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Junction of the Warrego and Darling rivers Selected Area

2019-20 Annual Summary Report

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Document control

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Cover image: Pelican resting on Dicks Dam in the Warrego River, March 2020. Photo Ben Vincent UNE

Managing water for the environment is a collective and collaborative effort, working in partnership with communities, private landholders, scientists and government agencies - these contributions are gratefully acknowledged.

We acknowledge the Traditional Owners of the land which we discuss here. We also pay our respects to Elders past, present and emerging.

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Abbreviations

Abbreviation	Description
ANZECC	Australian and New Zealand Environment and Conservation Council
CEWO	Commonwealth Environmental Water Office
GL	gigalitre
GPP	Gross Primary Production
NPP	Net Primary Production
ER	Ecosystem Respiration
ha	hectare
km	kilometre
LTAAY	long term average annual yield
LTIM Project	Long-Term Intervention Monitoring Project
MER Project	Monitoring, Evaluation and Research Project
MDBA	Murray-Darling Basin Authority
ML/d	Megalitres per day
mS/cm	millisiemens per centimetre
NP	National Park
NSW	New South Wales
SCA	State Conservation Area
Selected Area	The Junction of the Warrego and Darling rivers Selected Area
Warrego-Darling Selected Area	The Junction of the Warrego and Darling rivers Selected Area

Executive Summary

Contributions of Commonwealth Environmental Water

Darling River zone

- Commonwealth environmental water contributed to a flow that connected the Darling River zone and provided access to in-channel habitats such as benches, snags and anabranch channels.
- This flow also enhanced water quality in this reach with reduced electrical conductivity and nutrient concentrations, increased the energy (kgC/day) available to aquatic food webs leading to an increased richness and diversity of invertebrate communities.

Warrego River zone

- Commonwealth environmental water contributed to the largest flow that has been seen down the Warrego River and Western Floodplain since 2012.
- This flow achieved complete inundation of the Warrego River channel network within the Selected Area and inundated over 11,500 ha of floodplain and channel. Floodplain water returned to the Darling River downstream of the Selected Area.
- This flow enhanced water quality by replenishing refuge pools in the Warrego channel. High nutrient concentrations following inundation of the Western Floodplain led to a short-term algal bloom that fuelled the aquatic food web on the floodplain.
- Floodplain vegetation during 2019-20 was in the best condition since the LTIM/MER project began in 2014 as a result of both inundation and rainfall.

The Junction of the Warrego and Darling rivers Selected Area (Warrego-Darling Selected Area, Selected Area) encompasses the Toorale National Park and State Conservation Area managed by NSW Department of Planning, Industry and Environment. Inflows of Commonwealth environmental water to the Warrego-Darling Selected Area via the Darling River from upstream tributaries have also been evaluated.

Monitoring of the ecological indicators for the MER project in 2019-20 was impacted in the second half of the water year due to COVID-19 related travel restrictions. Unfortunately, this coincided with significant flow events through the Selected Area. As a result, monitoring some indicators reflected the drier conditions over the summer period.

The Warrego-Darling Selected Area is complex in terms of its ecosystems, hydrology and the way in which Commonwealth environmental water is accounted and managed both within the Selected Area and within upstream tributaries. In 2019-20 flows through the Selected Area were very low for the first half of the year. A large flow pulse moved through both the Warrego and Darling Rivers in March-May 2020, driven by contributions from the Border Rivers, Moonie, Condamine Balonne, Macquarie-Castlereagh and Warrego

catchments (Appendix A). This flow peaked at about 1/3 channel capacity in the Darling River zone (15,000 ML/d), comprised around 12% Commonwealth environmental water and inundated a range of in-channel habitats. In the Warrego River, flows peaked at 4,300 ML/d at Fords Bridge upstream of the Selected Area and contained around 7% Commonwealth environmental water. This was the largest flow down the Warrego River since 2012 (Appendix B). Within the Selected Area, the gates at Boera Dam were opened for 77 days, allowing connecting flows to the Darling River for this duration. These flows were augmented by water flowing around Boera Dam through the eastern Bywash, which is the first time it has run since the LTIM/MER project began in July 2014. A total of 16,212 ML flowed through to the Darling River comprising 36% Commonwealth environmental water. Significant volumes flowed onto the Western Floodplain during this event with a total of 11,500 ha of floodplain and channel network inundated. Floodplain flows were sufficient to inundate the entire length of the Western Floodplain and connect to the Darling River downstream of the 'Talowla' property.

Key Responses to Flow

Water Quality and Metabolism

- Reduced electrical conductivity and nutrient concentrations were observed in the Darling and Warrego rivers in response to higher flows (Appendix C). The improvement in water quality was most pronounced in the Darling River downstream of the confluence with the Warrego and within the Warrego channel refuge pools, highlighting the importance of these replenishing connection events in improving and sustaining good water quality within the Selected Area.
- Turbidity was consistently high during flow events, and reduced at all sites following the March-May 2020 flow, except on the Western Floodplain where it remained relatively low as a result of settling due to lower water velocities (Appendix C).
- Total Nitrogen and Phosphorus exceeded trigger values on all but two occasions (Appendix C). A short-lived algal bloom was observed on the Western Floodplain following inundation linked to elevated nutrient concentrations and high temperatures. Consistent with long-term trends there were no adverse environmental outcomes recorded in response to high nutrient concentrations.
- Extensive inundation and enhanced water quality led to increased energy availability across the Selected Area (Appendix C). Commonwealth environmental water added over 21,000 kg of carbon (around 12% of gross primary production) to aquatic food webs in the Selected Area, contributing substantial energy to aquatic food webs that fuelled an increased richness and diversity of invertebrate communities.

Ecology

- Bird and frog communities were less abundant and diverse during MER monitoring before the March-May flow event, being reflective of the dry prevailing conditions (Appendices E,G). Warrego River waterholes were acting as refuge habitats supporting vulnerable (brogla) and listed migratory (great egret) bird species. Anecdotal evidence from NPWS rangers suggest a positive bird breeding response following the flow event, with juveniles of many species observed.
- Frog surveys for the LTIM/MER project have shown the specificity of some species to channel or floodplain habitats (Appendix G). This demonstrates the importance of protecting multiple types of habitats, maintaining the refuge habitats in the Warrego

channel and delivering water to the floodplain, to enhance the diversity of the frog communities across the Selected Area.
- While the richness of fish communities in the Warrego and Darling rivers is similar to that expected before European settlement, species abundance was observed to be highly variable (Appendix F). Of particular note was the critically low capture rate of some iconic fish species such as Murray cod and freshwater catfish that were certainly in a 'bust' period at the time of sampling, when flow conditions were low.
- The Warrego River within the Selected Area continues to support relatively large numbers of juvenile golden perch at times, however, there are very few mature-sized individuals (Appendix F). This suggests this section of the river forms a nursery rather than being a source area for this species. This highlights the need to provide connectivity, using flows and fishways to allow the unimpeded movement of this species through the system.
- Flows through the Selected Area reduced invertebrate densities through dilution and changed the community assemblage from one dominated by benthic (bottom dwelling) species to one dominated by pelagic (water column) species such as Daphnia (water fleas) that are known to be a dominant food resource for juvenile fish (Appendix C).
- Vegetation communities on the Western Floodplain were thriving during surveys undertaken in October 2019 with the highest species richness and vegetation cover measured throughout the LTIM/MER project to date (Appendix D). This was in response to good spring rainfall and inundation in May 2019. The response in coolibah woodlands that were inundated was shown to be greater than those that received rainfall alone.
- Flowering and seed setting of floodplain tree species such as coolibah was observed on the floodplain in March 2020. If followed by favourable conditions, particularly flooding in summer, a germination event may be triggered.

Communications

- A broad range of products and strategies were used to communicate the findings from the MER project.
- The short stories posted on the 2rog website were well received by a range of stakeholders. Personal and cultural stories tended to receive more attention and positive feedback.

