mountains across Australia.

Figure 32. Stream mesocosms used in the MountainFlows component of the Australian Mountain Research Facility (Photo credit: https://www.amrf.org.au/)

Results

This project is within the early planning phase with artificial stream mesocosms under construction. An update on the project development and status will be provided in the 2022-23 EOMRP report.

Conclusions

No conclusions can be drawn at this time.

Next steps

Field work will begin in spring and summer of 2023. There will be a progress report completed in 2024 and a published paper in 2025.

River regulation and the impact on macroinvertebrate egg laying and recruitment

Project Team

Andrew Brooks and Han Wahjudi (University of Melbourne).

Project collaborators

This project is a collaboration with the University of Melbourne.

Introduction

Many freshwater insect adults lay eggs on emergent rocks in fast flowing habitats such as riffles. Between 2018 - 2021, we examined the influence of river regulation upon emergent rock availability and oviposition by stream insects in dammed rivers versus free-flowing tributaries with natural flow regimes.

Project aims

This project aims to determine whether altered flow regimes limit the supply of stream insect eggs in dammed rivers, by limiting the availability of egg laying (oviposition) habitat downstream of Blowering and Burrinjuck dams (Figure 33).

Key project questions

- Do irrigation flows in regulated rivers affect stream insects by limiting the availability of egg-laying sites during summer, reducing recruitment success?
- Do cease to flow and extreme low flows in unregulated rivers affect stream insects by limiting the availability of oviposition sites, reducing recruitment success?

Link to water management activities

- Development of relationships between flow and insect oviposition sites will help determine which components of the low flow regime need to be protected by minimum flow releases from dams and cease to pump rules in unregulated rivers.

Methods

On each sampling occasion, we quantified emergent rock density and abundance at regulated and unregulated sites to determine the relationship between flow and the availability of potential egg-laying habitat. In addition, egg masses were identified and counted on each emergent rock.

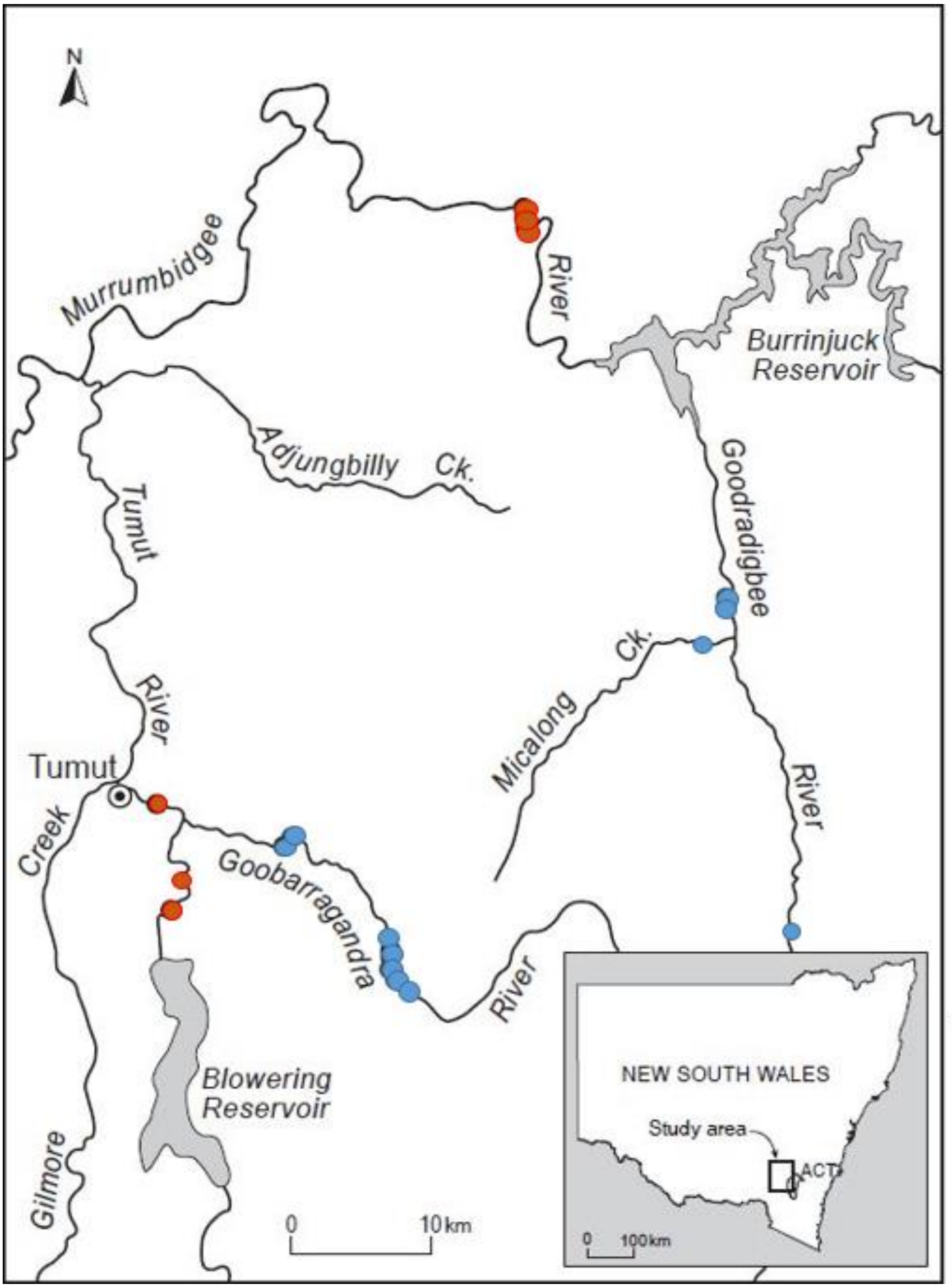


Figure 33. Map of 2019 survey sites (n=17 sites, 5 rivers) in the Murrumbidgee River catchment.

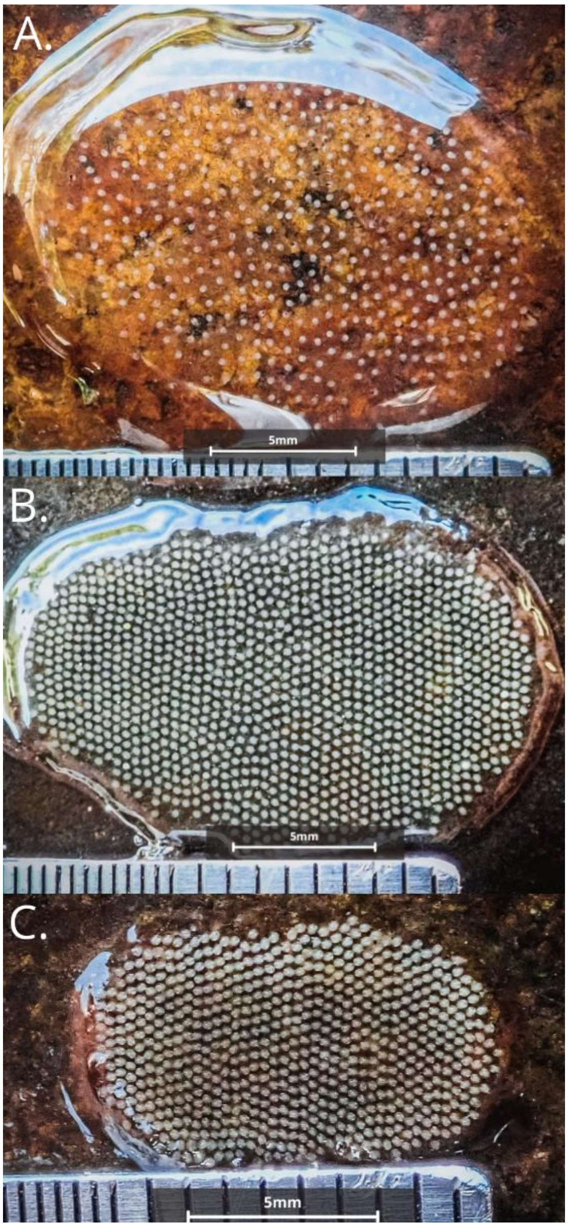


Figure 34. Representative examples of Hydrobiosidae egg masses of A-Type (a) *Apsilochorema gisbum* and E-Type (b) *Ethochorema brunneum* and (c) *Taschorema evansi.* Photo credit: Handoko Wahjudi.

Results

Caddisflies, which includes the family *Hydrobiosidae*, often failed to lay eggs in regulated rivers below major dams, despite high numbers of adults, because flow regulation submerged, or stranded, emergent rocks throughout the year.

We also found evidence of oviposition (egg laying) failure in unregulated rivers after extended periods of low flow during late summer, when no eggs were found despite abundant emergent rocks and the presence of adults. This was caused by prolific algal growth which encrusted otherwise suitable oviposition habitat. Algal growth is facilitated by low flows reducing scouring.

Figure 35. Encrustment of oviposition habitat (emergent rocks) in the Murrumbidgee Catchment, NSW: Examples of emergent rocks with benthic algae (A & B), films of detritus (C & D) and riffles covered by sheets of algae and detritus (E & F). In (A & B), emerged portions of the rock were clean, but the submerged portions where Hydrobiosid females lay eggs were covered by algae. Photo credit: Handoko Wahjudi.

