Native Fish Recovery Strategy

Jerom Stocks and Iain Ellis

August 2023

	Native Fish Recovery Strategy
	Recovery Reach Program
	Lower Darling-Baaka Recovery Reach
	Fish community monitoring
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Cover photo: Juvenile Golden Perch in the Lower Darling-Baaka (NSW DPI Fisheries).

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DPI Fisheries acknowledges that it stands on Country which always was and always will be Aboriginal land. We acknowledge the Traditional Custodians of the land and waters, and we show our respect for Elders past, present and emerging. We recognise that First Nations people were the first managers of rivers and land in this country. We are committed to providing places in which Aboriginal people are included socially, culturally, and economically through thoughtful and collaborative approaches to our work.

Contents

Introduction

The Native Fish Strategy

Following the Menindee Fish Deaths in 2018 – 19, NSW Department of Primary Industries (DPI) Fisheries in collaboration with agencies initiated a range of actions to preserve as many native fish as possible during the unprecedented low flow conditions. The Australian and Basin State Governments also recognised that longer-term actions were needed to rebuild healthy and resilient native fish populations given the deep connection people have to native fish.

As a result, through 2019 – 20 the Australian Government committed to develop the **Native Fish Recovery Strategy** (NFRS, or "the Strategy"), which complements the current water reforms including the Water Act 2007 and Basin Plan 2012. The Strategy provides a high-level framework to guide investment and implement foundation actions. It emphasises community engagement and ownership, focusing on recovering rivers of basin-scale significance in a way that complements existing initiatives.

The Strategy has a 30-year horizon to 2050, with implementation stages spanning ten years followed by major reviews. In the initial ten years of the Strategy, a range of actions would be implemented across the Murray–Darling Basin, targeting four broad outcomes:

- recovery and persistence of native fish,
- threats to native fish are identified and mitigated,
- communities are actively involved in native fish recovery,
- recovery actions are informed by best available knowledge.

A key feature of the implementation of the Strategy is the concept of **Recovery Reaches** and the use of **Recovery Coordinators** to develop and maintain the community partnerships. These arrangements will help foster collaboration and partnerships in fish management at local and regional scales and seek to have technical expertise, traditional ecological knowledge, and local know-how included in fish recovery actions.

Lower Darling-Baaka Recovery Reach

In this document we refer to the Lower Darling River as the Lower Darling-Baaka River (LDBR) in recognition of the traditional custodians of the region. Here, we report on the Native Fish Recovery Strategy fish community sampling activities implemented in the **Lower Darling-Baaka Recovery Reach** (LDBRR) during the 2022/23 period.

The LDBRR consists of the Menindee Lakes, approximately 600 km of the Darling-Baaka River downstream to the junction with the Murray River at Wentworth, and the ephemeral Great Darling Anabranch to its west (Figure 1). Aside from the Menindee Lakes regulatory infrastructure, weirs exist at Weir 32 (just downstream of the Menindee Lakes), Pooncarie and Burtundy. The Murray River lock and weir at Wentworth (Murray Lock 10) creates a Weir Pool that extends up the lower reach of the Darling-Baaka to near Ashvale Station.

Our understanding of the ecological connectivity between the LDBR and connected waterways up and downstream is rapidly improving. For example, Golden Perch spawned as far north as the Border Rivers have been captured in the Menindee Lakes. Similarly, Golden Perch that developed as juveniles in the LDBR contribute substantially to population recovery through the Lower Murray, including through the South Australian River Murray. Consequently, we have sought to contribute to native fish recovery in river and floodplain systems adjacent/downstream of the LDBR to maximise such outcomes, and in doing so contribute to broader basin scale native fish recovery.

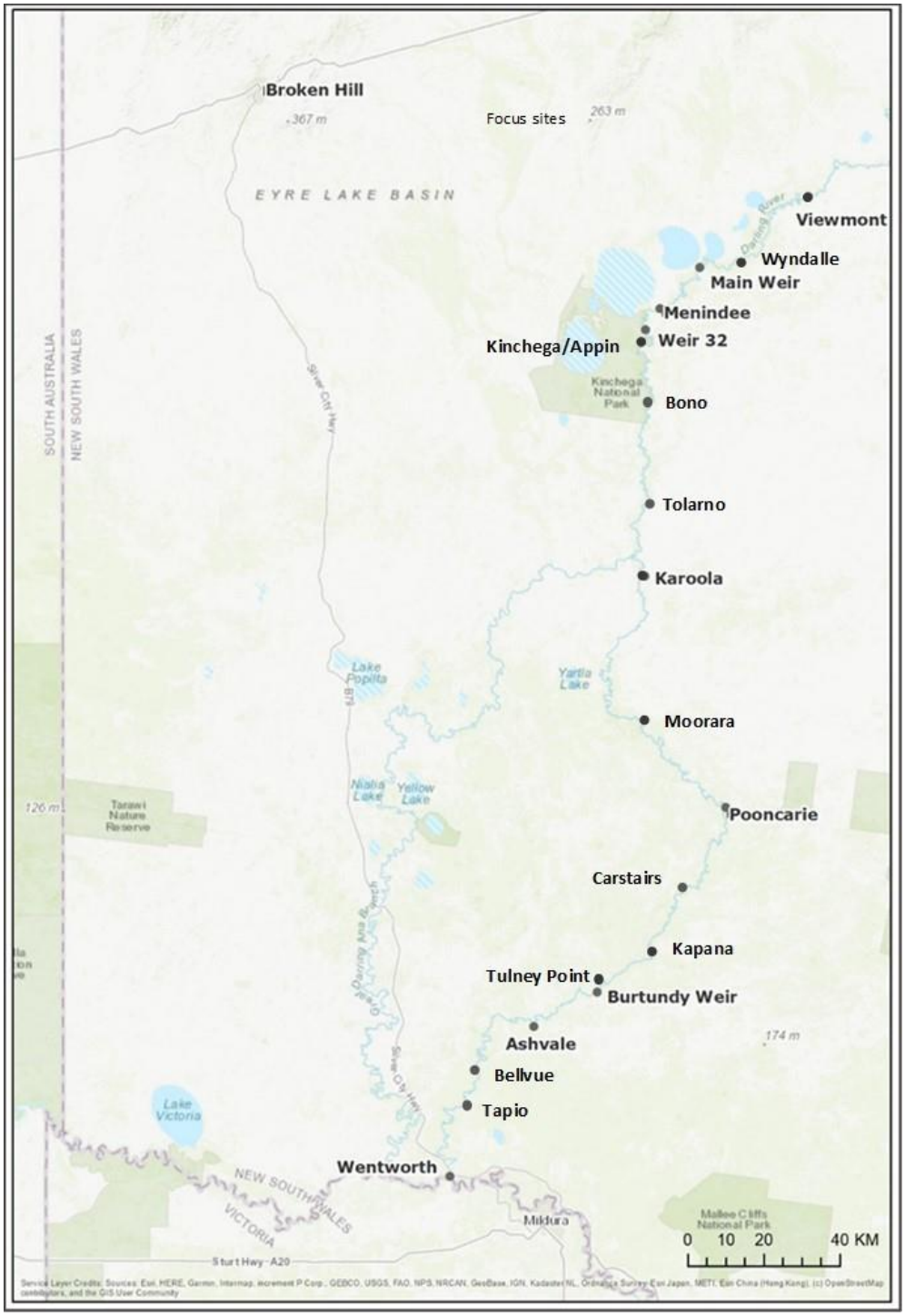

Figure 1. The Lower Darling region in far west NSW showing locations of key stations, towns, and weirs. The mass fish kill events of summer 2018 – 19 occurred throughout approximately 40 river kilometres from Menindee Main Weir downstream to Weir 32. Subsequent deaths occurred throughout the river downstream of Menindee to Ashvale.

Fish values in the Lower Darling-Baaka

The LDBR is significant for native fish species in the Murray-Darling Basin including iconic species such as Golden Perch and Murray Cod (vulnerable), as well as other threatened species including Silver Perch and Freshwater Catfish. It also supports a suite of small and medium-bodied fish species and is home to the threatened Darling River Snail (critically endangered). The LDBR is also part of the Darling River Endangered Ecological Community. Prior to the Millennium Drought the fish community of the Lower Darling region was in 'moderate' condition (Davies et al 2010). The LDBR Murray Cod population is traditionally considered a robust population, which generally exhibited large numbers of juveniles as well as a range of adult size classes (Wallace et al. 2008). It is also important in relation to recovery of adjacent populations in the mid and lower Murray River system considering the 2011 and 2016 blackwater fish deaths which impacted thousands of river kilometres along the Murray, but in which the LDBR was largely spared.