Implications for the Commonwealth's Environmental Water Management

- The lower Warrego River forms an important nursery for fish recruits such as golden perch, which enter the reach via drift from upstream. Promoting downstream connection and passage of these recruits through the lower Warrego River and into the Darling River using water for the environment should be an ongoing priority for the CEWO. Connection events also enhanced water quality in remnant pools and in the Darling River downstream of the confluence with the Warrego, and contributed substantial amounts of energy (kg C/day) to the Warrego and Darling Rivers that fuelled a positive food web response.
- The occurrence of iconic fish species such as Murray cod and freshwater catfish in critically low numbers during the 2019-20 water year is concerning. Developing species specific strategies to effectively manage these species is required. Strategies would likely include restocking, but also the provision of flows during critical periods to ensure vital aspects of their lifecycle, such as spawning and recruitment, occur frequently enough to guarantee their longevity.

- The good condition of vegetation communities on the Western Floodplain during 2019-20 is encouraging, given the drought conditions experienced at the site in recent years. So too is the evidence of flowering and seed setting of floodplain tree species such as coolibah. The use of water for the environment to promote inundation of the floodplain, particularly over the 2020-21 summer period would be encouraged to stimulate recruitment in these species.

1 Monitoring and Evaluation of Environmental Water in the Junction of the Warrego and Darling Rivers Selected Area

1.1 Introduction

This report presents the monitoring and evaluation results from the first year of the Monitoring, Evaluation and Research (MER) project at the Junction of the Warrego and Darling rivers Selected Area (Warrego-Darling Selected Area, Selected Area). The project was undertaken as part of a larger project funded by the Commonwealth Environmental Water Office (CEWO) to monitor and evaluate water for the environment across the Murray-Darling Basin. The MER project is an extension of the Long-Term Intervention Monitoring (LTIM) Project, with both projects being implemented at seven Selected Areas since 2014-15. These projects aimed to deliver five high-level outcomes:

1. Evaluate the contribution of Commonwealth environmental watering to the objectives of the Murray-Darling Basin Authority's (MDBA) Environmental Watering Plan.
2. Evaluate the ecological outcomes of Commonwealth environmental watering at each of the seven Selected Areas.
3. Infer ecological outcomes of Commonwealth environmental watering in areas of the Murray-Darling Basin not monitored.
4. Support the adaptive management of Commonwealth environmental water.
5. Monitor the ecological response to Commonwealth environmental watering at each of the seven Selected Areas.

While results specific to the Warrego-Darling Selected Area are reported here, a broader Basin Scale analysis will be produced by the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

This report describes the Warrego-Darling Selected Area watering actions and the ecological outcomes of the application of Commonwealth environmental water in the Selected Area during the first year of the MER Project. In addition, comparisons over the past 6 years of LTIM/MER have also been made. Detailed analysis, methods and results are presented in the Appendices referred to in the summary report.

1.2 Junction of the Warrego and Darling Rivers Selected Area

The Warrego-Darling Selected Area is located in north-western New South Wales (NSW), situated 80 km south-west of Bourke (Figure 1). It is contained within the boundary of the Toorale National Park (NP) and State Conservation Area (SCA) (Figure 2). The Selected Area is approximately 92,000 ha and receives flow from both the Darling and Warrego river systems. The Darling River catchment drains the north westerly portion of the Murray-Darling Basin and has a total catchment area of 699,500 km^2. Most of its tributaries (Macquarie, Castlereagh, Namoi, Gwydir, Macintyre and Condamine-Balonne Rivers) drain from the Great Dividing Range in northern NSW and southern Queensland and provide relatively high amounts of runoff to the catchment.

In contrast, other catchments such as the Warrego and the Paroo Rivers to the west, drain more arid, flat catchments and only flow intermittently during periods of high rainfall in their upper catchments, usually manifesting downstream as slow-moving floods of relatively long duration. The Warrego-Darling Selected Area shows high climatic variability, with low annual average rainfall and high evaporation.

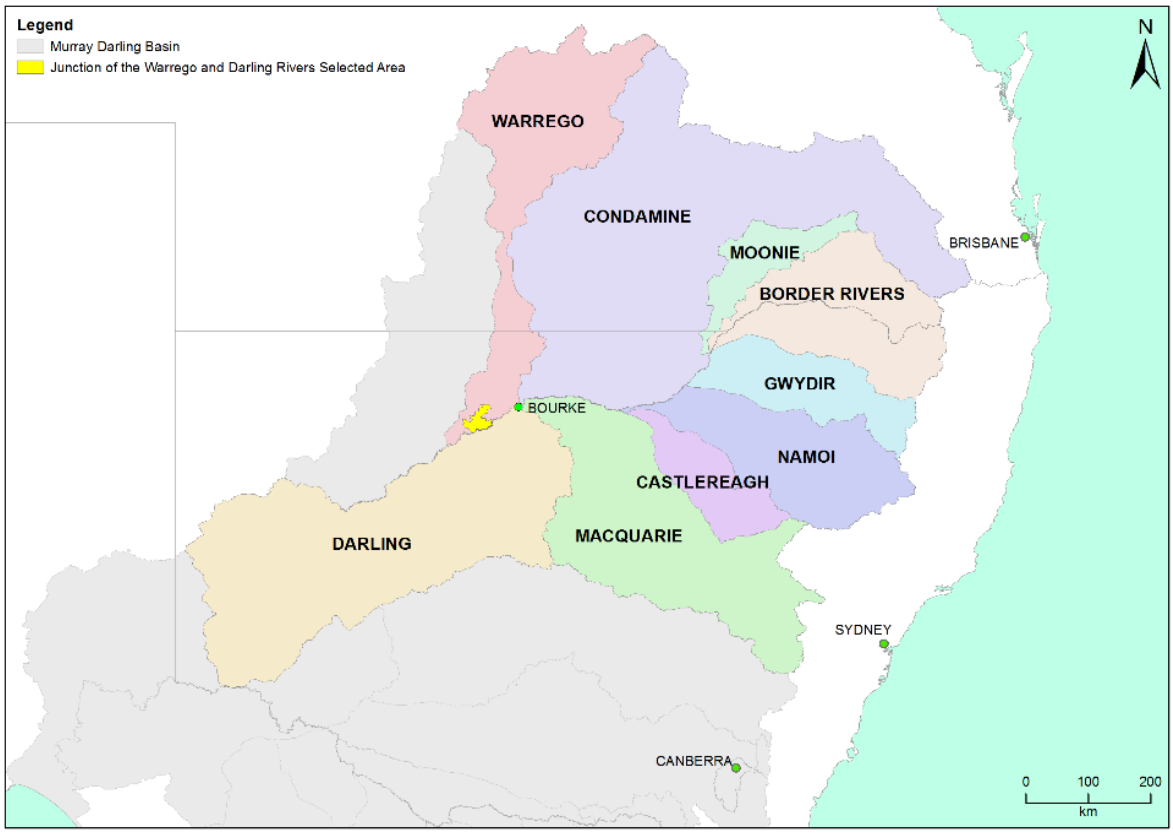


Figure 1 The location of the Warrego-Darling Selected Area within the Murray-Darling Basin, showing upstream catchments.