Conclusions

In regulated rivers, we found that oviposition failure was caused by unseasonal irrigation flows submerging all emergent rocks during spring and summer.

In unregulated rivers, we found that algal growth may limit habitat during summer, and restrict oviposition periods to cooler seasons when local supplies of females are low relative to habitat.

Recommendations

Protection of low flows and small flow pulses in unregulated rivers during summer is critical to ensure there are enough sites of sufficient quality to enable egg-laying and the recruitment of juvenile stream insects.

Management options in regulated rivers are limited, but possibilities may include adding of artificial emergent rocks and developing minimum flow releases that provide adequate habitat.

Next steps

Several peer-reviewed publications are currently being prepared. These findings provide critical information for setting minimum flow rules in both regulated and unregulated water sharing plans to support the survival of stream insects.

Giant dragonfly – assessing eDNA detectability and environmental water requirements

Project Team

Joe Cairns.

Project collaborators

This project is a collaboration with the University of New South Wales.

Introduction

The giant dragonfly (*Petalura gigantea*) is listed as endangered under the *Biodiversity Conservation Act (2016)* and the species depends on habitat provided by upland swamps, which are an endangered ecological community.

The giant dragonfly depends on the protection of baseflows in swamp catchments to maintain its habitat. Threats to the species include urbanisation, stormwater discharges, bushfires, and long wall mining.

Figure 36 Endangered giant dragonfly in an upland swamp in the Blue Mountains. Photo credit: Bec Wood.

Project aims

This research project aims to improve monitoring techniques for the species. This will allow us to assess the effectiveness of water management rules for protecting the species and consider rule revisions where needed.

The project will refine eDNA sampling methods for this species, plus refine hydrological models for upland swamps, to establish the environmental water requirements for giant dragonfly, and inform the evaluation of water sharing plans.

Key project questions

- Is Giant dragonfly eDNA detectable in discharges from swamps with known populations?
- What flows need to be protected to maintain habitat for Giant dragonfly?

Link to water management activities

- Answering these project questions may improve and facilitate the distribution monitoring of an endangered species. Establishing environmental water requirements for the species will improve scientific advice on cease to pump rules in catchments containing upland swamps.

Methods

Giant dragonfly monitoring is usually completed during the flying season, which is November through to January. The use of eDNA methods could make this species detectable in swamp discharges outside of this timeframe as well.

Giant dragonfly exuviae were collected in November 2021 to develop assays, and eDNA samples were collected from 2 swamps with confirmed populations.

Results

At this stage only preliminary results have been received from the laboratory. One of the 6 samples collected identified the presence of giant dragonfly, indicating that eDNA sampling may be useful for detecting the species, though further work will be required to refine the method. This will include filtering greater sample volumes, and sample collection outside of the flying season.

Water balance models have been developed for 3 swamps in the Woronora special area. These models will be used to generalise the range of flow percentiles required to maintain giant dragonfly habitat.

Conclusions

No conclusions are drawn at this time.

Next steps

Further sampling of discharges from swamps with known giant dragonfly populations will be required to refine and validate the use of eDNA methods for detecting the giant dragonfly.

Water balance modelling based on differing climatic scenarios will be completed to help develop environmental water requirements for the species.

Fauna diversity

A vast variety of fauna is dependent on rivers and floodplains in NSW. This includes aquatic invertebrates, frogs, fish, turtles, waterbirds, platypus, and many terrestrial species.

Many species have aquatic life cycles, whilst others access water sources for food and breeding opportunities. Healthy rivers and floodplains should support a high fauna diversity (number of species). However, freshwater fauna populations have declined by 84% since 1970 (Almond et al. 2022); twice the rate of decline of biodiversity in terrestrial or marine environments. Further, one quarter of global Critically Endangered species are freshwater species (Almond et al. 2022). The main causes of biodiversity loss are flow alteration, pollution, habitat degradation and loss, overexploitation of species, and invasive non-native species.

This section summarises projects that monitor overall fauna diversity and identify the influence of flow regimes and water management decisions on this diversity.

The importance of floodplain pool habitats and hydrological regimes for fauna in the northern Murray-Darling Basin

Project Team

Daniel Coleman, Tim Haeusler, Anna Helfensdorfer and Lauren MacRae.

Project collaborators

This project is led by the department, consulting with the Department of Primary Industries — Fisheries and the Environment and Heritage Group of the Department of Planning and Environment.

Introduction

Floodplain pools are an important habitat for fish, frogs, reptiles, and other fauna species. However, regulation of river flows by dams, floodplain structures, and channelling of water into storages disrupts connectivity and changes the timing, frequency and duration of inundation events for these communities.

There are 2 key water resource activities that have changed floodplain hydrology in NSW. These are floodplain harvesting and floodplain structures.

Floodplain harvesting is the process of the diversion, extraction or impoundment of water flowing across floodplains. It is one process that changes the volume, frequency and timing of floodplain inundation for plant and animal communities.

Floodplain structures are a form of development on the floodplain, which can disrupt the natural flood pathways and reduce connectivity across the floodplain. Currently, there is a significant knowledge gap of the diversity of fauna species using floodplain pool habitats, and how they are affected by changes to natural flows from activities.

Figure 37. Gulligal Lagoon in the Namoi catchment as viewed from a drone. Floodplain lagoons in the northern Murray-Darling Basin provide an important habitat refuge within a highly modified landscape. Photo credit: Tim Haeusler.

Project aims

This project aims to improve our understanding of the ecology of floodplain pools by determining the influence of inundation history, water persistence, level of connectivity, and other pool features on floodplain fauna. The results will contribute to the monitoring and evaluation of floodplain environments as required under the *Water Management Act (2000)*, the *Basin Plan (2012)* and instruments such as floodplain management plans.

Key project questions

- What fauna species use floodplain pools in the northern Murray-Darling Basin?
- Do pool characteristics, including inundation history, connectivity, and water persistence influence fauna richness?
- Does inundation history, connectivity, and water persistence influence use of floodplain pools by golden perch?

Link to water management activities

- Evidence of the success (or otherwise) of water sharing plan strategies and rules and the Basin Plan in achieving environmental outcomes on the floodplains of the northern Murray-Darling Basin.
- The baseline data will be used to monitor floodplain fauna persistence after implementation of the Floodplain Harvesting Policy.
- Evidence of golden perch connectivity requirements can be used to refine floodplain management plans by determining how floodplains structures disrupt connectivity to critical floodplain pools for this species.

Methods

Site selection

This project focuses on the floodplain pools of the Border Rivers, Namoi, Gwydir and Barwon-Darling catchments in the northern Murray-Darling Basin. Water Observations from Space (WOfS) data were analysed using remote sensing techniques to categorise pools based on their historical persistence on the floodplain.

Sites with greater than 40% persistence within the WOfS dataset were selected and then intersected with named floodplain pools (for example, lagoons, waterholes, billabongs and cowals). Local agency staff were consulted to select the final sites to incorporate a range of persistence categories, and for ease of access, with wet conditions limiting the total number of sites to 31 across the 4 catchments (Figure 39).

Data collection

Environmental DNA sampling was conducted using a Smith-Root eDNA backpack sampler (Figure 38). Six eDNA sub-samples were collected at each floodplain pool site, targeting the range of microhabitats present at a site, including snags, flooded forest, submerged, floating or emergent macrophytes. A target volume of 1 L was set for each sub-sample (microhabitat type) with a maximum of 2 filters used per sub-sample.

Laboratory analyses of fish and vertebrate metabarcoding was conducted by EnviroDNA with further, more targeted, analyses possibly following initial results. Water quality was measured using a multiprobe for water depth, dissolved oxygen, electrical conductivity, turbidity, pH and water temperature. Six water quality readings were taken at each site: 3 samples at zero to 50 cm depth and 3 samples at 50 to 100 cm depth. Maximum pool depth was estimated using a Deeper Pro + sonar cast from a fishing line. Drone imagery and video were collected when conditions allowed.

Vegetation surveys were conducted once or twice per site based on the homogeneity of riparian vegetation immediately surrounding the floodplain pool. Percentage cover of each vegetation class (for example, bare ground, trees, shrubs, emergent, native/non-native) was estimated within a 40 x 10 m quadrat, with 2 m of aquatic area and 8 m of riparian area along a 40 m length of the pool edge.

Surface area and minimum connectivity distance (distance to channel) data were calculated in ArcGIS 10.6.1.

Figure 38. eDNA sampling using the Smith-Root backpack sampler at Baroona Waterhole, Gwydir catchment. Photo credit: Daniel Coleman.

Data analysis

Most taxa were identified to species level, although some waterbirds that could only be identified to genus. The data was transformed to a taxa richness measure to account for the different levels of identification. The total number of taxa detected was pooled across filter replicates to represent one estimate of taxa richness per site. The data was filtered to only include all native water dependent animals (native fish, waterbirds, turtles and rakali) for analysis. Non-native fish were excluded from the analysis as they were not target species. Only 4 amphibians were present at a small number of sites, and were excluded due to the timing of sampling (winter) and reduced likelihood of amphibian DNA being present.