In a whole of Basin context, the region is important for the breeding and recruitment (growth and survival) of Golden Perch (Sharpe 2011). Adults are known to spawn in response to flow events upstream in the Darling catchment, with larvae and young fish drifting downstream, developing in nutrient rich water as they do so. Many reach the Menindee Lakes where they exhibit strong growth and survival in warm, food-rich waters (Sharpe 2011; Stuart and Sharpe 2017). On subsequent flow events that re-connect the Menindee Lakes with the LDBR, juvenile and adult return to the river channel and disperse both upstream and downstream (i.e. north to the Barwon-Darling system and its tributaries, or south to the Murray River system). Recent science demonstrates that Golden Perch in the Lower and Mid-Murray system contain strong representation by fish that began life in the Darling-Baaka River (Zampatti et al. 2018).

The fish community of the Lower Darling-Baaka suffered a series of significant fish kill events in recent decades, culminating in the mass deaths of millions of native fish at Menindee during summer 2018 – 19. Each event was linked to prolonged low flow or cease to flow conditions, or recommencement flow events (following cease to flow periods) which caused sudden deterioration in water quality (Ellis and Meredith 2004; NSW DPI 2019). There have been subsequent mass fish deaths in the LDBR near Menindee again in autumn 2023, with the death of tens of millions of native fish following significant flooding events across the region which contributed to hypoxic blackwater conditions upon flood recession.

Flow history

The compounding impacts of drought, water storage/extraction and climate change in the Northern MDB (Northern NSW and Queensland) over the last 20 – 30 years has resulted in a gradual suppression of flows reaching he Menindee Lakes, which in turn contributes to higher risk of conditions that can lead to fish deaths during droughts (Vertessy 2019). Figure 2 shows recorded flow in the Darling-Baaka River at Wilcannia and highlights a reduction in inflows to the Menindee lakes resulting from an increased frequency and duration of very low or cease to flow (< 20 ML/day) periods in the last 20 to 30 years (Vertessy 2019, Thoms and Sheldon 2000).

The modification of the Menindee Lakes System (MLS) in the 1960s to capture and store inflows in the lakes resulted in a suppression of flow variability in the LDBR (i.e. releases from the MLS) (Figure 3). The reduction of inflows to the MLS from the Northern MDB in recent decades has resulted in further reductions of flow releases from the MLS to the LDBR, with low or cease to flow events increasing in frequency and duration. Two exceptionally long cease to flow events occurred in 2015 – 16 and 2018 – 19, with very low flow (<10 ML/day) at Burtundy persisting for well over a year (over 500 days in each case). In the most recent of these, flow in the LDBR were low through 2018, and absent through most of 2019 (Figure 4). During this extended period of low/no flow millions of native fish died in the three mass fish death events at Menindee in summer 2018 – 19, and subsequently along the LDBR through 2019 and early 2020 (NSW DPI 2019, Thiem et al. 2019, Stocks et al. 2019, Vertessy 2019, Ellis et al. 2021, Stocks et al. 2021).

Following widespread rainfall in the Northern MDB, flow returned to the Menindee Lakes and LDBR in early 2020. With inflows continuing through 2020 and 2021, the MLS reached capacity in late

2021. Releases from the MLS were managed from December 2021 to March 2023 to maintain 'airspace' in the lakes and minimise flooding of property at Menindee and in the LDBR (Figure 3).

During and following the recession of floodwaters in early 2023, mass fish deaths related to poor water quality occurred in the Menindee Town Weir Pool and along the LDBR channel and floodplain from Weir 32 to Wentworth. DPI Fisheries estimated tens of millions of Bony Herring, thousands of Golden Perch, and dozens of Murray Cod and Silver Perch perished in the Menindee Town Weir Pool between Menindee Main Weir and the outlet from Lake Menindee (some 35km of river). This was the same stretch of river affected by multiple mass fish deaths in 2018 – 19.

Major fish deaths were also reported along the LDBR downstream of Menindee Lakes following flood recession. DPI Fisheries attended a major fish kill at a recently disconnected wetland near Karoola Station where hundreds of thousands of dead Bony Herring, thousands of Golden Perch and dozens of Murray Cod were documented. In other cases landowners provided reports with photographs of hundreds of dead Murray Cod in other disconnected wetlands. Unfortunately, due to the impacts of widespread flooding, poor access to floodplain habitats (and in many areas the river itself) meant fish deaths along the LDBR were under-reported.

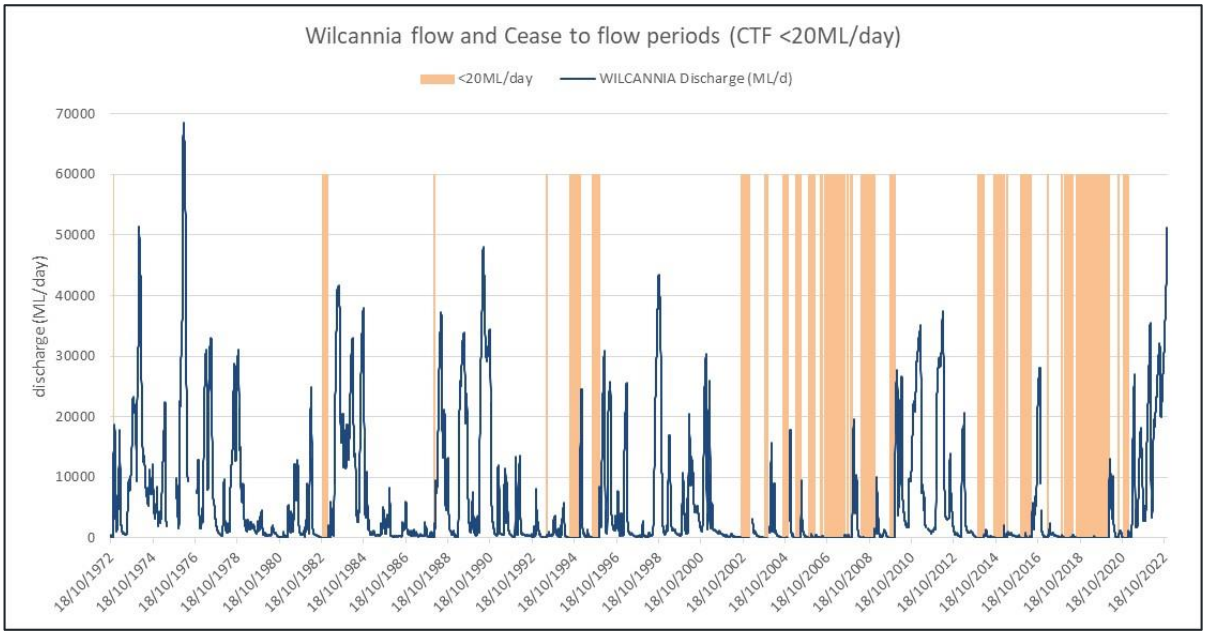

Figure 2. Historic flow in the Lower Darling-Baaka River at Wilcannia (upstream of the Menindee Lakes), including very low flow periods (less than 20 ML/day) highlighted in orange. Data sourced from WaterNSW.