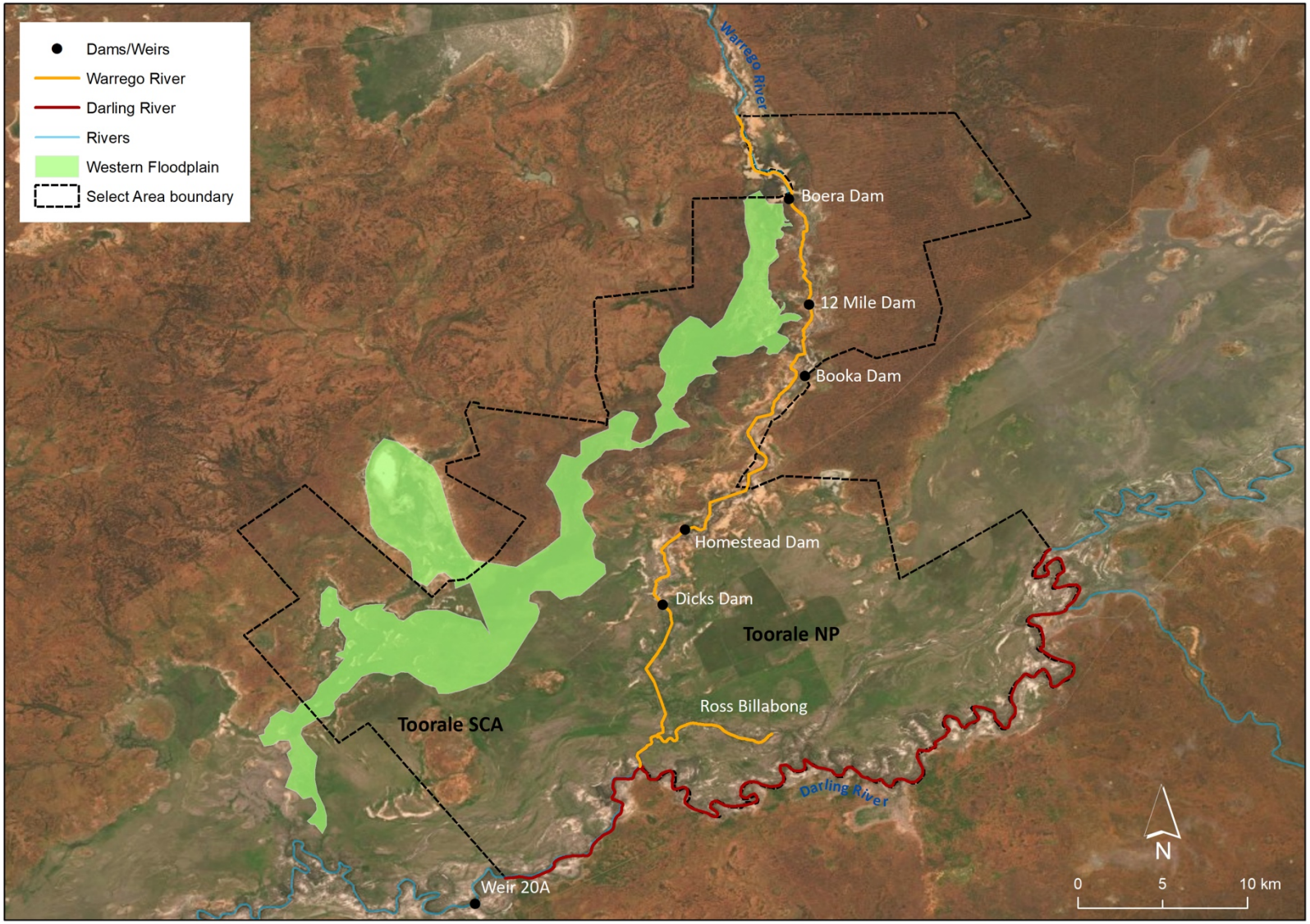


Figure 2 Junction of the Warrego and Darling rivers Selected Area monitoring zones.

Within the Selected Area, three monitoring zones were defined (Table 1, Figure 2). These zones represent discrete regions of the Selected Area in terms of their geomorphology, hydrology, environmental assets, environmental watering targets and expected outcomes from Commonwealth environmental water delivery.

Table 1 Selected Area monitoring zones.

Zone	Extent	Description	Potential target flow types for monitoring
Western Floodplain	The Western Floodplain of the lower Warrego River from Boera Dam offtake to the Darling River.	A large floodplain surface heavily dissected by small flood-runners. Floodwaters inundate this floodplain from overflows at Boera Dam.	Overbank – infrastructure assisted.
Warrego River	The lower Warrego River channel extending from the northern boundary of Toorale National Park to the junction with the Darling River, including Ross Billabong.	A single meandering channel that decreases in bankfull capacity downstream. Flows in this lower section of the Warrego River are controlled by a series of five in-channel structures. (currently under redevelopment – see S 1.3 below)	Base flows Freshes up to 600[1] ML/d.
Darling River	The Darling River from the eastern boundary of the Toorale National Park near Hells Gate, to Weir 20A downstream of the western boundary of Toorale State Conservation Area.	A single meandering channel that has a bankfull height ranging 12-15 m. The bankfull channel is complex and there are a series of natural rock bars and a weir at the downstream end of the reach that influence flows along this section of the river.	Base flows Freshes: 300 – 500 ML/d 1,000-5,000 ML/d 5,000-10,000 ML/d 10,000-30,000 ML/d

[1] This capacity is likely to increase to ~1,650 ML/d with the completion of the Toorale Infrastructure Project.

1.3 Water Management

Over the last 150 years, the hydrology of the Warrego River within the Selected Area has been highly modified. Six dams have been constructed to provide stock and domestic water supply, irrigate the Western Floodplain to improve pasture growth, and more recently to provide water storage for irrigated agriculture (Figure 2). Since the establishment of Toorale NP and SCA in 2008, dam maintenance has been largely discontinued in line with preferred park management. As a result, the condition of some dams has degraded, and several have become fully breached (Aurecon 2009). Approval for the redevelopment of these structures is currently underway through the Toorale Infrastructure project with the removal of Peebles Dam, the lowermost dam on the Warrego system having already occurred in October 2019 (DPIE 2020). The characteristics and status of the ramaining dams are outlined below (Gawne *et al*. 2013):

- Boera Dam: a large storage of approximately 3,000 ML, likely to have been first established in the 1870s. Water persists for around 12 months after filling without further inflows from local runoff. Management of this dam can preferentially divert water down the Western Floodplain.
- 12 Mile Dam: less than 1,000 ML in volume, this dam has been breached since 2008 and not reinstated.
- Booka Dam: approximately 1,000 ML.
- Keernie (Homestead) Dam: 1,500 – 2,000 ML (Breached).
- Dicks Dam: 500 – 1,000 ML.
- Peebles Dam: removed in October 2019.

These dams have been retrospectively licenced under the provision of the NSW *Water Act 1912*. This includes separate licenced amounts for the Warrego River at 8.1 gigalitres (GL) long term average annual yield (LTAAY), the Western Floodplain (accounted at Boera Dam) at 9.7 GL (LTAAY) and the Darling River at 7.6 GL (LTAAY). These licences are owned by the Commonwealth and managed by the CEWO in consultation with the NSW National Parks and Wildlife Service (NPWS) and the Kurnu-Barkindji Joint Management Advisory Committee.

Conditions placed on these licences determine how Commonwealth environmental water can be managed within the Selected Area. Before these licences can be accessed, downstream demand to the Darling River must be met during times of low flow. That is, if sustained inflows are entering Boera Dam, and the Darling River flow at Louth is below 330 ML/d, then water must be let through the regulator pipes on Boera Dam and all downstream dams on the Warrego to flow to the Darling River until flows at Louth have reached 330 ML/d. Once this has been achieved, the CEWO, in consultation with the NPWS and the Kurnu-Barkindji Joint Management Advisory Committee, can choose whether to continue to release water down the lower Warrego channel therefore activating their Warrego River licence, or close the regulator gates, and hold water in Boera Dam to divert water to the Western Floodplain.

If flows in the Darling River exceed 979 ML/d at Louth, the CEWO can access a high flow floodplain licence to divert water to the Western Floodplain. The CEWO have developed a Water Use Strategy for Toorale to aid decision making surrounding the operation of Commonwealth environmental water at this site (Appendix C in Northern Intersecting Streams Portfolio Management[1]). This strategy will be revised and updated in consideration of the Toorale Water Infrastructure project and NSW Intersecting Streams long-term watering plan.

Unlike other Selected Areas, Commonwealth environmental water that flows into the Warrego-Darling Selected Area is primarily unregulated, and is thus reliant on rainfall, flows and water management decisions in upstream tributaries. The Border Rivers, Gwydir, Namoi and, to a lesser extent, Macquarie tributaries, are exceptions to this, whereby

[1] http://www.environment.gov.au/system/files/resources/a3126565-16b2-4d81-96fa-13438d93425d/files/portfolio-mgt-plan-northern-intersecting-streams-2019-20.pdf).

regulated environmental water has the potential to influence flows in the Selected Area, particularly during periods of low flow in the Barwon-Darling system. Other water management actions, such as the release of stock and domestic flows, rainfall rejection flows and embargos on upstream pumping also influence flows in the Selected Area. These are undertaken in accordance with the relevant long-term watering plans in both Queensland and NSW.