We also tested the use of eDNA to estimate biomass or abundance of 2 common native fish species using eDNA concentration (or eDNA reads). This has been done with some success for fish (Lacoursière-Roussel et al. 2016, Rourke et al. 2022). To do this, we standardised the eDNA concentration across sites by dividing the total volume filtered by the total concentration of a species eDNA to get a measure of eDNA reads per mL for that species. This was considered a relative estimate of fish abundance or biomass and was only performed on the most abundant native fish: bony bream and spangled perch.

Summary statistics, bar plots and 2-way ANOVAs were used to analyse differences in taxa richness and native fish eDNA concentrations across sites and valleys. Regression trees were used to identify if levels of connectivity, vegetation cover, depth, surface area and other variables were important determinants of water dependent taxa richness and golden perch presence. Golden perch presence/absence was selected as an indicator as it responds to flows, is thought to use floodplain habitats and is of ecological and social significance within the Basin. All analysis were performed in R Studio.

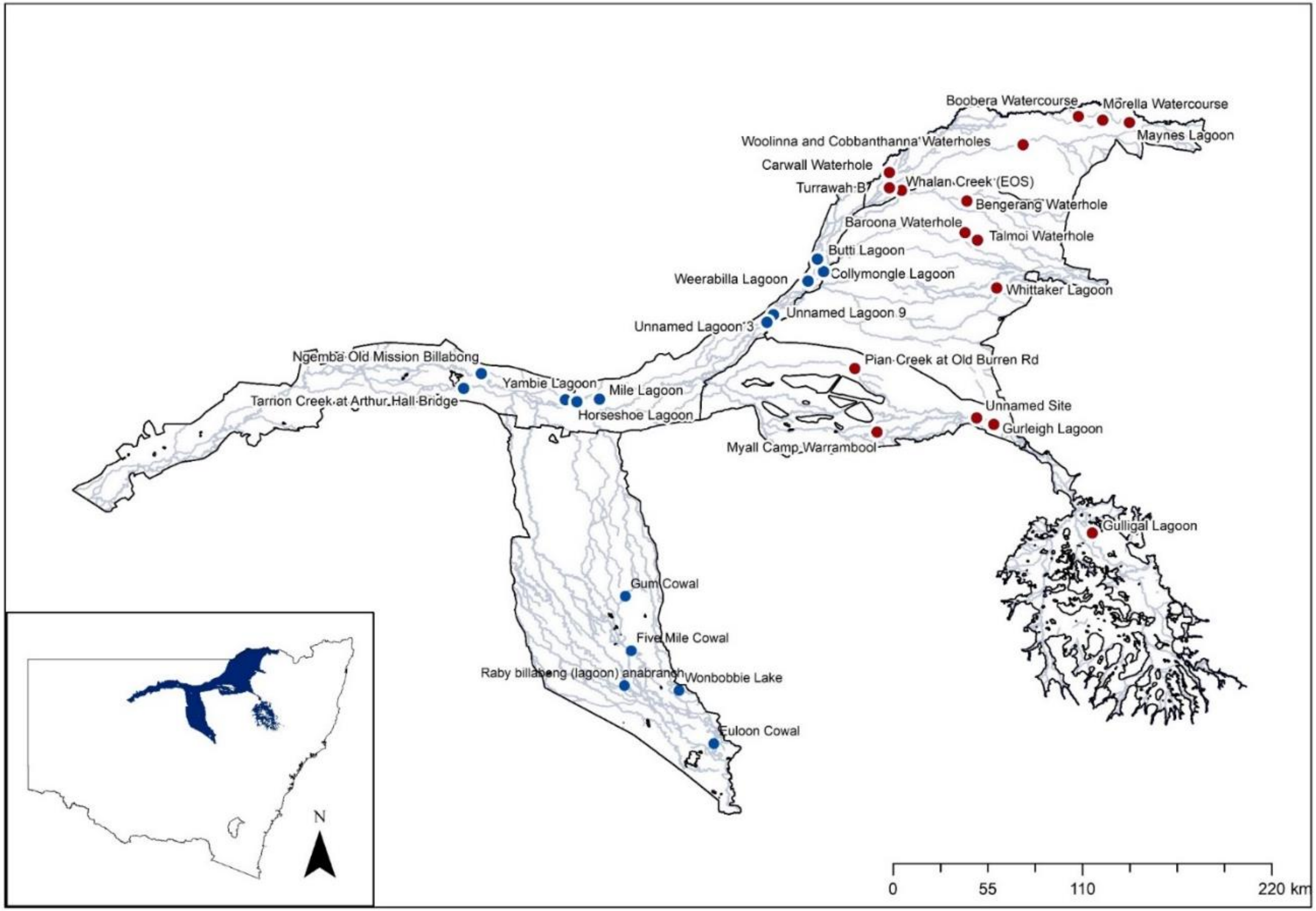


Figure 39. Map of eDNA floodplain pool sample sites in the northern Murray-Darling Basin. Red circles are pools surveyed in 2022 and the blue dots represent future sites to be surveyed in 2023.

Results

Initial analysis of eDNA samples collected in May/June 2022 is provided below. A comprehensive analysis of all sites will be presented in the 2022-2023 theme report.

Fauna richness in floodplain pools of the northern Murray-Darling Basin

A total of 50 taxa were recorded across the 16 pools sampled in 2021-2022. Of these, 78% (39) of the detected fauna are considered water dependent, including water birds, turtles, rakali and native fish. No threatened species were detected in any floodplain pool. The highest taxa richness (12 taxa) was recorded at the Myall Camp Warrambool site in the Namoi valley, and the lowest (5 taxa) at Maynes lagoon and Carwall waterhole in the Border Rivers (Figure 40). Rakali and turtles were only present at 3 and 4 sites respectively. The most common native species were both fish: bony bream and spangled perch, which were detected at every site.

There was no significant difference ($F^{(2,13)}$ = 2.131, p = 0.158) between the mean number of taxa across each valley (Figure 41). However, the mean taxa richness in the Namoi was higher than the mean taxa richness across all 16 sites, and the mean number of taxa within the Border Rivers and Gwydir. The Border Rivers had relatively lower fauna richness compared to the Namoi and Gwydir, despite more sites being surveyed within this valley.

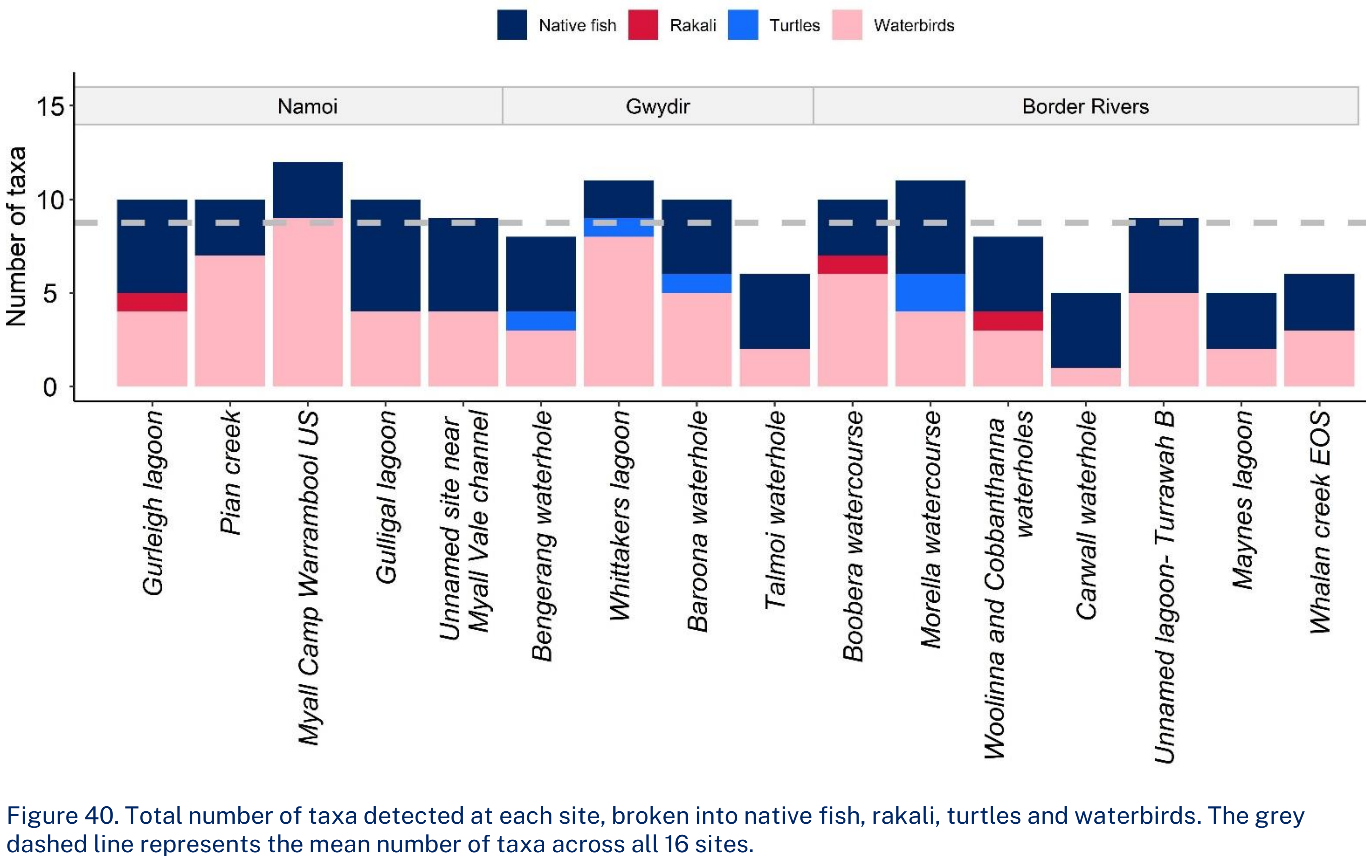


Figure 40. Total number of taxa detected at each site, broken into native fish, rakali, turtles and waterbirds. The grey dashed line represents the mean number of taxa across all 16 sites.