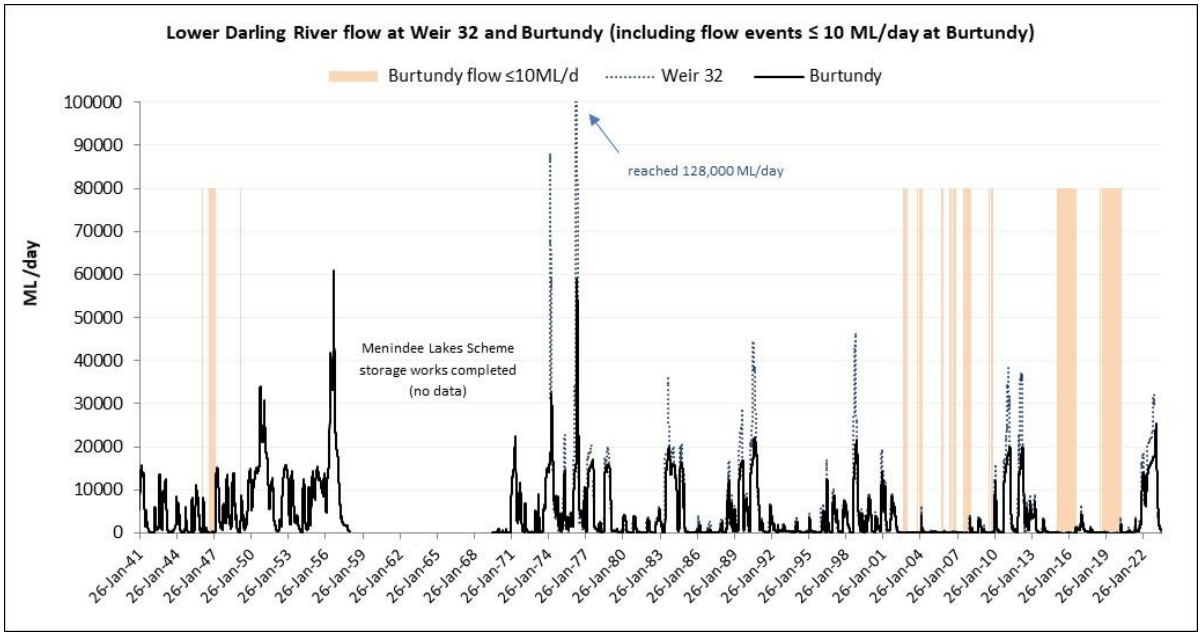

Figure 3. Flow records on the Lower Darling-Baaka River at Burtundy since 1941 and Weir 32 since 1974. Low and no flow events at Burtundy (of 10 ML/day or less) are shown as orange bars. Bank full is approximately 10,000 – 15,000 ML/day (note that y-axis differ between plots). Data sourced from WaterNSW.

Fish Community Monitoring

Following the Menindee fish kills in 2018/19, a monitoring program was initiated to investigate the impacts of these fish kills, and document subsequent changes in the fish community in the LDBR over time. The key to this monitoring program was the establishment of a baseline fish community condition dataset including river downstream of Weir 32 and the Menindee weir pool, to which improvements or deterioration could be compared. Prior to this program there was little data pertaining to the fish community in the Menindee weir pool.

This report presents an ecological assessment of the impacts of the fish kills in the Lower Darling over the 2018/19 and 2019/20, and now Autumn 2023 on the fish community and tracks the population trajectory.

A detailed description of the 2018 – 2020 first round of this work was published in *Stocks JR, Ellis I, van der Meulen DE, Doyle J, Cheshire KJM (2021) Kills in the Darling: Assessing the impact of the 2018-2020 mass fish kills on the fish communities of the Barwon-Darling River, a large lowland river of southeastern Australia. Marine and Freshwater Research Special Edition – Fish Kills. https://www.publish.csiro.au/MF/MF20340*

Methods

Monitoring was conducted by standardised electrofishing, unbaited bait traps and opera house traps at seven (7) sites within each of two (2) 'reaches', these being the **Menindee Weir Pool** (from Weir 32 to the Menindee Main Weir) and the **Pooncarie Reach** (river between Weir 32 and Pooncarie) (Figure 4). For full methods refer to Stocks et al. (2021).

Differences in species abundance, diversity and size composition between the two (2) reaches was assessed in June 2019, six months after the Menindee fish deaths (Round 1).

The Menindee Weir Pool was again sampled in October 2019 (nine months post the Menindee fish deaths, Round 2), however sampling in the Pooncarie Reach could not be conducted because the river had contracted to a series of pools and electrofishing access was precluded.

Monitoring in both reaches was repeated in June 2020 (Round 3) following a return of flow to the system in early 2020, and again in June 2021 (Round 4) providing three (3) consecutive years of repeat annual sampling (June) in both reaches. Round 4 was conducted after a second Barwon-Darling flow event in two years delivered inflows to Menindee that facilitated filling of Lakes Menindee and Cawndilla (which had been dry since 2018). Environmental flows targeting native fish outcomes in the LDBR were delivered from the Menindee Lakes during spring and summer of 2020 – 21.

DPI Fisheries had a range of fish research and monitoring surveys scheduled in the LDBR region in 2022. These efforts were deferred due to poor access, limited efficiency of electrofishing under high-flow conditions, and then fish deaths in March 2023 following which surveys were again postponed avoiding additional stress on surviving fish in the system.

As water quality improved through April and May of 2023, fish surveys in the LDBR resumed. Round 5 of fish community monitoring in the Menindee Weir Pool Reach and the Pooncarie Reach were completed in late May 2023 (Round 5).

Table 1. Timing of fish condition monitoring conducted for the LDBR RR project.

Round	Date	Reaches surveys
1	June 2019	Both
2	October 2019	Menindee Weir Pool only
3	June 2020	Both
4	June 2021	Both
5	May 2023	Both

Limitations and delays

Widespread flooding in the LDBR throughout late 2022 substantially hampered the delivery of on ground activities in the LDBR RR. Coupled with frequent local storm activity, access via regional roads to large areas along the LDB was frequently limited, affecting the delivery of planned activities. As such the MDBA and DPI Fisheries agreed to extend the duration of project contract to June 2023 to allow for delivery of planned activities.

With the recession of floods in early 2023 mass fish deaths related to poor water quality at Menindee and along the LDBR led to further delays in delivering activities to avoid imposing additional stress to at risk fish communities. When local conditions improved in April and May of 2023, DPI Fisheries staff were able to complete outstanding activities relating to monitoring activities in the Menindee Lakes and LDBR.

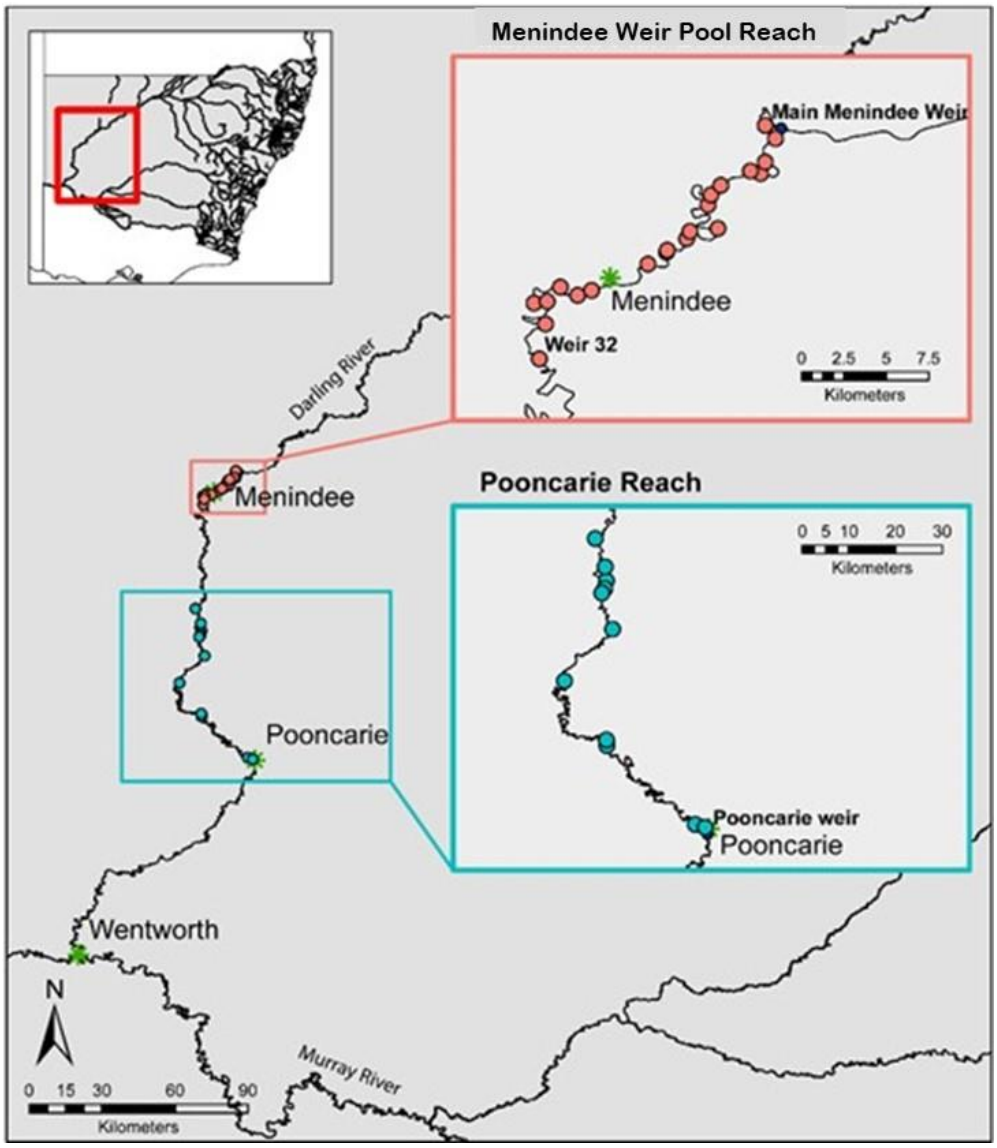

Figure 4. Sites within the Menindee Weir Pool and Pooncarie Reach at which fish community sampling was conducted in the Darling Baaka River, Australia between June 2019 and May 2023. Green asterisks indicate towns.