Adding to the complexity of environmental water accounting and delivery in the Warrego-Darling Selected Area is the fact that the Selected Area, and its upstream tributaries, fall into multiple water planning areas, each with discreet rules, licence types and accounting procedures. Thus, tracking Commonwealth environmental water between and through these areas is challenging and is being addressed through work under the NSW Water Reform Action Plan[2] and northern Basin toolkit.

[2] https://www.industry.nsw.gov.au/water-reform

2 Environmental Watering in the Warrego-Darling Selected Area in 2019-20

Rainfall was highly variable at the Selected Area during the 2019-20 water year (Figure 3), with above average rainfall in July, November, and February-April and well below average rainfall in August-October, December and April-May. Total rainfall in November, March and April was more than twice the monthly average, which contributed to an annual total of 318 mm that was close to the long-term average annual total (316 mm).

Mean monthly maximum and minimum temperatures were similar to the average in all months except December and January where they were higher than average (Figure 4). Consistent with the average, the highest average maximum temperature was recorded in January (40.7 °C) and the lowest average minimum temperature recorded in August (3.9 °C).

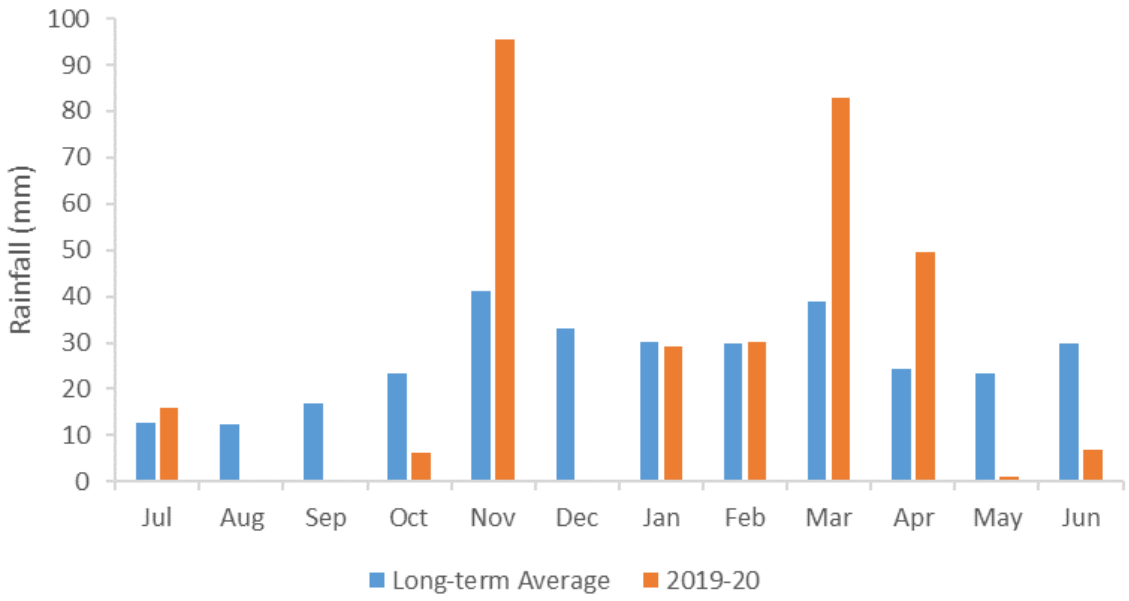


Figure 3 Monthly rainfall at Bourke Airport during the 2019-20 water year compared to the long-term average (Source: BoM, 2020a).

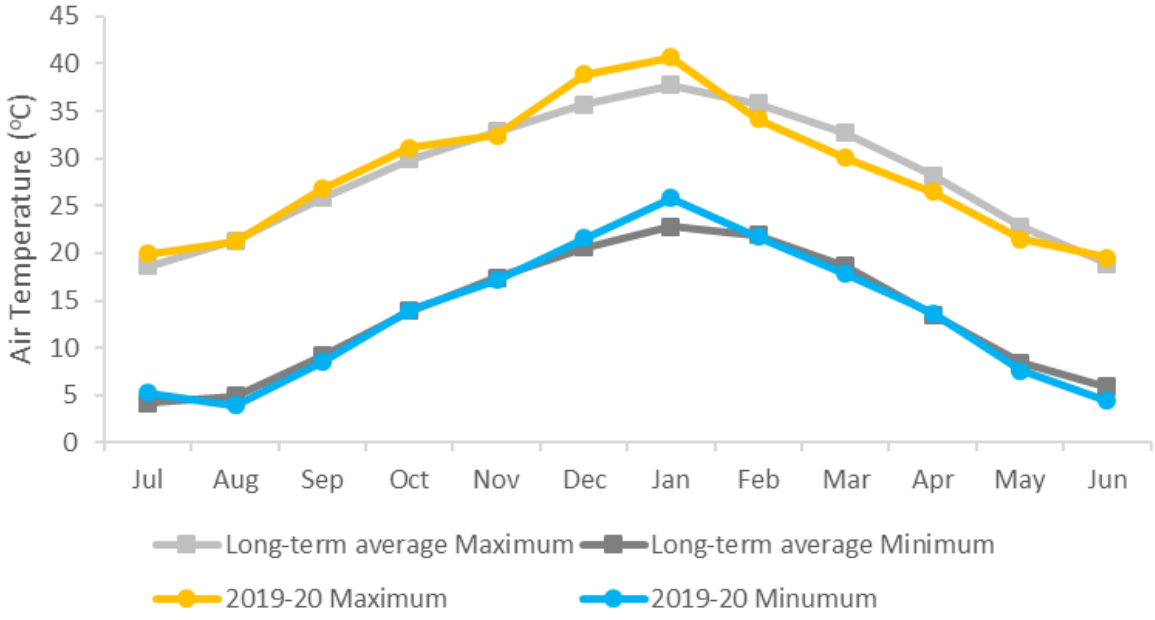


Figure 4 Mean maximum and minimum temperatures at Bourke Airport over the 2019-20 water year compared to the long-term average (Source: BoM, 2020b)

The 2019-20 water year was marked by strong contrast in flow and inundation conditions within the Selected Area. The first nine months of the year were very dry with decreasing inundation in the Warrego River channel dams and pools and on the Western Floodplain. A significant flood event commenced in early March 2020 and continued until late May in both the Warrego and Darling catchments. This event peaked at over 4,300 ML/d at Fords Bridge on the Warrego River upstream of the Selected Area and contained around 7% Commonwealth environmental water (Appendix A: Darling River Hydrology). This was the largest flow in the Warrego system since 2012. This flow provided significant inundation of the Western Floodplain and connected the Warrego River through to the Darling River for an extended period (Appendix B: Warrego River Hydrology). During this time, the Boera Dam gates were open and 16,212 ML of water for the environment (36% of total flow volume) was released into the lower Warrego River below Boera Dam.

In the Darling River, a relatively large flow pulse peaking at over 15,000 ML/d at Bourke occurred in February-May 2020. This was the largest flow of the 2019-20 water year (478 GL total volume) and included 12 % environmental water from upstream take in the Border Rivers, Moonie, Condamine-Balonne, Macquarie-Castlereagh and Warrego catchments.

3 Key Outcomes from Environmental Water Use

3.1 Monitoring

3.1.1 Annual watering priorities

The Warrego-Darling Selected Area falls within the Northern Intersecting Streams region where the majority of Commonwealth environmental water holdings provide access to unregulated flows. The CEWO have defined several long term expected outcomes from the use of Commonwealth environmental water in the Northern Intersecting Streams, that link to the outcomes of the Basin-wide Environmental Watering Strategy developed by the Murray-Darling Basin Authority (Commonwealth of Australia 2019a, Table 2).

Table 2 Summary of long term expected outcomes from environmental watering in the northern unregulated river (Source: Commonwealth of Australia, 2017).