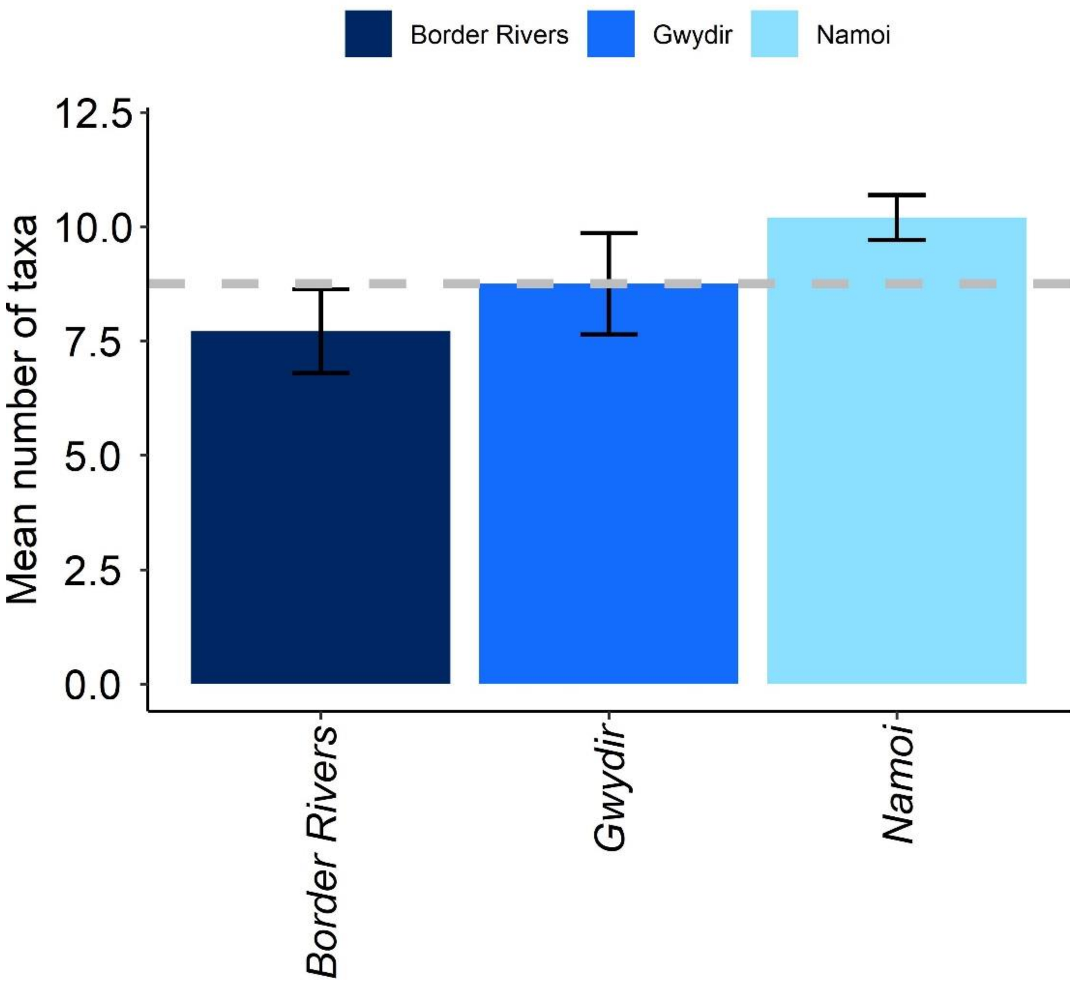


Figure 41. Mean number of taxa (±1SE) for native water dependent fauna in the Border Rivers (sites = 7), Gwydir (sites = 4), and Namoi (sites = 5) valleys. The grey dashed line represents the mean number of taxa across all 16 sites.

Native fish abundance in floodplain pools of the northern Murray-Darling Basin

The concentration of eDNA for 2 abundant fish species which occurred at every site (bony bream and spangled perch) were used to identify if different floodplain pools, valleys and site variables influenced the abundance of these species. There was no significant difference in eDNA concentrations for bony bream ($F^{(2,13)} = 1.222$, $p = 0.326$) or spangled perch ($F^{(2,13)} = 1.406$, $p = 0.28$) among the 3 valleys (Figure 42).

The site with the greatest concentration of spangled perch eDNA was Whittaker lagoon in the Gwydir valley. This site had 4 times higher concentration than the mean for all 16 sites. The concentration of bony bream eDNA was highest in the Myall Vale channel site within the Namoi valley. This site had 3.3 times higher concentrations than the mean across all sites.

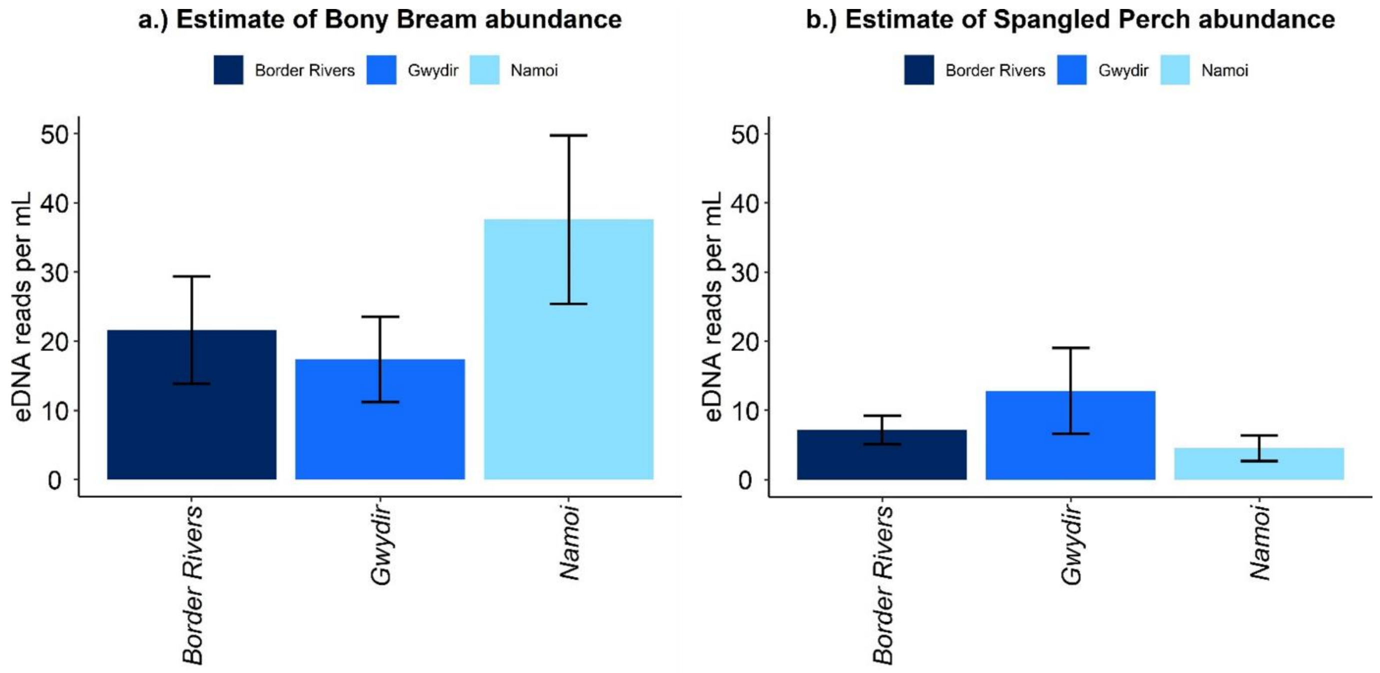


Figure 42. Mean concentration of eDNA (reads per mL) for a.) bony bream and b.) spangled perch as an estimate of abundance in the Border Rivers (sites = 7), Gwydir (sites = 4), and Namoi (sites = 5) valleys.

Influence of floodplain pool characteristics on richness

We investigated the influence of surface area, minimum connectivity distance to a channel, aquatic vegetation cover, tree and shrub cover, depth, and maximum persistence using regression trees and random forests. These results are preliminary, as more data is required to be confident of these associations. However, based on the data across 16 sites, surface area, aquatic vegetation cover, tree and shrub cover, and maximum pool depth were key drivers of higher fauna richness (Figure 43).