Results and discussion

Reach comparison Round 1, June 2019

Under Stage 1 of the Lower Darling Recovery project, monitoring six months after the 2018 –19 Menindee fish deaths (June 2019) recorded significantly lower abundances of Murray Cod, Bony Herring, Carp Gudgeon and introduced (pest) Goldfish in the Menindee Weir Pool compared to the Pooncarie Reach (Figure 5).

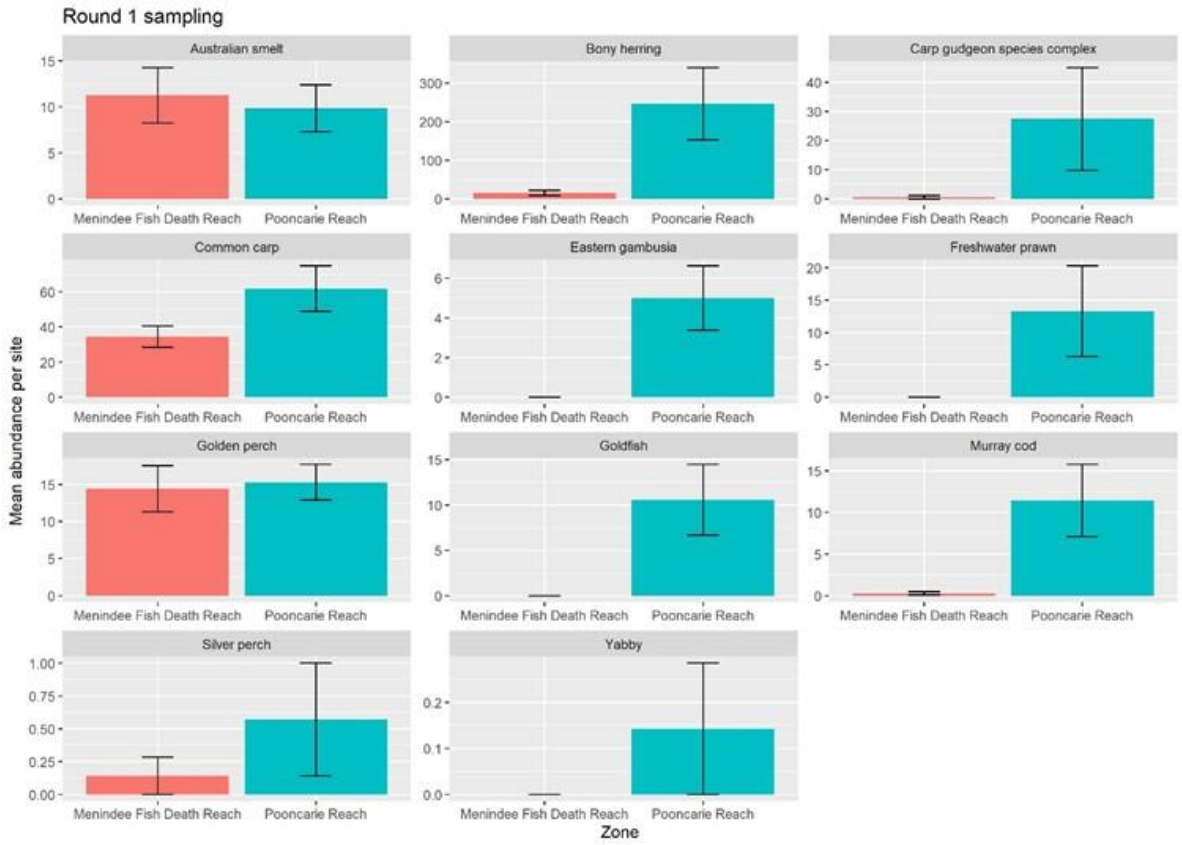

Figure 5. Comparison of mean abundance per site between the Menindee Weir Pool and Pooncarie Reaches during Round 1 of sampling (June 2019, six months after the 2018-19 Menindee fish deaths). Presented in Stocks et al. (2021).

Only two (2) Murray Cod and one (1) Silver Perch were detected in the Menindee Weir Pool in the June 2019 surveys, whereas 81 Murray Cod and four (4) Silver Perch were detected in the Pooncarie Reach with the same sampling effort. Common Carp abundance was also lower in the Menindee Weir Pool, although the difference was not statistically significant.

There was no significant difference in Golden Perch abundance between the two (2) reaches (101 sampled in the Menindee Weir Pool compared to 107 in the Pooncarie Reach) despite the deaths of thousands of Golden Perch during the Menindee fish deaths. High numbers of Golden Perch were likely present in the Menindee Weir Pool prior to the fish deaths. This was likely due to the species tendency to migrate upstream and the lack of fish passage from the Town Weir Pool upstream to Lake Wetherell. Australian Smelt also showed no difference in abundance between the two reaches in June 2019.

Reach comparison Round 5, May 2023

In March 2023, mass fish deaths occurred in the Menindee Town Weir Pool of the LDBR. May 2023 surveys (Round 5) documented some significant changes in the fish population in comparison to surveys conducted in 2019, 2020 and 2021.

Within both reaches the five (5) most abundant species detected were (from most abundant to least abundant): Common Carp, Bony Herring, Goldfish, Spangled Perch and Golden Perch. Common Carp abundances were much higher in 2023 than in previous surveys conducted in 2019, 2020, and 2021 using similar methods. Spangled Perch and Olive Perchlet were detected in the Menindee Lakes and LDBR in May 2023 following dispersal from warmer regions in the Northern Basin during flooding. Figure 6 shows comparison of mean abundance per site between the Menindee Weir Pool and Pooncarie Reaches during Round 5 (May 2023), noting the different scales between plots.