BASIN-WIDE OUTCOMES (Outcomes in red link to the Basin-wide Environmental Watering Strategy)	**Expected outcomes for northern intersecting streams assets**		
	In-channel assets	Off-channel assets	
		Wetlands, lagoons and billabongs	Anabranches and effluent creeks
Vegetation	Maintain riparian and in-channel vegetation condition, growth and survival.	Maintain and improve wetland vegetation condition, growth and survival in targeted sites. Maintain floodplain vegetation (with use of unregulated holdings and flows).	
Waterbirds		Maintain foraging, roosting and breeding habitats at targeted sites on the floodplain to support waterbirds.	
Fish	Provide flows that improve habitat conditions and support different life stages (migration, spawning,	Support natural flow variability and connectivity between the river channel, wetlands anabranches and floodplains.	
Invertebrates	Provide habitat (e.g. pools and riffles) and conditions (low flows, freshes, scouring flows) to maintain /improve micro and macroinvertebrate condition and diversity.		
Other vertebrates	Provide habitat and conditions to support survival and recruitment of native aquatic fauna (e.g. platypus, native water rat, frogs, turtles).		
Connectivity	Support longitudinal connectivity in the major unregulated streams.	Support lateral and longitudinal (anabranches) connectivity between the river, wetlands, and floodplains.	

BASIN-WIDE OUTCOMES (Outcomes in red link to the Basin-wide Environmental Watering Strategy)	**Expected outcomes for northern intersecting streams assets**		
	In-channel assets	Off-channel assets	
		Wetlands, lagoons and billabongs	Anabranches and effluent creeks
Processes	Support **primary production, nutrient and carbon cycling and biotic dispersal and movement.**		
Water quality	Maintain water quality within channels and pools.	Support more natural water temperature, flow regimes and connectivity to support nutrient cycling and water quality benefits.	
Resilience	Provide refuge habitat for fish and other aquatic fauna.		

The evaluation of Commonwealth environmental water, and its management in the Warrego-Darling Selected Area during 2019-20, is structured around these broader objectives and priorities, with the specific outcomes associated with each Commonwealth environmental watering event provided in Table 3.

Table 3 Expected outcomes from the use of Commonwealth environmental water during the 2019-20 water year relevant to the Warrego-Darling Selected Area.

Flow Type	Expected outcomes for water year	Contributions to longer term objectives	Contribution to the following BP objective	Were these outcomes achieved?
Fresh in Warrego River zone	Maintain water quality Provide refuge habitat End of system connectivity Fish reproduction Biotic dispersal and movement Nutrient and sediment cycling	Connectivity Fish diversity Process	Biodiversity Ecosystem function	Yes, good water quality was maintained in the waterholes of the Warrego River, and significant longitudinal and lateral connectivity achieved throughout the river network, Western Floodplain with return flows from the floodplain back into the Darling River. Invertebrate communities were maintained throughout the event.
Fresh in Darling River zone	Maintain water quality Provide refuge habitat End of system connectivity Fish reproduction Biotic dispersal and movement Nutrient and sediment cycling	Connectivity Fish diversity Process	Biodiversity Ecosystem function	Yes, good water quality was maintained throughout this event in the Darling River and access to in-channel habitats such as snags, benches and anabranch channels provided. Nutrients from bench surfaces were released into the River ecosystem. Invertebrate communities were maintained throughout the event

3.1.2 Darling River Flows and Ecosystem Function

Three flow pulses occurred through the Darling River zone of the Selected Area during 2019-20 (Appendix A: Darling River Hydrology, Figure 5). The first was a small event that occurred in November 2019 that broke a 178-day period of no flow. This pulse provided a short 18-day period of connectivity which inundated a small proportion of low-lying snags in the reach. A much larger and sustained flow commenced in late February 2020, peaking at over 15,000 ML/d at Bourke Town and maintained flow through the reach until the end of the water year. This flow resulted in a period of 127 days of longitudinal connectivity and was augmented by 52 days of environmental flows (52,203 ML). 84% of snags, 72% of benches and 90% of anabranch channels were inundated within the Darling River reach, providing habitat for aquatic biota, and liberating dissolved nutrients stored in bench and anabranch sediments into the river ecosystem.

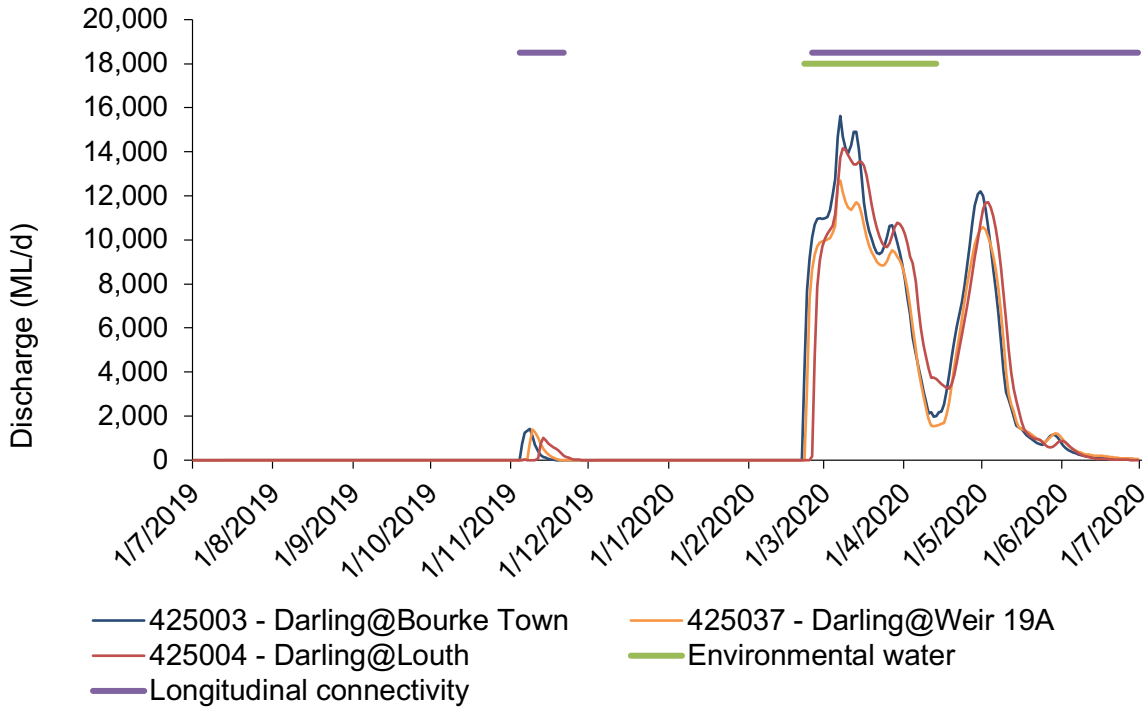


Figure 5 River flows and longitudinal connectivity within the Darling River from Bourke Town to Louth during the 2019-20 water year.

3.1.3 Warrego River Flows and Inundation

Two periods of inflow into the Selected Area occurred down the Warrego River during 2019-20 (Appendix B: Warrego River Hydrology). The first in November 2019 increased water levels in Boera Dam but did not contribute to downstream flows as the Boera regulator gates were not opened. Instead, localised rainfall runoff caused rises in Dicks dam downstream (Figure 6).

During the second and larger inflow event Boera Dam, levels quickly increased above the Western Floodplain connection level (Figure 6) even with the Boera Gates open, and remained above this level to the end of the water year. Downstream (longitudinal) connectivity to the Darling River commenced on the 8 March 2020 when the Boera Dam gates were opened and thus continued until 24 May 2020 when they were closed. The eastern bywash connects the Warrego River around Boera Dam during significant flow events. For the first time since the LTIM/MER project commenced the eastern bywash flowed, connecting the system around the Boera Dam wall. Sentinel imagery indicates that the eastern bywash was connected by 21 March 2020 and ceased connection by 25 April 2020. This contributed to a maximum of 1,568 ha of inundation along the Warrego channel from Boera Dam to the Darling River confluence (Appendix B: Warrego River Hydrology).