Influence of floodplain pool characteristics on golden perch presence

Golden perch were selected as a key indicator due to the well documented response of this species to flows, their ecological and social significance and the spatial distribution of results (that is, it did not occur everywhere but was not super rare either).

Based on the data across 16 sites, the level of connectivity, measure of the minimum distance to a river channel and surface area were key drivers of whether golden perch would be present at a site (Figure 44). However, more data is required to be confident of the detected association between pool characteristics and golden perch presence. These associations will be investigated further in the 2022/23 EOMRP report using additional sites collected in the Macquarie, Gwydir and Barwon-Darling.

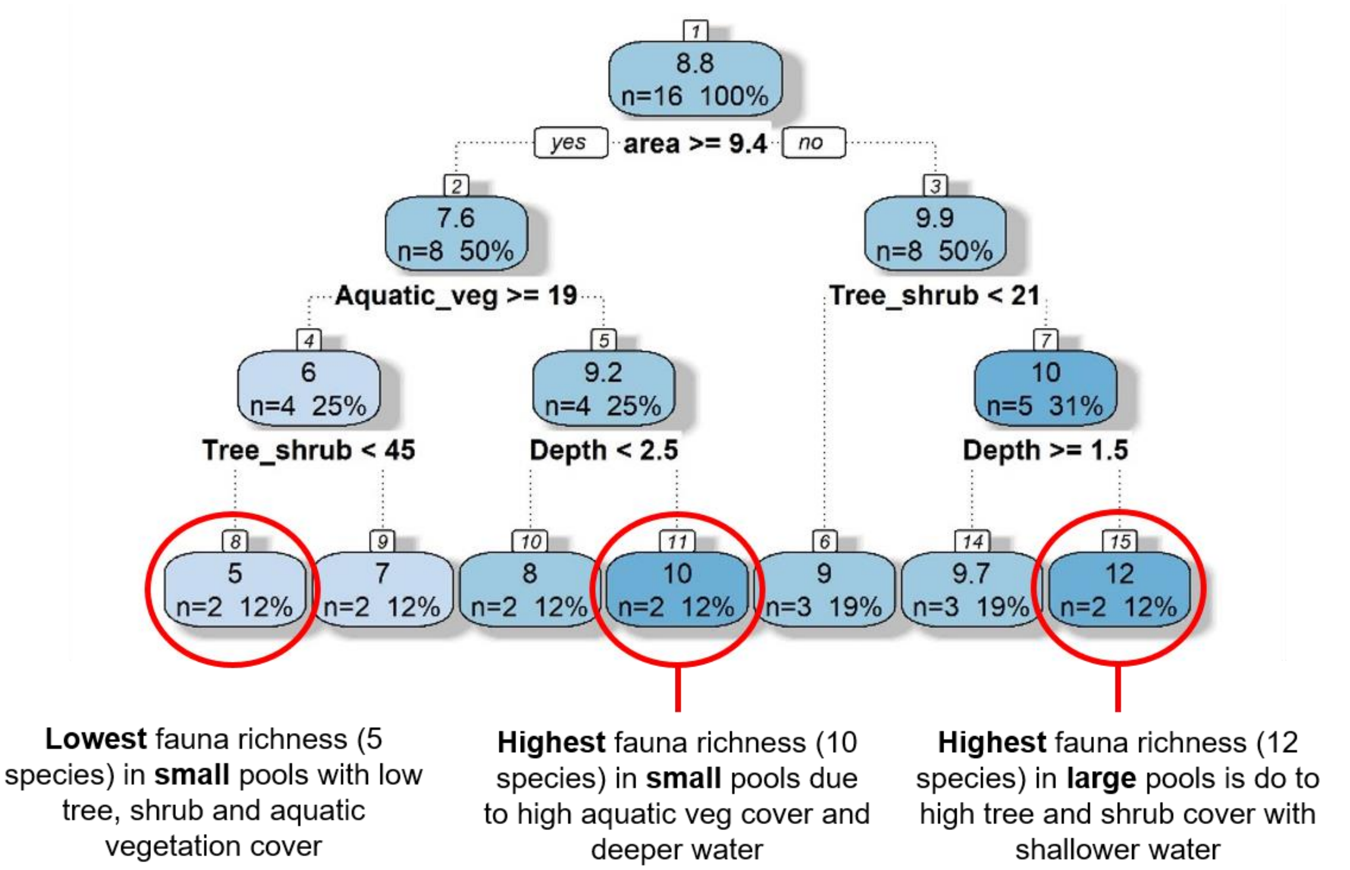


Figure 43. Regression tree outcomes for key pool characteristics of water dependent fauna richness. The first number within each leaf (box) is the mean richness. The 'n' represents the number of sites within each leaf followed by the percent (%) of sites in each leaf.

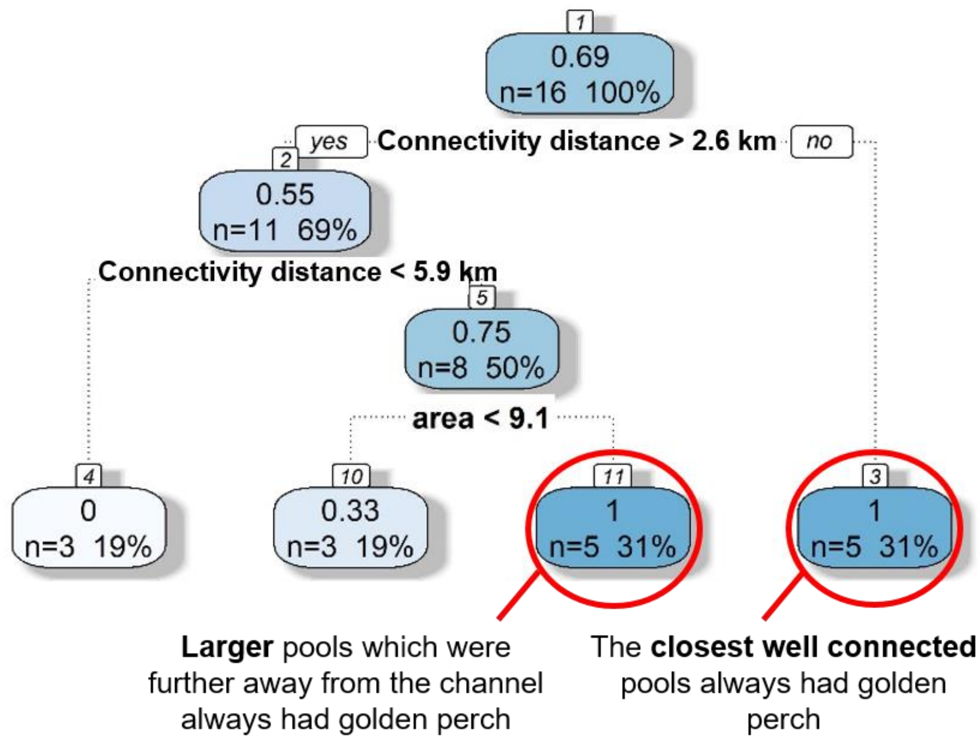


Figure 44. Regression tree outcomes for key pool characteristics that contributed to the presence of golden perch. The first number within each leaf (box) is the mean percent of sites with golden perch. The 'n' represents the number of sites within each leaf followed by the percent (%) of sites in each leaf.