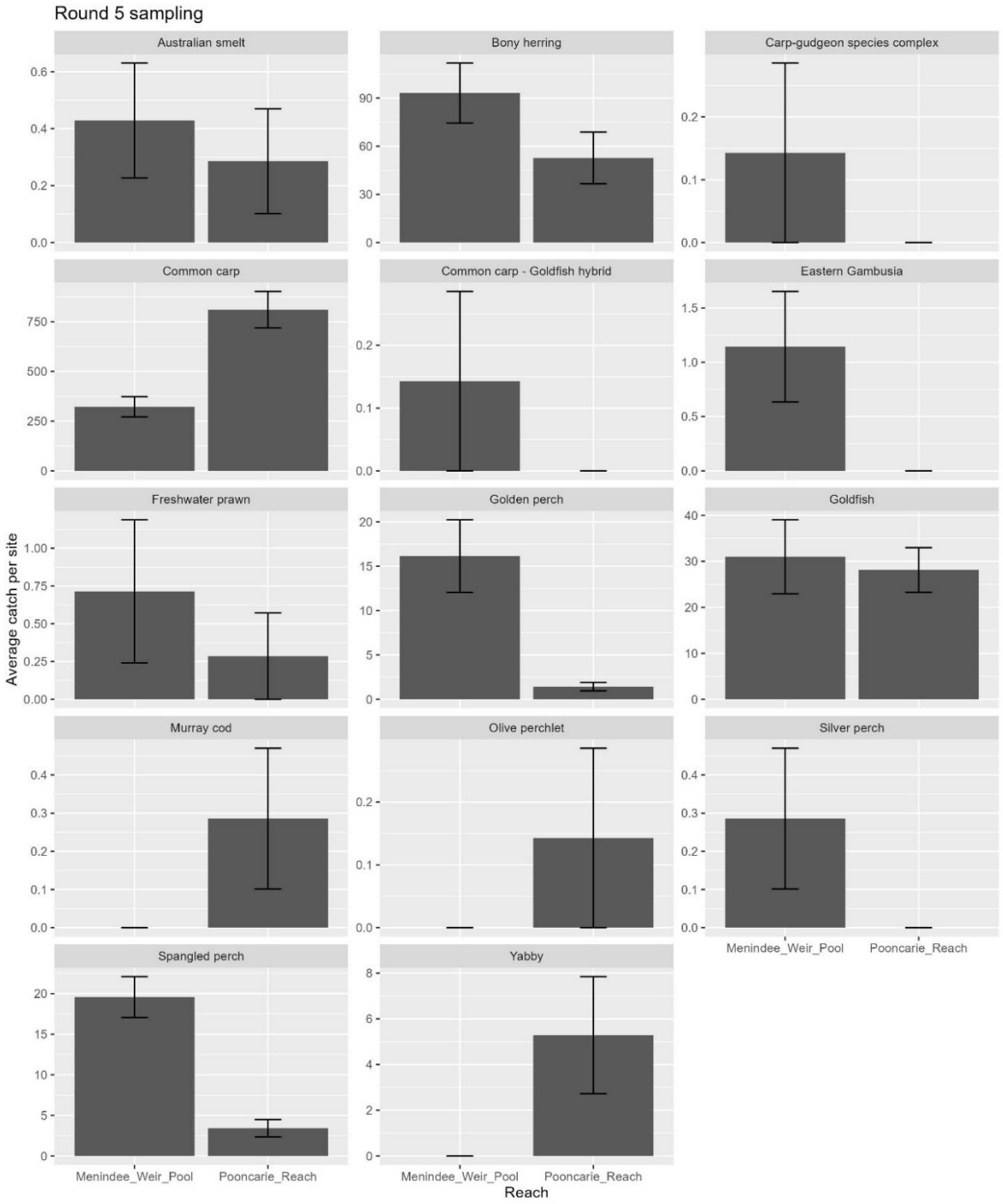

Figure 6. Comparison of mean abundance per site between the Menindee Weir Pool and Pooncarie Reach during Round 5 of sampling (May 2023), two months after the March 2023 fish deaths.

Bony Herring, the most affected species during the fish deaths, were still more abundant in the Menindee Weir Pool than the Pooncarie Reach in May 2023. Golden Perch abundance was also substantially higher in the Menindee Weir Pool than in the Pooncarie Reach, as were Silver Perch and Spangled perch. The higher abundance of these four (4) species may reflect their capacity to move towards refuge areas at Lake Menindee outlet during the March 2023 fish deaths. The small-bodied species Australian smelt, Carp gudgeon and Eastern Gambusia were each more abundant in the Menindee Weir Pool despite the March 2023 fish deaths, as were Freshwater Prawn.

No Murray Cod were recorded in the Menindee Weir Pool in May 2023, although DPI Fisheries were notified of captures by recreational anglers in this reach. Silver Perch abundance was low in the Menindee Weir Pool, and none were recorded in the Pooncarie Reach in May 2023. The abundance of Yabbies was higher in the Pooncarie Reach than in the Menindee Weir Pool.

Common carp were the most abundant species within each sampling reach, being more abundant in the Pooncarie Reach than the Menindee Weir Pool (Figure 6).

Rounds 1 to 5: Menindee Weir Pool

Figure 7 shows changes in abundance for fish species in the Menindee Weir Pool over five (5) survey events (June 2019, October 2019, June 2021, June 2021 and June 2023). Figure 8 shows the population structure (length frequency distributions) for fish species in the Menindee Weir Pool and Pooncarie Reach in June 2021 (pre-flood) and May 2023 (post flood and the March 2023 fish deaths).

Small-bodied fish and crustaceans

Small-bodied fish species such as Australian Smelt and Carp Gudgeon are typically < 15cm in length. Small-bodied fish and freshwater crustaceans like Freshwater Prawns and Yabbies are important food sources for larger bodied fish species and piscivorous birds.

- The abundance of Australian Smelt in the Menindee Weir Pool decreased between Rounds 1 and 2, suggesting low breeding/recruitment after the 2018-19 Menindee fish deaths as conditions deteriorated due to an absence of inflows in the Menindee Weir Pool and competition for limited resources increased. Abundances of Australian Smelt increased through Rounds 3 and 4 indicating some population recovery following the return of flow to the LDBR through local breeding of immigration from downstream. Round 5 sampling demonstrated another decline in Australian Smelt abundance, most likely attributed to the March 2023 fish death.
- Carp Gudgeon increased in abundance in the six months post the Menindee Weir Pool fish deaths, before decreasing through Rounds 3, 4 and 5. Given the species preference for slow flowing or still water this likely reflects changing hydraulic conditions the weir pool from still (lentic) in Rounds 1 and 2 to flowing (lotic) after flow returned to the LDBR in early 2020.
- No threatened Olive Perchlet have been detected in the Menindee Weir Pool during this program.
- Abundances of Freshwater Prawn and Yabbies in the Menindee Weir Pool also indicated some recovery from Rounds 2-4 after being absent from catches during Round 1 (post the initial 2018-19 fish death). Abundance of both decreased again after the March 2023 fish deaths.
- Abundances of the introduced pest Eastern Gambusia have remained low throughout this program.

Bony Herring

Bony Herring is considered a “boom-bust” generalist species that can increase in abundance rapidly during wetter periods (especially floods). Bony Herring are an important food source for larger bodied fish species and piscivorous birds (Lintermans 2023).

- The abundance of Bony Herring in the Menindee Weir Pool decreased between June and October 2019 (Rounds 1 and 2), suggesting low breeding/recruitment after the 2018-19 Menindee fish

kills related to deteriorating conditions and competition for limited resources in the Menindee Weir Pool through 2019.

- Bony Herring abundance increased between June 2020 and June 2021 (Rounds 3 and 4), driven by juvenile fish (40-100 mm in length) after flow returned in March 2020 (see Figure 8).
- Bony Herring abundance decreased between June 2021 (Round 4) and May 2023, (Round 5) after the March 2023 fish deaths, but was still significantly higher than detected in Rounds 1 and 2 (i.e. after the 2018-19 fish kills).
- In May 2023, the Bony Herring population in the Menindee Weir Pool consisted of two (2) main cohorts of fish 40-80 mm and 160-220 mm in length (Figure 8).

Common Carp and Goldfish (introduced pest species)

Common Carp and Goldfish are introduced generalist species that breed in shallow still or slow flowing habitats, particularly inundated floodplains. Thus, we expect populations to increase in abundance following floodplain inundation.

- There was a substantial increase in Common Carp and Goldfish abundance in the Menindee Weir Pool following recent widespread flooding (Round 5, May 2023) compared to surveys in 2019, 2020, and 2021 (Figure 7).
- The Common Carp population in the Menindee Weir Pool in May 2023 consisted of both juvenile fish 80-200 mm in length (likely 0 -1 years old) and larger adults 250-400mm (likely 2-3 years old), with smaller abundances of larger adult size classes (Figure 8).
- Having been low in abundance through Rounds 1-4, the Goldfish population in the Menindee Weir Pool consisted primarily of a cohort of fish 80-160 mm in length likely to have originated during flooding in 2021-22 (Figure 8).
- The increased abundance of these pest species will cause ongoing challenges for native fish, emphasising the need for effective and integrated pest management strategies to mitigate their impact, enhance native fish recovery, and maintain the balance in the ecosystem.

Murray Cod

Murray Cod are a large, long-lived species that breed annually in ‘nests’ which are protected for several weeks by adult males. Higher flows prior to spawning period increase primary productivity, providing resources for larval fish and stable flows during the nesting period prevent nest abandonment; each contribute to breeding and recruitment success, although being large (high oxygen demand) and less mobile than species like Golden Perch, they can be more susceptible to local water quality issues such as hypoxia.

- Detections of Murray Cod within the Menindee Weir Pool have been low throughout the 5-year sampling period, indicating no significant improvement in abundance since June 2019 (after the Menindee 2018-19 fish deaths) (Figure 7).
- Murray Cod were not captured in the Menindee Weir Pool in the May 2023 (Round 5) survey.
- Anecdotally, recreational fishers have reported catching Murray Cod in the Menindee Weir Pool since the March 2023 fish deaths. These catches have typically been near the Menindee Lake outlet where releases from Lake Menindee maintained suitable dissolved oxygen levels through March and April of 2023.

Golden Perch

Golden Perch is a highly mobile and highly fecund (100s of 1,000s of eggs per female), with breeding and recruitment success generally related to periods of higher flows or floods.

- A significant decrease ($P<0.05$) in the abundance of Golden Perch in the Menindee Weir Pool was identified between Rounds 1 and 4 (June 2019 and June 2021) (Figure 7).
- Despite this decrease in abundance, Round 4 monitoring detected the presence of multiple juvenile size classes (100-200 mm) representing 1–2-year-old recruits (Figure 8). These juvenile

Golden Perch are likely to be the result of spawning upstream in the Barwon-Darling and its tributaries in response to flow events in early 2020 and again in early 2021. Eggs and larvae then drifted downstream in floodwaters, many reaching the productive nursery habitat offered by the Menindee Lakes or dispersing into the LDBR downstream.