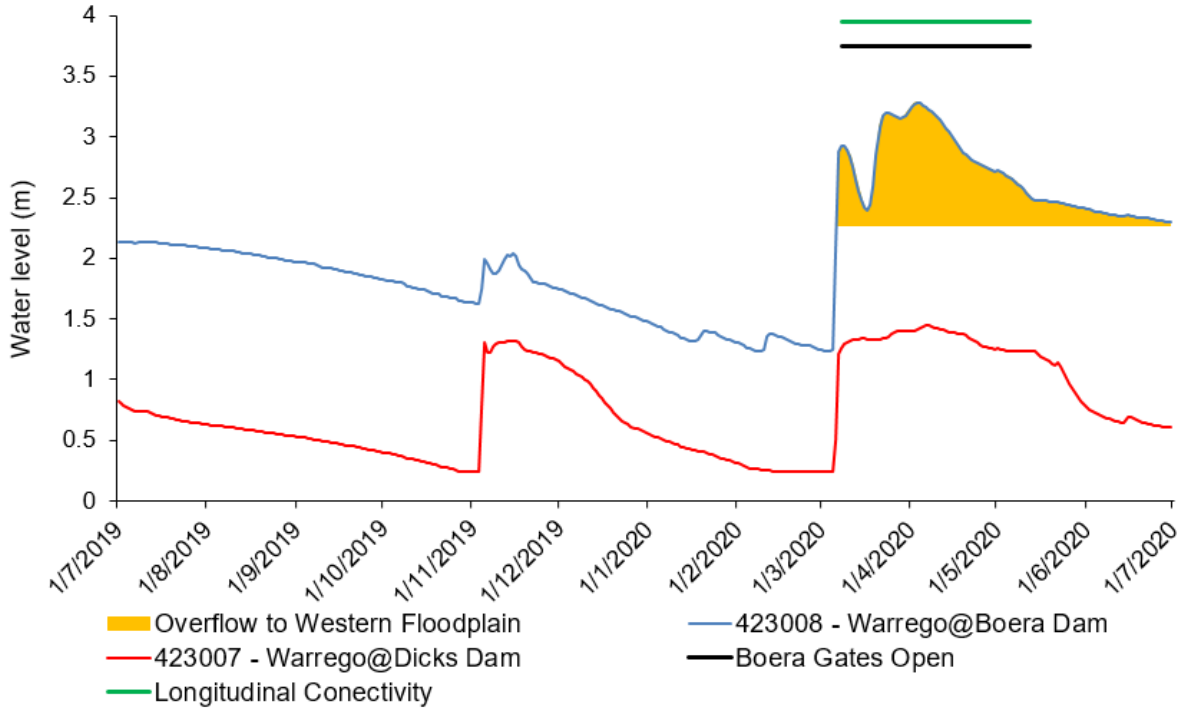


Figure 6 Boera and Dicks Dams levels 2019-20 water year, with downstream connectivity and connection to the Western Floodplain indicated.

The water year started with approximately 492 ha of floodplain and wetland inundation combined across the Selected Area (Appendix B: Warrego River Hydrology). The mapped inundated area declined from July 2019 to March 2020, although the November flow event increased inundation within the Warrego channel dams by a small amount. The flow event that commenced in March 2020 led to a substantial increase in inundation both on the Western Floodplain and the Warrego channel. Total inundation peaked at over 11,500 ha in April (Figure 7) and then declined steadily to the end of the water year. This was the greatest extent of floodplain and wetland inundation observed in the LTIM/MER project, with the Western Floodplain connecting to the Darling River downstream of the Selected Area for the first time since 2012 (Figure 8).

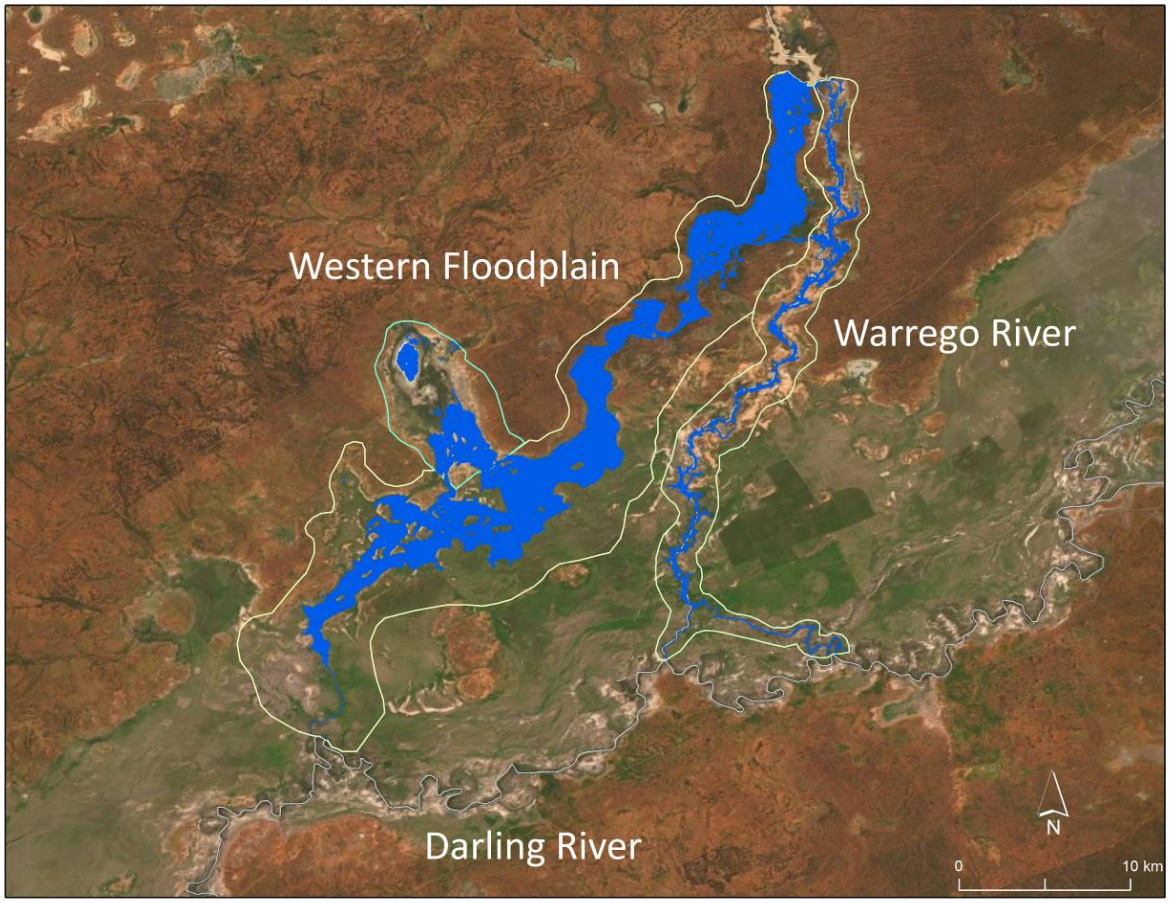


Figure 7 Maximum inundated area observed within the Selected Area in 2019-20.

Figure 8 Connection of Western Floodplain to Darling River at Talowla 26 April 2020 (Photograph provided by Sonya Ardill courtesy of NPWS).

3.1.4 Water Quality and Metabolism Responses to Flow

Water quality in the Warrego and Darling Rivers was highly variable during the 2019-20 water year with few clear trends apparent in response to connection and inundation (Appendix C: Food webs). Turbidity remained high during peak discharges, up to 10 times the guideline trigger values, but reduced at all sites following the February-May 2020 flow. The Western Floodplain had consistently lower turbidity as a result of the slower moving water, vegetation cover and greater opportunity to settle. In response to improved water clarity and high nutrient concentrations on the Western Floodplain, a short-term and localised algal bloom was recorded. As has been found in previous monitoring, nutrient concentrations in all systems was high, with Total Nitrogen and Total Phosphorus exceeding trigger values on all but two occasions. Consistent with long term trends of maximum productivity associated with prolonged inundation and high temperatures, there were no adverse environmental outcomes recorded in response to high nutrient concentrations and the localised algal bloom.

Reduced Electrical Conductivity and nutrient concentrations were observed in the Darling and Warrego rivers in response to higher flows. The improvement in water quality was most pronounced in the Darling River downstream of the confluence with the Warrego and as replenishing flows in Warrego channel refuge pools, highlighting the importance of these connection events to maintaining good water quality in the Selected Area.