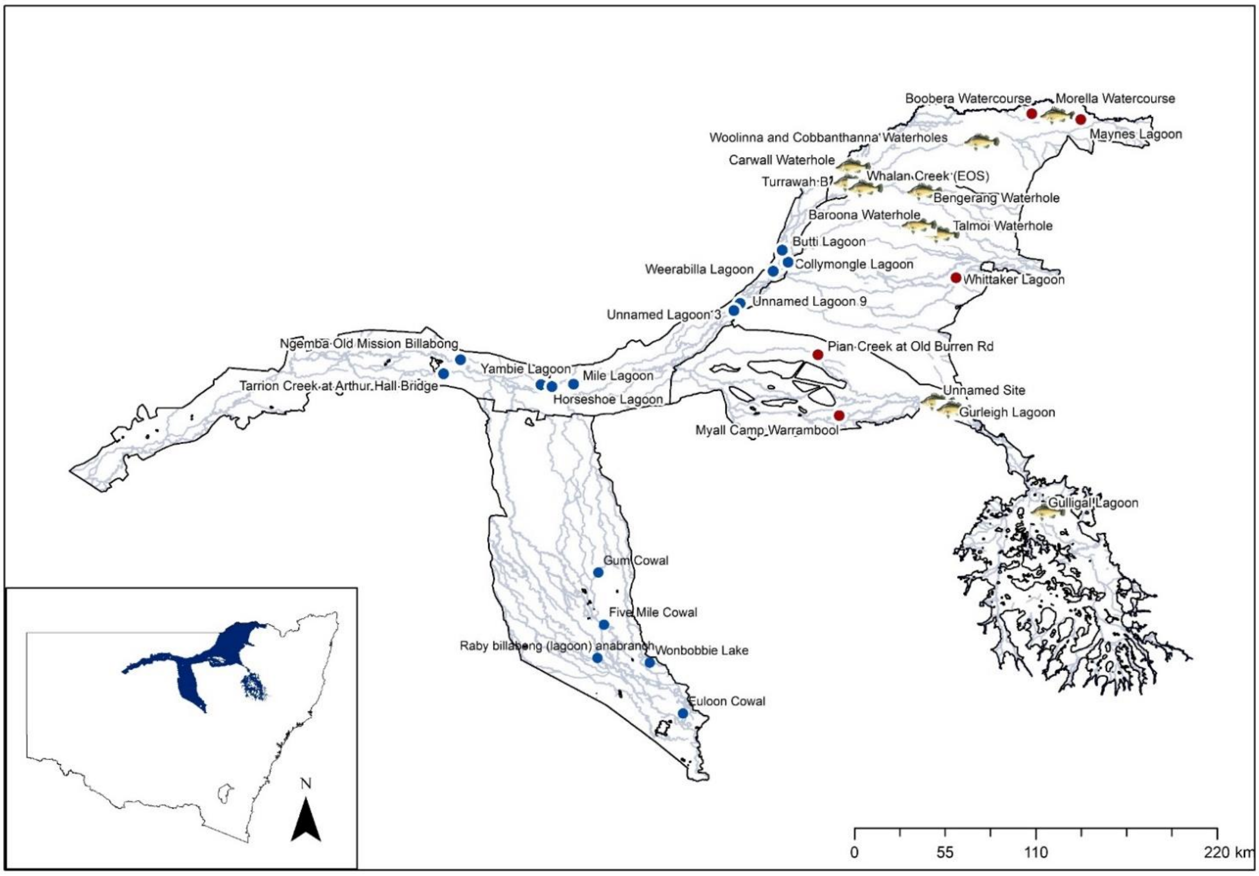


Figure 45. Distribution of Golden Perch across the surveyed floodplain pool sites. Note, blue circles have not been sampled yet.

Conclusions

Our preliminary analysis produced the following key findings:

- The number of fauna taxa using floodplain pools is highly variable within and between valleys in the northern Murray-Darling Basin.
- Native fish and waterbirds are the most species-rich groups using floodplain pools.
- Fauna richness appears to be greatest in the Namoi and lowest in the Border Rivers.
- Bony bream and spangled perch are common and have high eDNA concentrations within floodplain pools. They are also likely to be key food items for fish eating waterbirds and other predators, making them important species within these environments.
- The key drivers of fauna richness appear to be pool surface area, aquatic vegetation cover and pool depth. Additional sites are required to explore these associations further.
- The main large bodied native fish using floodplain pools is golden perch. The presence of this species appears to be driven by proximity to a main channel (that is, good connectivity), with larger pools (surface area) important if the distance to a main channel is more than 6km.
- Floodplain pool persistence is not a key driver in determining fauna richness or golden perch presence after broad scale flooding.

Recommendations

We have shown that floodplain pools can support a large number of fauna, including large bodied fish like golden perch. The large number of floodplain pools in the northern Murray-Darling Basin

(Figure 46) suggests that they are a significant component of the floodplain environment, particularly as refuges between flood events.

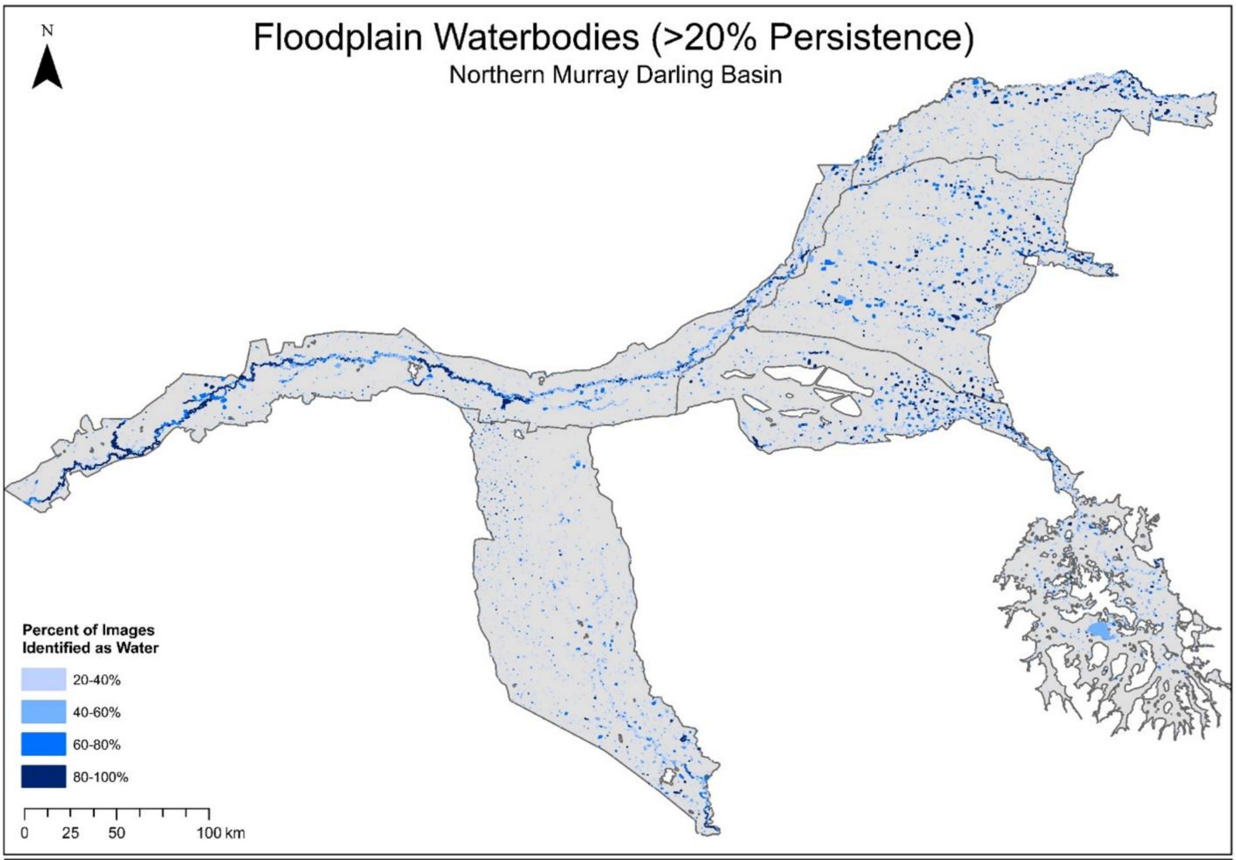
Our preliminary analysis identified lower fauna richness in the Border Rivers, compared to the Namoi and Gwydir, which could indicate issues with connectivity and inundation on the floodplain in this valley. Further, the size of a floodplain pool and level of connectivity appears to be important for fauna richness and golden perch populations. This information can be used to prioritise large floodplain pools with connectivity issues (that is, floodplain structures) for mitigation under NSW's floodplain management plans.

Next steps

The next stage of this project will investigate the influence of connectivity and inundation history on fauna richness and golden perch distribution in more detail. The department is in the process of generating inundation data and undertaking fauna surveys for additional sites in the northern Murray-Darling Basin. This information will allow an analysis of the importance of inundation history and connectivity on floodplain pool fauna.

The final stage of this project will investigate the influence of the implementation of the Basin Plan on a large number of floodplain pools in the northern Murray-Darling Basin (Figure 46). We will investigate long-term trends in floodplain pool inundation using the Digital Earth Australia Waterbodies tool. Using data as far back as the 1990s, we will be able to identify whether the identified floodplain pools in Figure 46 are inundated and persisting for longer in the years after the Basin Plan was implemented. Combining these outcomes with our findings for floodplain fauna will allow an interpretation of environmental outcomes due to specific water sharing plan rules and outcomes pre and post the Basin Plan.