- Despite the fish deaths in March 2023 Golden Perch abundance in the Menindee Weir Pool increased significantly between Rounds 4 and 5 (Figure 7).
- The Menindee Weir Pool population sampled in Round 5 was dominated by adult fish >300 mm in length, with another prominent cohort of fish from 100-200 mm in length, which are likely to be 1-2 years old (Figure 8).
- Given movement of Golden Perch is often related to flow, we suggest floodwaters and subsequent releases of water from the Menindee Lakes attracted adult Golden Perch to the Menindee Weir Pool from further downstream during protracted high flows from 2021-23.

Silver Perch

- Silver Perch abundance in the Menindee Weir Pool has been low throughout the program. Only two (2) Silver Perch were recorded in the reach in the May 2023 (Round 5) surveys (Figure 7).

Spangled Perch

- Spangled Perch were detected in the Menindee Weir Pool in May 2023 (Round 5). These fish dispersed from warmer regions in the Northern Murray-Darling Basin in recent floodwaters but are unlikely to persist for more than 1-2 years in the LDBR as winter temperatures decrease below their tolerance limits.

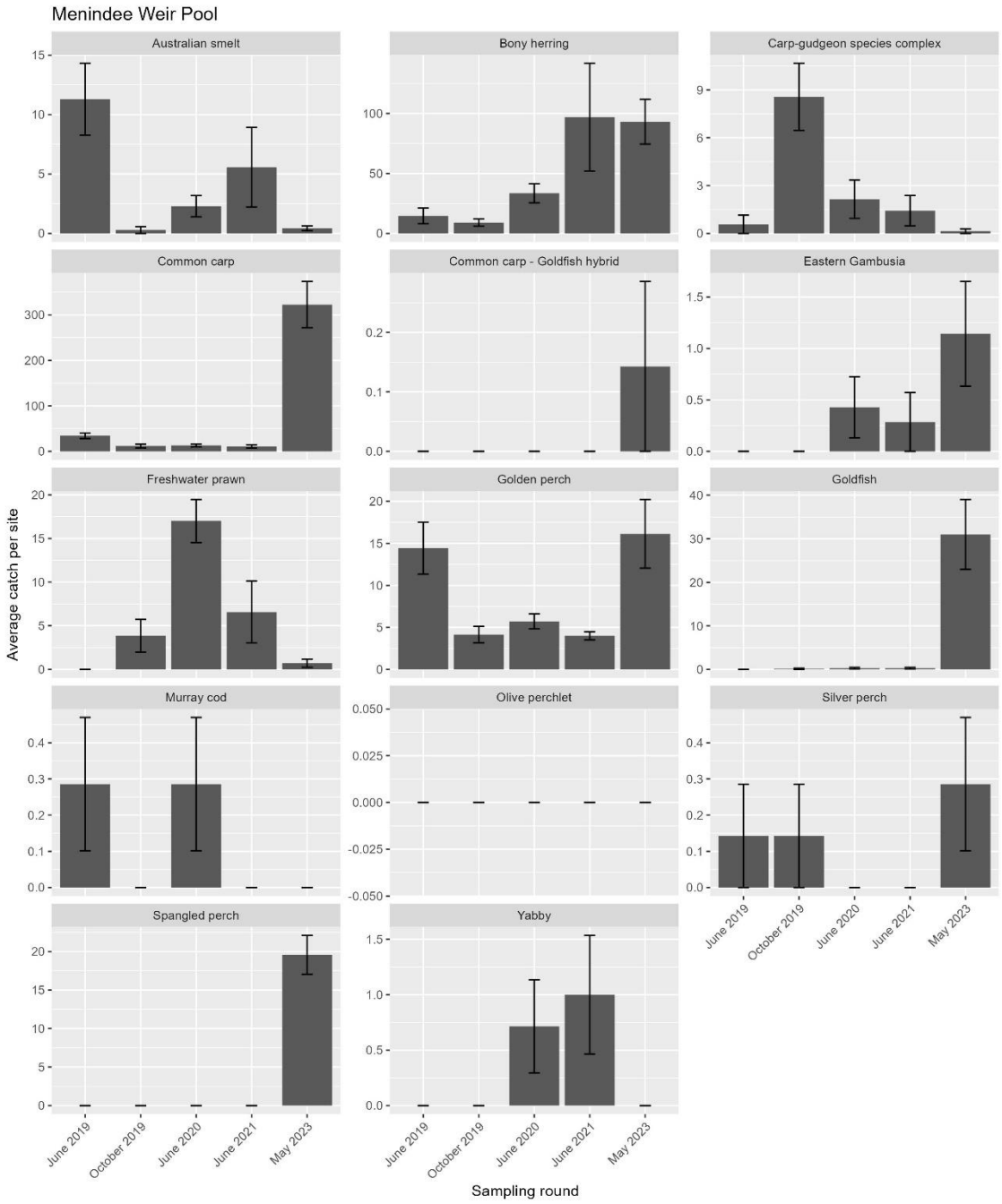

Figure 7. Mean abundances per site in the Menindee Weir Pool during Round 1 (June 2019), Round 2 (October 2019) Round 3 (June 2020) Round 4 (June 2021) and Round 5 (May 2023).

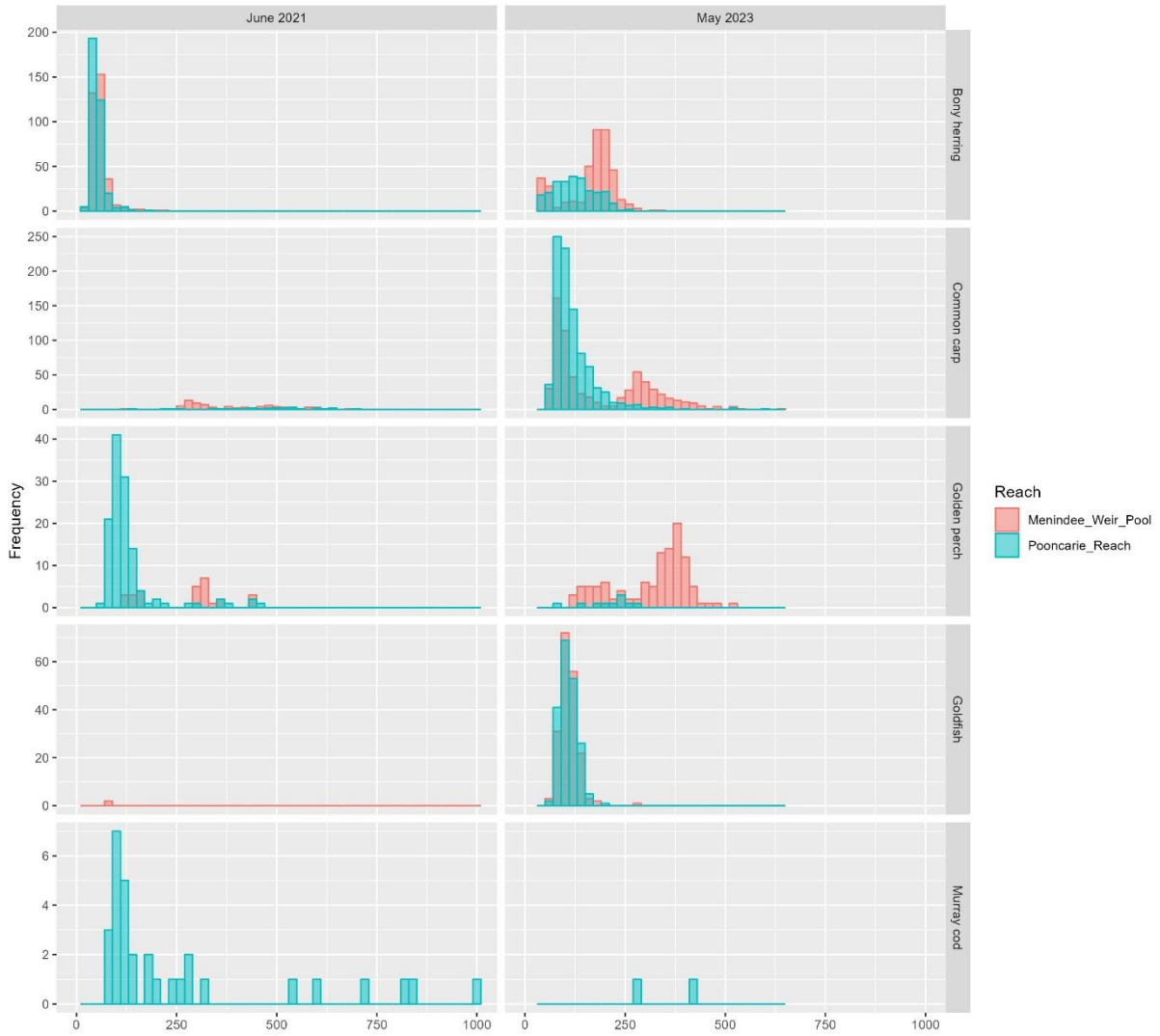

Figure 8. Length frequency plots for large-bodied species sampled in the Menindee Weir Pool and Pooncarie Reach in June 2021 and June 2023.