Despite consistently high nutrient concentrations at all sites that should theoretically drive positive primary productivity, rates of stream metabolism continued to be highly variable and strongly heterotrophic, regulated by very high turbidity and poor light availability at all sites and times. Both the Darling and Warrego rivers acted as carbon sinks, consuming significantly more carbon than they produced, although the Warrego had lower rates than the Darling. Of particular interest is that gross primary productivity (GPP) decreased longitudinally downstream in both the Darling and Warrego rivers, suggesting the lower nutrient and higher carbon concentrations in the water from the Warrego are enhancing ecosystem respiration (ER) in the Darling River downstream of the confluence. Ecosystem respiration and net primary production (NPP) both peaked in mid-February during the flow event when water temperatures remained high, which was consistent with the long term pattern showing that water temperature (along with increased turbidity) is a major regulator of primary production in these systems.

There were no clear temporal patterns in GPP, ER or NPP overall or within any site to indicate that the inundation event influenced productivity rates within the Warrego or Darling Rivers. However, extensive inundation and connection, and enhanced water quality led to increased energy availability across the Selected Area. Commonwealth environmental water added over 21,000 kg of carbon (12% of the total GPP) to aquatic food webs in the Selected Area. This carbon production contributed substantial energy to aquatic food webs that fuelled an increased richness and diversity of invertebrate communities. Prolonged inundation allowed the invertebrate community assemblage to shift from one dominated by benthic (bottom dwelling) species to one dominated by pelagic (water column) species such as Daphnia (water fleas) that are known to be a dominant food resource to support juvenile fish.

3.1.5 Ecological Responses to Flow

Monitoring of the ecological indicators for the MER project in 2019-20 was impacted in the second half of the water year due to COVID-19 related travel restrictions. Unfortunately, this coincided with the more significant flow events through the Selected Area. As a result, monitoring for some indicators such as frogs, waterbirds and fish reflected the drier conditions over the summer period, while for the vegetation and food webs indicators that were sampled later in the year, some influence of the larger flows was observed.

Bird and frog communities were surveyed in December and February while dry conditions prevailed with patterns in abundance and diversity over the season more reflective of localised rainfall preceding surveys and seasonal patterns, rather than flow (Appendix E: Waterbirds, Appendix G: Frogs). In the context of the 6 years of the LTIM/MER project, both bird and frog communities were less abundant and diverse this water year. Even so, the Selected Area continued to support species listed as vulnerable under the NSW *Biodiversity Conservation Act 2016* (BC Act; brolga) and Migratory species listed under international agreements (great egret). Booka Dam continued to be a stronghold for frogs, and the newly sampled Dicks Dam supported a relatively abundant and diverse waterbird community (Figure 9). Aquatic habitat on the Western Floodplain during these surveys was limited to one small waterhole and as such bird and frog communities at this site were depauperate in comparison to the other channel sites surveyed.

Monitoring for the frog indicator over the LTIM/MER project has shown differences in abundance and diversity of frog communities in channel and floodplain habitats. Some species, such as the wrinkled toadlet (Figure 10) have only been detected on the floodplain while other species (rough frog, water holding frog, new Holland frog, salmon striped frog) have only been detected in channel sites. These results show the importance of protecting multiple types of habitats, maintaining the refuge habitats in the Warrego channel and delivering water to the floodplain, where frogs obtain high abundances and different species assemblages.

Figure 9 Great egrets listed under JAMBA and CAMBA international agreements perched above Dicks Dam, March 2020.

Figure 10 The wrinkled toadlet (Uperoleia rugose) which is found in Floodplain habitats within the Warrego-Darling Selected Area.

Fish monitoring for the MER project has been expanded to include the Darling River zone within the Selected Area and also 5 sites on the upper Warrego River between Cunnamulla and Charleville QLD, in addition to the previously monitored lower Warrego River zone. Fish sampling was undertaken in June-August and November-December 2019, when flow conditions at all sites were low. Fish species richness was similar between the three zones (Darling, Upper Warrego and lower Warrego) and was similar to the suite of species expected to occur before European Settlement (Appendix F: Fish). However, the abundance of species varied greatly between species and monitoring zone. The Darling River displayed the most abundant fish community with relatively high numbers of bony herring and carp-gudgeon, whereas the lower Warrego was characterised by higher numbers of golden perch and common carp, and the upper Warrego was characterised by higher abundances of Murray-Darling rainbowfish and Australian smelt. More than 9,000 individual fish were captured from all three zones and of these only 7 Hyrtl's tandan, 4 Murray cod (listed as Vulnerable under the EPBC Act 1999) and 1 freshwater catfish were captured (Figure 11). Previous studies have recorded larger numbers of these species. This highlights the boom and bust nature of fish populations in the Warrego and Darling Rivers, with the recent drought conditions, low flows and sporadic fish kills appearing to heavily impact these species.

Figure 11 Hyrtl's tandan (Neosilurus hyrtlii; length 273 mm Top) and Murray cod (Maccullochella peelii; length: 910 mm; bottom) were recorded in very low numbers during 2019-20 water year.

Golden perch abundance and population structure varied considerably among each of the three zones. The Warrego River within the Selected Area has been shown to support large numbers of young-of-year golden perch at times and very few, if any mature-sized individuals (Commonwealth of Australia 2019). In contrast, the fish communities of the upper Warrego and Darling River were found to comprise reasonable numbers of mature-sized golden perch, as well as varying numbers of young-of-year individuals. These data suggest that the lower Warrego forms a nursery, rather than being a source of golden perch. Golden perch larvae drift downstream *en masse* post-hatch, dispersing over many hundreds of kilometres in their first few weeks of life (Stuart and Sharpe 2019). As such, the source of juvenile golden perch collected in the lower Warrego and Darling zones would most likely be a result of spawning occurring much further upstream in either the upper Warrego or further upstream in the Barwon-Darling. This highlights

the need to provide connectivity, using flows and fishways to allow the unimpeded movement of this species through the system.

Invertebrate monitoring showed patterns consistent with previous years (Appendix C: Foodwebs). Microinvertebrate richness was greater in channel sites (Warrego and Darling) than on the Western Floodplain. While densities were similar across zones, they were much higher during the low flow conditions than during the flow event, due to higher productivity in the warmer summer months and the dilution effect during the flow event. There was a shift in invertebrate community composition from a community dominated by benthic microcrustaceans (harpacticoids and ostracods) in December 2019 to a community dominated by pelagic microcrustaceans (Daphnia and Bosminids) and free-living nematodes in March 2020.

In October 2019, vegetation communities on the Western Floodplain were thriving, with species richness and vegetation cover the highest observed in the six years of LTIM/MER project monitoring (Appendix D: Vegetation). The high species richness measured was predominantly driven by terrestrial forb species that had responded strongly to floodplain inundation and localised rainfall in Spring 2019. Coolibah Woodland Wetland sites that experienced both rainfall and inundation in Autumn 2020 showed higher richness and cover than Coolibah Woodland Wetland sites that had only received rainfall. Inundated sites also maintained their cover for longer. This suggests that inundation affords a greater moisture subsidy for species in these communities than rainfall alone.

Throughout the two survey periods, plant growth, flowering and seed setting was apparent, particularly in the Lignum Shrubland Wetland, Coolibah-River Cooba-Lignum Woodland and Chenopod Shrubland vegetation communities (Figure 12Figure 13). The March 2020 inundation event combined with at least average rainfall may result in good seed set for species such as Coolibah, which if followed-up by favourable conditions in the 2020-21 water year, could trigger a germination event. This could form a target for future water delivery on the Western Floodplain, especially during summer, which has been identified as being of high demand in the 2020-21 CEWO Water Management Plan (CEWO 2020).

Inundation promoted amphibious and terrestrial damp species, while extended periods of drought favoured terrestrial dry species. These observations indicate both the inherent resilience in this system and the potential for it to transition into a drier, more terrestrial vegetative state in the absence of inundation. Given the recent inundation event observed in March 2020, combined with average rainfall, increased productivity on the Western Floodplain is a pattern which may continue into the start of the 2020-21 water year.

Figure 12 A flowering Coolibah tree (Eucalyptus coolabah) on the banks of Boera Dam, March 2020

Figure 13 Inundated lignum swamp on the Western Floodplain, March 2020.