A



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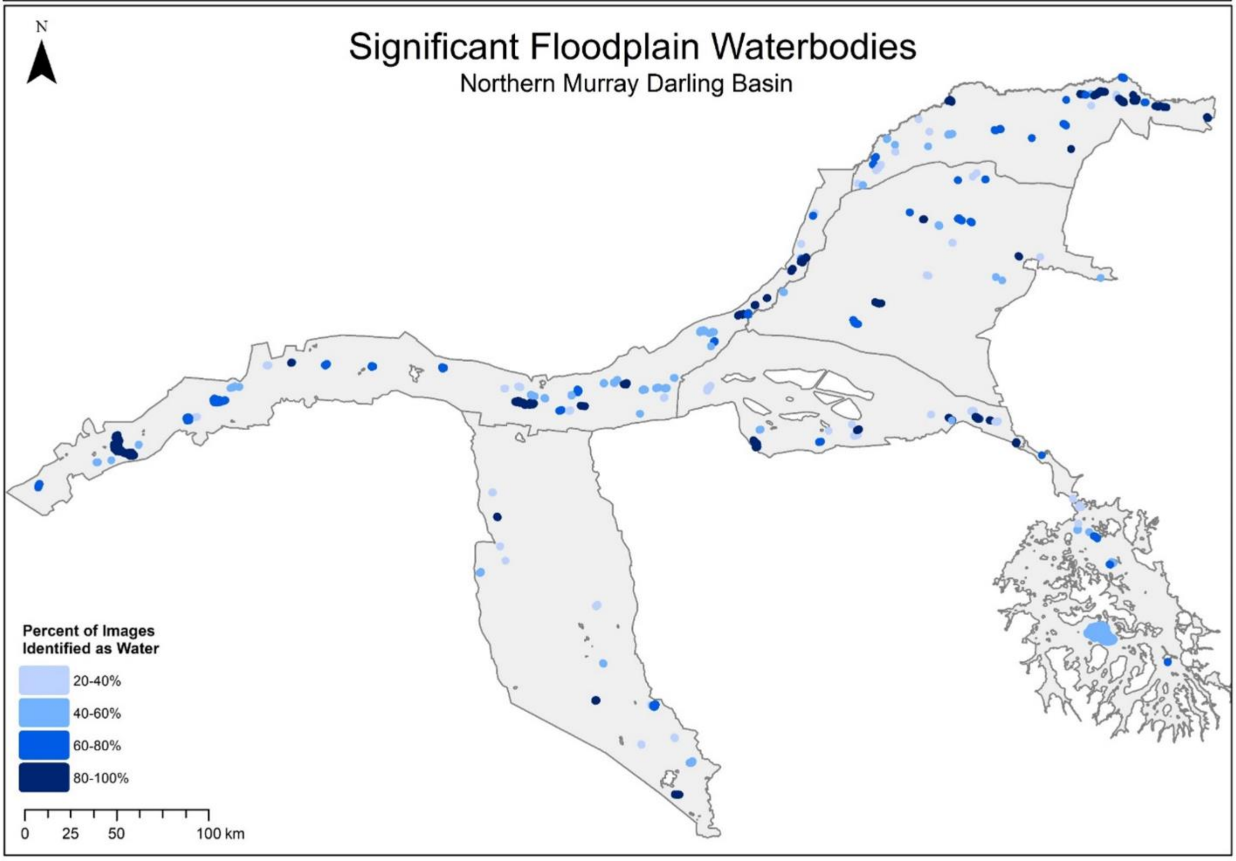

Figure 46. Floodplain waterbodies identified using the Water Observations from Space (WOFS) tool, which displays the detected surface water for the period 1987 to present. The first map: a.) shows all waterbodies including storages which were persistent >20% of the time. The second map: b.) shows significant floodplain waterbodies which are named lagoons, waterholes, billabongs and other floodplain habitats.

The Great Australian Wildlife Search

Project Team

Bec Wood

Project collaborators

This project is a collaboration with the Murray Darling Basin Authority, Department of Primary Industries — Fisheries, the Environment and Heritage Group of the Department of Planning and Environment, state governments including Victoria, Queensland and South Australia, La Trobe University, Odonata Foundation and EnviroDNA.

Introduction

There is a lack of knowledge of the occurrence and distribution of flow dependent wildlife such as threatened fish, frogs and platypus in NSW. Studies on where aquatic species live and what their habitat preferences are needed to improve management decisions. This information will then be used to assess the environmental objectives in water sharing plans and improve the conservation of threatened species.

The Great Australian Wildlife Search is a citizen science and environmental DNA project to map the distribution and occurrence of wildlife within rivers and streams. This project will use multispecies Environmental DNA (eDNA) analysis to determine the presence/absence of threatened species and flow dependent fauna across NSW. The data collected will be used to improve threatened species mapping through updated knowledge of species occurrence across NSW, focusing on the Murray Darling Basin.

The program will improve the department’s community engagement and outreach in monitoring waterway health and provide an excellent opportunity to engage with stakeholders on the importance of biodiversity in their local rivers.

Figure 47 The Great Australian Wildlife search will target aquatic wildlife such as fish, frogs and platypus. Photo credit: Michele Darmanin.

Project aims

This project aims to use the data collected by the Great Australian Wildlife Search to increase the baseline data collection for aquatic organisms and provide a spatially representative site selection methodology for eDNA monitoring across NSW. The compiled data set will be used to improve evidence driven management options for NSW surface water resources.

Key project questions

- How do we design and collect spatially representative eDNA data to inform water management decisions across NSW?
- What is the current known distribution of aquatic fauna relative to water use in NSW?

Link to water management activities

- To improve our scientific records for aquatic fauna and guide the development of water sharing plan rules in areas where a species environmental flow requirements are known.
- The enhanced dataset for aquatic species distributions will be used to update the HEVAE and RCI spatial layers.

Methods

This project uses innovative approaches for citizen science and eDNA sample collection. La Trobe University have been engaged to undertake the study design to provide spatially balanced sample sites across NSW and to enable site prioritisation and study design to inform flow-relationships. This will enable the collection of a state-wide dataset that would not otherwise be possible by the department alone.

Results

This project is currently underway. The study design is due to be completed by the beginning of 2023, sampling within the Basin is scheduled for Spring 2023 and analysis of results and reporting will occur in 2024. A project update will be provided in the 2022-23 EOMRP report.

Conclusions

No conclusions can be drawn at this time.

Recommendations

No recommendations are made at this time.

Next steps

During the data collection stage citizen scientists will be involved to collect ~2000 eDNA samples across NSW waterways, focussing on the Murray Darling Basin. This will require the help of many community groups, government agencies, independent research groups and universities across NSW. We will be collaborating with the Department of Primary Industries — Fisheries, the Environment and Heritage Group of the Department of Planning and Environment, the Murray Darling Basin Authority and other state agencies and experts across eastern Australia to determine priority species and sites for the project.

The eDNA kits will be distributed by the Odonata Foundation and EnviroDNA. They will include educational material and instructions for taking water samples for eDNA analysis. The samples will be sent to EnviroDNA for laboratory analysis for multi species eDNA tests (metabarcoding) targeting key flow dependent species at each site.

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Appendix 1 Maps of sampling sites for 2021-2022 in the coastal water sharing plan areas sampled to date.