Rounds 1 to 5: Pooncarie Reach

Fish deaths occurred throughout the LDBR downstream of Weir 32 between June 2019 and March 2020 as disconnected refuge pools contracted, and water quality deteriorated. Based on fish kill reports received by DPI Fisheries we estimate thousands of Murray Cod died in drying pools between Menindee and Burtundy. While only low numbers of dead Golden Perch or Silver Perch were reported during 2019-2020, this is likely because dead individuals sunk or were removal by predators. We are unable to estimate the scale of deaths for these species, but it is also likely to be order of thousands. Hundreds to thousands of Common Carp were also estimated to have perished.

Figure 9 shows changes in abundance for fish species in the Pooncarie Reach from four (4) survey events (June 2019, June 2021, June 2021 and June 2023). Sampling in the Pooncarie Reach could not be conducted in October 2019 (Round 2) because the river had contracted to a series of pools and electrofishing access was precluded. Figure 8 shows the population structure (length frequency distributions) for large bodied species in the Menindee Weir Pool and Pooncarie Reach in June 2021 (pre-flood) and May 2023 (post flood and the March 2023 fish deaths).

Small-bodied fish and crustaceans

- The abundance of Australian Smelt, Carp Gudgeon and Freshwater Prawn each decreased in the Pooncarie Reach between Rounds 1 and 3 (June 2019 and June 2020), suggesting poor breeding/recruitment as the LDBR contracted to pools in 2019. Round 3 was conducted after

flow returned to the system but prior to the onset of spring breeding for these species. Abundances for these species increased in Round 4 (June 2021) indicating some population recovery a year after flow resumed in the LDBR.

- In May 2023 (Round 5) abundances of Australian Smelt and Freshwater Prawn in the Pooncarie Reach had crashed and was significantly lower than in 2021 ($P<0.05$). Carp Gudgeon abundance had also decreased although this was not statistically significant ($P>0.05$).
- A threatened Olive Perchlet was detected in the Pooncarie Reach in May 2023, highlighting the dispersal capabilities of the species during flooding and connectivity it provides.
- Abundances of Yabbies in the Poooncarie Reach were low from Round 1 - 4 after being absent in monitoring results during Round 1 but were significantly higher in May 2023 post flooding.
- Abundances of the introduced pest Eastern Gambusia decreased between Rounds 1 and 3 and remained low in remaining surveys.

Bony Herring

- Bony Herring abundance decreased significantly ($P<0.05$) between Rounds 1 and 3 (June 2019 and June 2020). This reflected a protracted dry period in which the river downstream of Weir 32 contracted to a series of refuge pools. Although Round 3 was conducted in June 2020 after flow returned to the system, it was prior to the onset of spring breeding for this species. According to historical DPI Fisheries databases, the June 2020 surveys recorded the lowest abundance of Bony Herring since 2004 in the LDBR.
- The abundance of Bony Herring in the Pooncarie Reach increased significantly between June 2020 and June 2021 ($P<0.05$), driven by juvenile fish (40-100 mm in length) after flow returned in March 2020 (Figure 8).
- Despite the fish deaths in March 2023, Bony Herring abundance in the Pooncarie Reach during Round 5 was not significantly different ($P>0.05$) to Round 4 (June 2021).

Common Carp and Goldfish (introduced pest species)

- The abundance of Common Carp and Goldfish decreased between Rounds 1 and 3 in the Pooncarie Reach, with this decrease statistically significant for Common Carp ($P<0.05$). The abundance of both species remained low in Round 4 (June 2021).
- There was a large increase in both Common Carp and Goldfish abundance in the Pooncarie Reach in Round 5 (May 2023) following widescale flooding ($P<0.05$).
- In May 2023 Common Carp population in the Pooncarie Reach was dominated by juvenile fish (80-180 mm) likely 0–2 year old. The Goldfish population consisted of fish 60-140 mm in length, also likely to be 0–2 year old fish (Figure 8).
- The increased abundance of these pest species will cause ongoing problems for native fish, emphasizing the need for effective and integrated pest management strategies to mitigate their impact, enhance native fish recovery, and maintain the balance in the ecosystem.

Murray Cod

- Murray Cod abundance in the Pooncarie Reach decreased between Round 1 (June 2019) and Round 3 (June 2020).
- Round 4 results indicated a small recovery in the Murray Cod population, driven by juvenile cohorts estimated to be 0+ and 1+ age classes (~60-200 mm) (Figure 8). This result indicated local breeding and recruitment success in spring 2020 and spring 2021, following the return of flows to the LDBR. This included operational flows augmented by deliveries of environmental water targeting specific hydrograph components that support river productivity, spawning, recruitment and dispersal by key fish species.
- The abundance of Murray Cod decreased significantly ($P<0.05$) in the Pooncarie Reach in Round 5 following widespread fish deaths along the LDBR in March 2023.

Golden Perch

- There was a significant reduction (P<0.5) in the abundance Golden Perch between Rounds 1 and 3 (June 2019 and June 2020). This reflected a protracted dry period in which the river downstream of Weir 32 contracted to a series of refuge pools and widespread fish deaths were reported. According to historical DPI Fisheries databases, the June 2020 monitoring recorded the lowest abundance of Golden Perch in the Lower Darling system since 2004.
- Golden Perch abundance in June 2021 (Round 4) increased significantly (P<0.05) in the Pooncarie Reach. The increase was driven by presence of multiple juvenile size classes (50-250 mm) representing 1–2 year old recruits (Figure 8).
- Golden Perch abundance in the Pooncarie Reach in May 2023 (Round 5) was significantly lower (P<0.5) than in June 2021 (Round 4). The decrease followed widespread fish deaths along the LDBR in March 2023.
- In May 2023, the Golden Perch population in the Pooncarie Reach was dominated by sub-adult fish <300 mm (Figure 8).

Silver Perch

- Silver Perch have not been detected in surveys in the Pooncarie Reach since Round 1 (June 2019).

Spangled Perch

Spangled Perch were detected in the Pooncarie Reach in May 2023 (Round 5). These fish likely dispersed from warmer regions in the Northern Murray-Darling Basin in recent floodwaters but are unlikely to persist for more than 1-2 years in the LDBR as winter temperatures decrease below their tolerance limits.