3.1.6 Summary

Much of the monitoring in the Warrego-Darling Selected Area for 2019-20 was undertaken before the larger flow pulses that occurred in Autumn 2020. During the larger flow pulses, the ability of the team to travel to the site to undertake monitoring was limited by COVID-19 related restrictions. As such the waterbird, frog and fish communities that were monitored over the summer period were lower in abundance and richness reflecting the prevailing drought conditions of the previous six months. Nevertheless, these results suggest that the waterholes in the Warrego and Darling Rivers within the Selected Area provide critical aquatic refuges during dry periods. Similarly, the improvement in water quality and aquatic habitats in refuge pools following inundation highlights the importance of connection events in maintaining good water quality and food webs in waterholes. Of particular note was the critically low captures of some iconic fish species such as the Murray cod and freshwater catfish that were certainly in a 'bust' period during this time (when flow conditions at all sites were low).

In contrast, vegetation on the Western Floodplain was in relatively good condition during both surveys in October 2019 and March 2020, as a result of good rainfall and inundation of the floodplain preceding both surveys. Our results from Coolibah Woodland sites suggest that inundation (rather than rainfall alone) elicited a better response in terms of both species richness and vegetation cover, with groundcover persisting in these sites for longer. Flowering and seeding was also evident for floodplain tree species such as Coolibah following inundation of the floodplain in March 2020. If favourable conditions occur in the 2020-21 water year, a germination event could be triggered. This could form a target for future water delivery on the Western Floodplain, especially during summer.

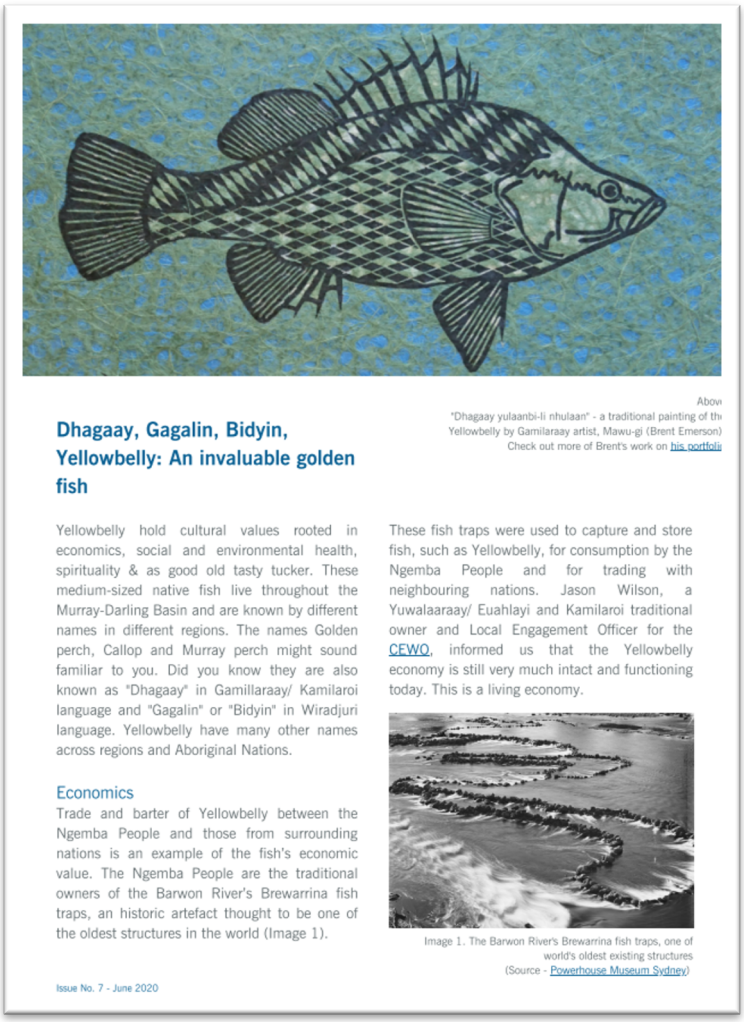
3.2 Research

The research component of the MER project in the Warrego-Darling Selected Area aims to build understanding of floodplain inundation patterns, food webs, vegetation (lignum) condition and biodiversity responses to flow. Many projects are in their infancy or progress on their field-based components was slowed by COVID-19 related travel restrictions. Protocols and methods have been generated for the inundation modelling and lignum condition projects, and these are currently being implemented to add to the suite of monitoring occurring for the MER project.

3.3 Communications and Engagement

A range of products and strategies were used to communicate the findings from the Warrego-Darling MER project in 2019-20. These included face-to-face meetings and presentations, teleconferences, newsletters, reports, stories and radio interviews. Post COVID-19, the focus turned to non-face-to-face communication strategies. Regular fortnightly teleconferences between MER project staff and CEWO Local Engagement Officers and MDBA Regional Engagement Officers helped to foster a collegiate approach to water for the environment communications across the northern basin. In terms of engaging a broader audience, the short stories posted on the 2rog website were extremely well received from a range of stakeholders. In this context, personal and

cultural stories tended to receive more attention and positive feedback on social media platforms where they were advertised. One particular story that focused on the cultural value of Yellowbelly, "Dhagaay", touched on people, culture and fish and provoked the strongest in-person response of all the stories posted (Figure 14).



Dhagaay, Gagalin, Bidyin, Yellowbelly: An invaluable golden fish

Abov
"Dhagaay yulaanbi-li nhulaan" - a traditional painting of th
Yellowbelly by Gamilaraay artist, Mawu-gi (Brent Emerson)
Check out more of Brent's work on his portfoli

Yellowbelly hold cultural values rooted in economics, social and environmental health, spirituality & as good old tasty tucker. These medium-sized native fish live throughout the Murray-Darling Basin and are known by different names in different regions. The names Golden perch, Callop and Murray perch might sound familiar to you. Did you know they are also known as "Dhagaay" in Gamillaraay/ Kamilaroi language and "Gagalin" or "Bidyin" in Wiradjuri language. Yellowbelly have many other names across regions and Aboriginal Nations.

Economics

Trade and barter of Yellowbelly between the Ngemba People and those from surrounding nations is an example of the fish's economic value. The Ngemba People are the traditional owners of the Barwon River's Brewarrina fish traps, an historic artefact thought to be one of the oldest structures in the world (Image 1).

These fish traps were used to capture and store fish, such as Yellowbelly, for consumption by the Ngemba People and for trading with neighbouring nations. Jason Wilson, a Yuwalaaraay/ Euahlayi and Kamilaroi traditional owner and Local Engagement Officer for the CEWO, informed us that the Yellowbelly economy is still very much intact and functioning today. This is a living economy.

Image 1. The Barwon River's Brewarrina fish traps, one of world's oldest existing structures
(Source - Powerhouse Museum Sydney)

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Figure 14 A story focused on yellowbelly or Dhagaay, published on the 2rog website, was a very effective communication product during 2019-20 (https://2rog.com.au/latestnews).

4 Implications for Future Management of Commonwealth Environmental water

MER project monitoring in 2019-20 was able to place the fish community within the Warrego River zone of the Selected Area into a larger context by including sampling in the Darling River and Upper Warrego River. While fish communities were in low abundance in the lower Warrego River, it forms an important nursery for fish recruits such as golden perch, which enter the reach via drift from upstream. Promoting downstream connection and passage of these recruits through the lower Warrego and into the Darling using water for the environment should be an ongoing priority for the

CEWO. Connection also brings additional benefits to water quality and food webs that support fish communities in waterholes along the Warrego channel.

The occurrence of keystone fish species such as Murray cod and freshwater catfish in critically low numbers during the 2019-20 water year is concerning. Developing species specific strategies to effectively manage these species is required. Strategies would likely include restocking, but also the provision of flows during critical periods to ensure aspects of their lifecycle such as spawning and recruitment occur frequently enough to guarantee their longevity.

The good condition of vegetation communities on the Western Floodplain during 2019-20 is encouraging, given the drought conditions experienced at the site in recent years. So too is the evidence of flowering and seed setting of floodplain tree species such as Coolibah. The use of water for the environment to promote inundation of the floodplain, particularly over the 2020-21 summer period would be encouraged to stimulate recruitment in these species.

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