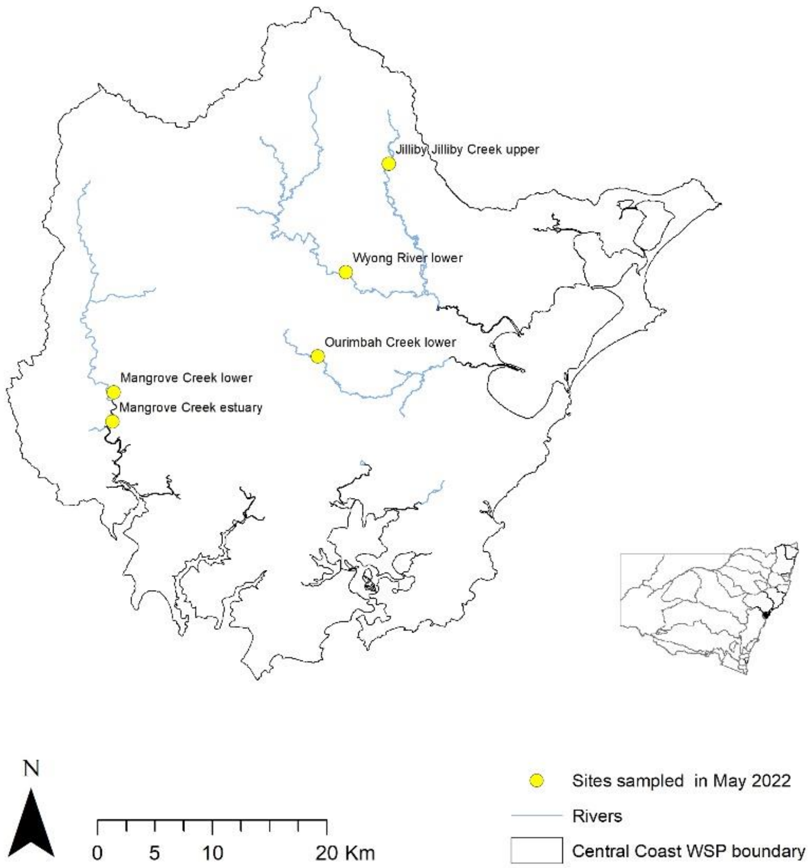

Figure 48 Sampling sites in the Central Coast WSP from 2022

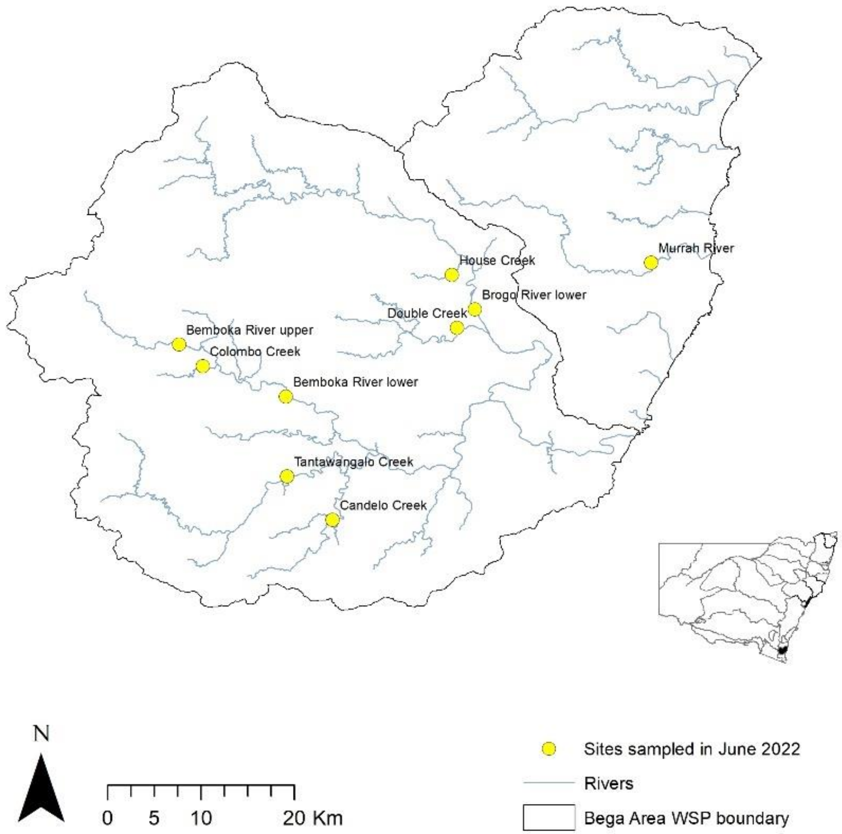

Figure 49 Coastal fish MER sampling sites in the Bega Area WSP (including Bega Brogo and Murrah-Wallaga catchments) from 2022.

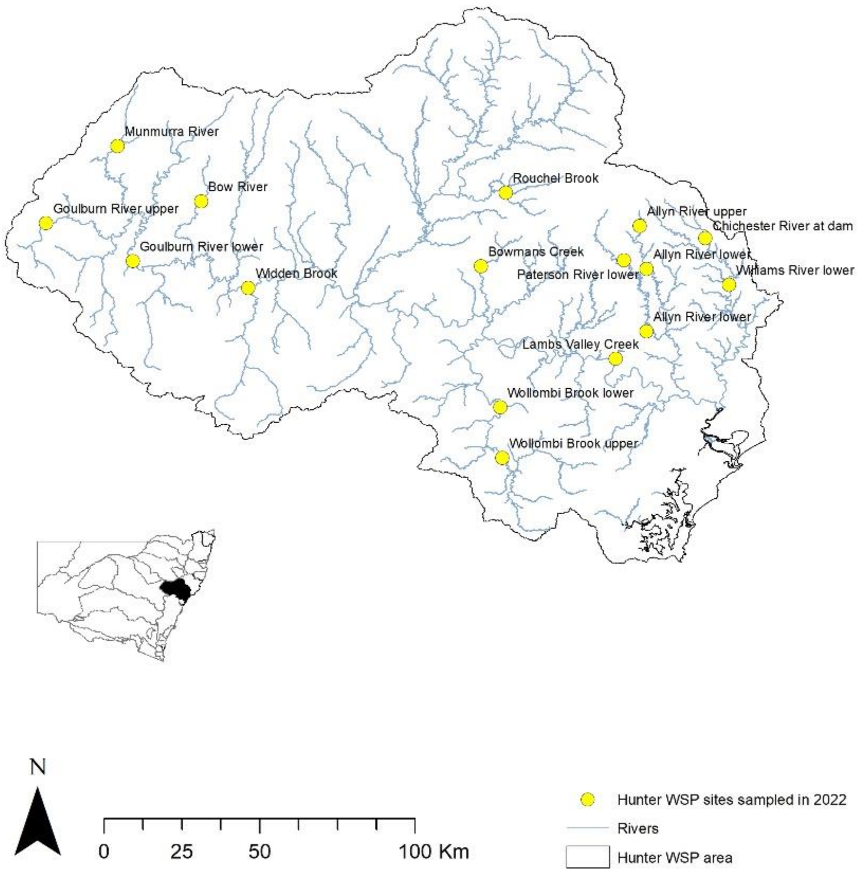

Figure 50 Coastal fish MER sampling sites in the Hunter River WSP from 2022

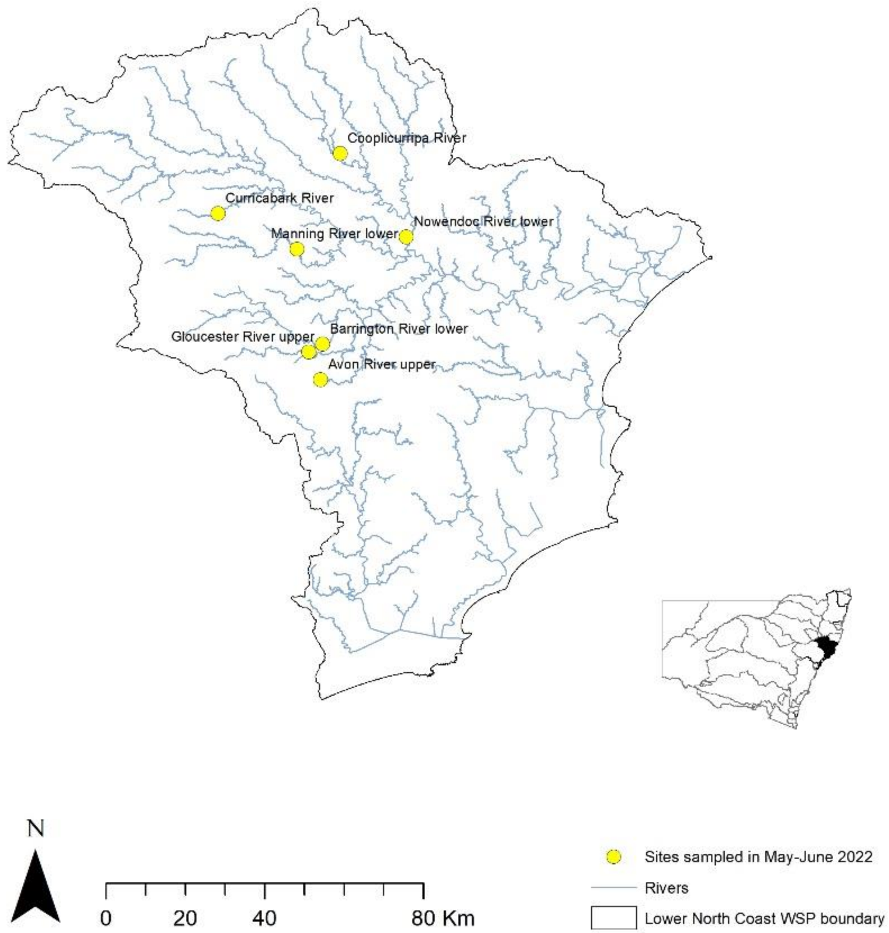

Figure 51 Coastal fish MER sampling sites in the Lower North Coast WSP from 2022

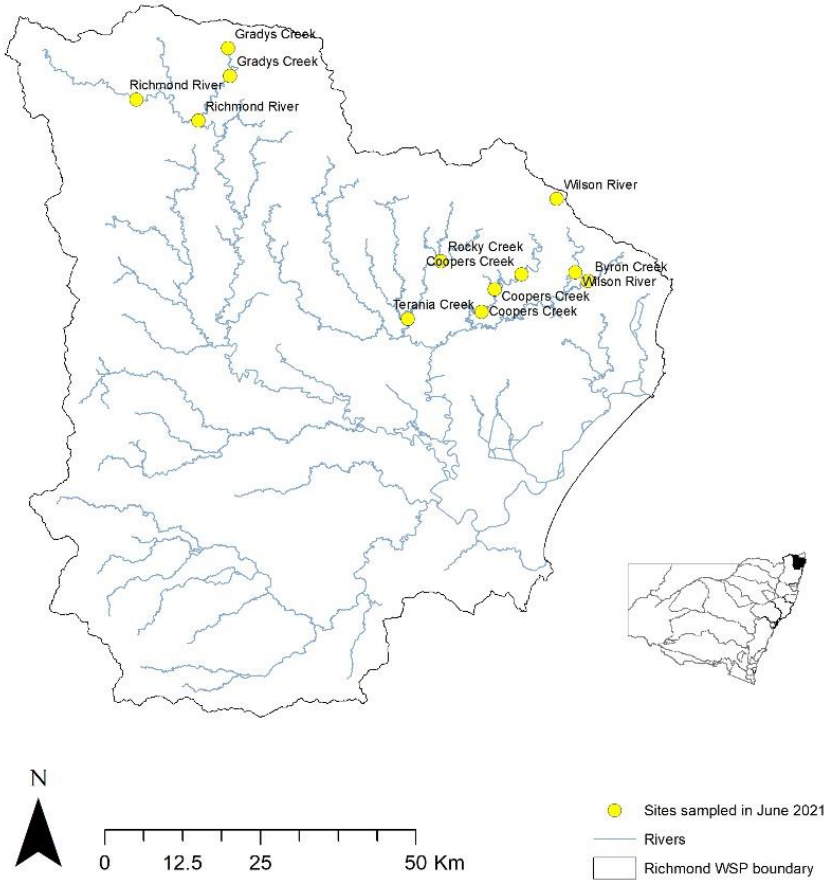

Figure 52 Coastal fish MER sampling sites for the Richmond River WSP from 2021