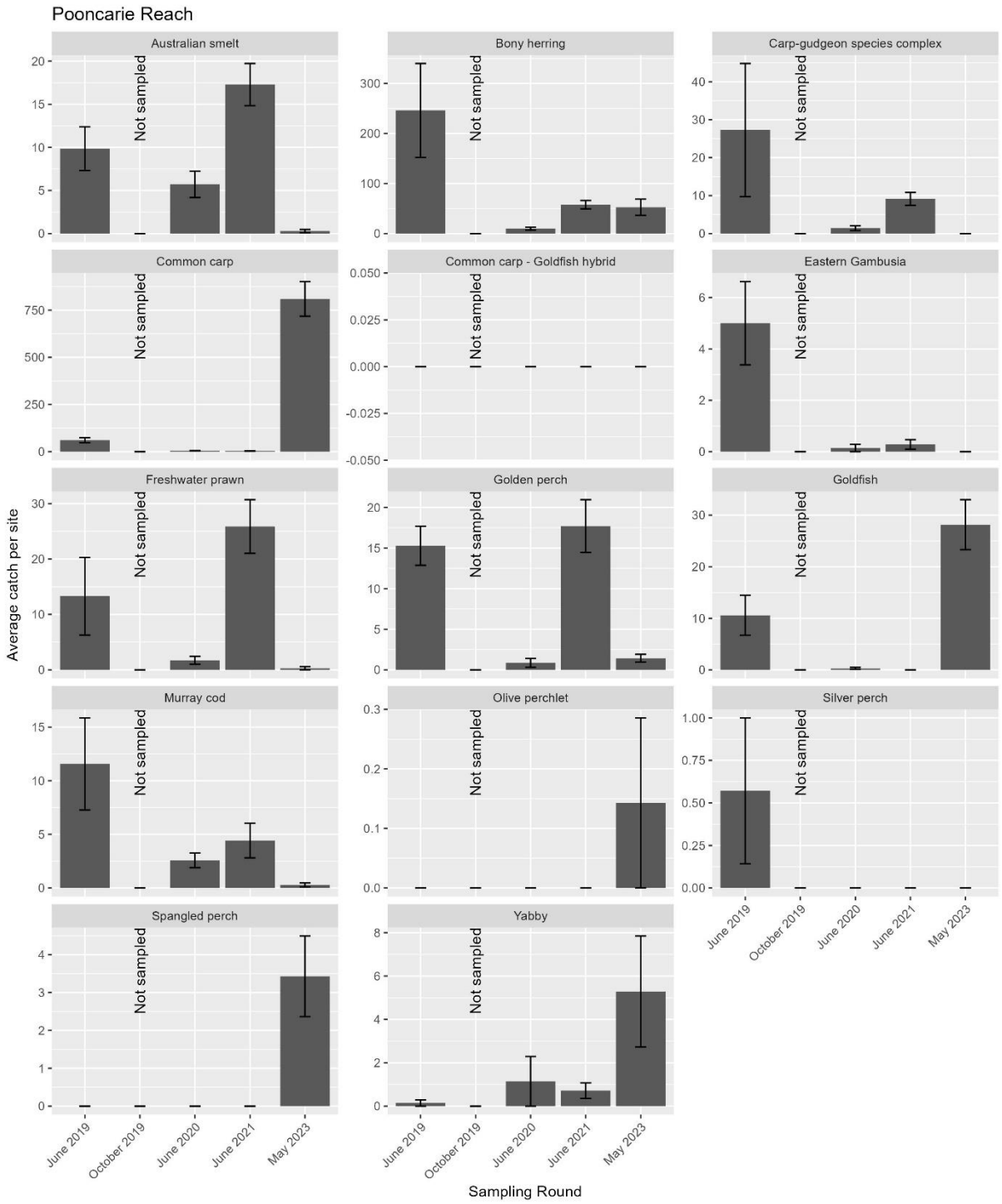

Figure 9. Mean abundance per site in the Pooncarie Reach during Rounds 1, 3, 4 and 5 (June 2019, June 2020, June 2021 and June 2023). Due to the river contracting to isolated pools, sampling could not be conducted in October 2019.

Concurrent event-based fish monitoring (conducted for the Commonwealth Environmental Water Office)

In addition to the annual condition monitoring of the LDBR fish community conducted under this project, concurrent event-based intervention monitoring funded by the Commonwealth Environmental Water Holder (CEWH) was conducted by DPI Fisheries during managed operational and environmental releases to the LDBR and the Greater Darling Anabranch (Stuart et al 2021). Although this work is separate to the LDBRR program, the two projects delivered in parallel provide multiple lines of evidence to document native fish recovery in the LDBR.

Under the intervention monitoring program for the CEWO, larval sampling in Spring 2021 confirmed a second consecutive year of breeding by Murray Cod in the LDBR. Surveys in the Menindee Lakes in 2021 and 2022 for the program detected Golden Perch from 50-400 mm in length, indicating a broad spread of cohorts (ages) (Figure 10). These cohorts have also been dispersing to the LDBR in environmental and operational releases from the Menindee Lakes since 2020 (see Stuart et al 2021).

In related research by DPI Fisheries, Golden Perch spawning was validated as having occurred during a flow event in the Northern Murray-Darling Basin in 2020 and 2021, with larvae collected at numerous locations from the Menindee Lakes upstream along the Barwon-Darling to the QLD border. Genetic and otolith techniques provide multiple lines of evidence to quantify the spatial extent of dispersal in Golden Perch larvae and juveniles (Thiem et al 2023).

Monitoring by DPI Fisheries also recorded native Olive Perchlet in Lakes Balaka and Cawndilla, and in the LDBR downstream of Weir 32 in June 2023 (Figure 10). Olive Perchlet are a threatened species which has not been reported downstream of Bourke in decades. Furthermore, a Hyrtl's tandan was reported captured by an angler in the Menindee Lakes in 2022 (see example in Figure 10) and multiple Spangled Perch have been reported by anglers (and in monitoring by DPI Fisheries). The occurrence of these species in the Menindee Lakes and LDBR highlights the potential for fish dispersal in connected flowing rivers in the MDB.

Figure 10. Golden Perch from a range of size classes sampled during LDBR and Menindee Lakes monitoring (top). Olive Perchlet, Hyrtl's Tandan and Spangled Perch detected in the LDBR in in recent years (bottom left to right).

Conclusions

The abundance of some native fish species in the Lower Darling-Baaka River has declined (in comparison to data collected since 2019) following the fish deaths events of early 2023. This is despite earlier demonstrated recovery of native fish from 2020-2022, driven by natural flows and deliveries of water for the environment to the LDBR.

Large-scale, extreme changes in flow conditions – from zero flow to major flooding in the space of four years – pose significant and ongoing risks and challenges to native fish. Such extreme changes represent a departure from the natural flow regime in the LDBR, which were typified by within-channel flow variability throughout the majority of years, punctuated by larger floods and occasional short cease-to-flow events (Mallen-Cooper and Zampatti 2020).

The risks to native fish that result from these broad changes in the LDBR flow regime include:

- Fewer within channel flow pulses – these events are important for river productivity, spawning by some species, supporting recruitment of young fish, and providing opportunities for movement, including downstream dispersal of young.
- Protracted periods during drought where the river contracts to a series of disconnected pools, prone to algal blooms and thermal stratification/de-stratification, which can result in mass fish deaths (as experienced during 2018 - 2020 at Menindee and along the LDBR).
- Long periods between flood events that flush floodplain carbon and nutrients into and along rivers. Regulation of our rivers has reduced flood frequency, so when major flooding does occur it mobilises unnaturally large volumes of carbon and other nutrients which contribute to poor water quality (e.g. hypoxic blackwater) and algal blooms.
- Ecosystem bottlenecks, where rapid increases in abundance of food and fish during floods (particularly pest species Carp) are followed by rapid reductions in habitat and resources, compounded by large aggregations of fish downstream of barriers to fish movement.
- Depletion of populations of key species throughout long stretches of the river system. Population recovery in these stretches can be compromised by existing barriers to movement from upstream and downstream waterways, as well as availability and access to preferred habitat.

Next Steps

DPI Fisheries and the MDBA will continue work to progress native fish recovery in the LDBR through informed flow management, meaningful on ground activities that improve habitat, and community engagement to empower stakeholders to support fish recovery activities.

It will be crucial to adaptively manage and conserve native fish and their habitats by using the best available knowledge. The long-term sustainability of native fish populations in the LDBR is dependent on a variable but perennial flow regime that supports the life history needs (spawning, breeding habitat, growth and dispersal) of different species. To achieve this, system-scale connectivity in water management and planning must be considered so that appropriate flows support the ecological, social, cultural and economic values of the LDBR.

The delivery of operational and environmental flows to the LDBR to support breeding, recruitment and dispersal of native fish will be a crucial part of future planning. It is noted that carefully planned and optimised delivery of environmental water in the LDBR in 2016/17, and again in 2020/21, contributed to positive outcomes relating to Murray Cod breeding and recruitment and dispersal of Golden Perch.

Annual monitoring of the fish community in the LDBR will be critical in assessing recovery of the fish community in coming years and will serve as a baseline to which impacts/benefits resulting from future recovery activities can be assessed (e.g. delivery of environmental water, restocking, pest fish management and habitat rehabilitation). Additional event-based monitoring will help inform the use of environmental water in the system and the active management of river operations.

With appropriate flow regimes, native fish communities will gradually recover, although catastrophic events such as fish kills related to lack of flow or hypoxic blackwater will hinder, and potentially undermine this recovery. Being long-lived, recovery of local populations of Murray Cod, Golden Perch and Silver Perch will take time and will depend on the provision of a flow regime spanning years (decades) that considers perennial (year-around) base flows and annual spring rises to support breeding, recruitment (survival and growth of young fish), and opportunities for movement and access to key habitat features. Commitment to meaningful native fish recovery in the LDBR must be supported by commensurate funding over appropriate timeframes.

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