Commonwealth Environmental Water Office Monitoring, Evaluation and Research Project:

Lower Murray
2019-20 Summary Report

A summary report prepared for the Commonwealth Environmental Water Office by the Lower Murray Selected Area team

April 2021

Commonwealth Environmental Water Office Monitoring, Evaluation and Research Project: Lower Murray 2019-20 Summary Report. A summary report prepared for the Commonwealth Environmental Water Office by the Lower Murray Selected Area team.

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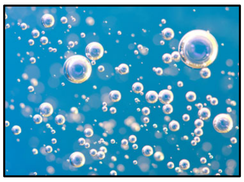
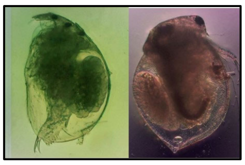
Glossary

anadromous	A life history that includes spending most of adult life at sea, but returning to freshwater for reproduction.
basal food source	A source of carbon (energy) at the base of a food web. For example, primary producers such as phytoplankton or plants.
base flow	Flows that are confined to the low flow part of the river channel.
biofilm	A collection of microscopic organisms (made up of algae, bacteria and fungi) attached as a 'film' on living (e.g. tree root) and non-living (e.g. wooden pylon) surfaces.
direct trade	Generally, water allocation transfers are permitted directly ('direct trades') to South Australia from the trading zones of New South Wales and Victoria, and by 'back trade' to South Australia from the trading zones of the connected New South Wales and Victorian tributaries. Direct trade to South Australia commonly involves to operation of Lake Victoria.
flowing water habitat	Water with flow velocities greater than 0.3 metres per second.
hydraulics	The physical characteristics of water flow, e.g. velocity (speed) and turbulence.
freshes	Flows greater than base flow but below bankfull level.
larvae	An early life stage of an animal, e.g. fish.
microinvertebrates	Invertebrates of microscopic size (e.g. rotifers, cladocerans and copepods), which may live in the water column, on the river floor or on vegetation along the river bank.
phytoplankton	Microscopic algae suspended in the water column that make their own food from sunlight through photosynthesis.
primary productivity	The rate at which energy is converted to organic compounds (food) by autotrophs (e.g. algae and plants) during photosynthesis.
recruitment	Survival past the critical stages of early life (e.g. larval) to become juveniles in a population. In this report, a fish that is sampled as a juvenile (~6 months old) in autumn is defined as a new recruit.
southern connected Basin	The southern connected Basin is a network of the Murray River and all tributaries that flow into it between the Hume Dam and the sea. The Lower Darling (below Menindee Lakes) is considered part of the southern connected Basin, whilst all rivers upstream of Menindee Lakes are considered as the Northern Basin.
spawning	The act or process of releasing or fertilising eggs.
unregulated flow	Unregulated flows occur when water in the system exceeds demands and are declared to be unregulated by the appropriate authority (source: http://www.bom.gov.au/water/awid/id-1026.shtml). They can be driven by substantial rainfall from upper tributaries, spills from headwork storages and rainfall rejection events.

Executive summary

In 2019-20, ~750 GL of Commonwealth environmental water was delivered to the main channel of the Lower Murray through a series of coordinated watering events, to achieve a range of environmental outcomes across the southern connected Murray-Darling Basin. This report presents the key ecological responses measured in the Lower Murray during 2019-20, as part of the Commonwealth Environmental Water Office (CEWO) Monitoring, Evaluation and Research (MER) Project. A technical report (Ye *et al.* 2021) provides detailed methods, results and evaluation of ecosystem responses to environmental water delivery.

Key outcomes of environmental watering in 2019-20

	***Lower Murray River:*** Spring flow pulse <u>Increased flowing habitat</u>: The length of river with **'flowing water' habitat** (greater than 0.3 metres per second) **increased** by 10% (for at least a four-week period).
	During spring–summer, increased water mixing and oxygen exchange (due to more flowing water) **decreased the likelihood of low oxygen levels** (e.g. <5 milligrams per litre, mg/L). Aquatic animals generally need oxygen levels above 5 mg/L, particularly during spring–summer, which is the main reproductive season of many species.
	**Increased Murray cod recruitment**, potentially supported by the increased extent of their favourable (flowing water) habitat during the spawning/early larval period, and increased larval food resources.
	<u>Increased water level variability:</u> Environmental water, in combination with weir pool manipulations, increased water level variability. Subsequent inundation of the river bank **increased the diversity of native vegetation on the bank**.
	In the river channel, **food production marginally increased** (by ~1%) due to changes in water level and channel width. Nevertheless, the amount (density) and variety (diversity) of **microinvertebrates increased** due to environmental water, likely through inputs from off-channel or upstream environments as a result of increased lateral and longitudinal connectivity.
	Spawning of golden perch occurred in the Lower Murray, but there was **negligible 'recruitment' and diminished golden perch population resilience**. The current fish community in the Lower Murray is characteristic of low river flows.

Lower Lakes and Coorong

Maintained connectivity between the river, Coorong estuary and Southern Ocean: Flows through the barrages to the Coorong were continuous throughout the year and comprised of 100% Commonwealth environmental water.

Winter flow pulse: Barrage flows during winter and spring facilitated connectivity and **promoted lamprey migration**. Migration between fresh and saltwater habitats is necessary for lamprey to successfully reproduce.

Annual barrage flow: Environmental water substantially **increased salt export** out of the Basin, **reduced salt import** into the Coorong and reduced salinity concentrations in the Coorong, which maintained estuarine habitats (e.g. for fish and aquatic vegetation) in the Coorong. This was crucial in maintaining species diversity and ecosystem functions.

Management implications

In 2019-20, the Lower Murray was climatically dry and experienced low flow conditions (<16,000 ML/d at the South Australian border, compared to bankfull flows ~45,000 ML/d). During this year, environmental water delivery created a winter (11,000 ML/d) and spring flow pulse (15,600 ML/d) in the LMR. Consequently, the proportion of weir pools (stretches of river between weirs) characterised by 'flowing water' habitat increased; although not to the extent that once characterised the LMR under natural (pre-regulation) conditions or as a result of higher flows (>20,000 ML/d) under current river management.

Smaller scale increases in flowing water habitat within weir pools may have benefited Murray cod as their life history operates over the spatial scale of 10s of km. In recent years, spring–early summer flows of 10,000–18,000 ML/d have been associated with Murray cod recruitment in the LMR, potentially due to enhanced spawning habitat area and survival of early life stages. However, more extensive increases in flow and hydraulic improvement is likely required to achieve greater ecological outcomes (e.g. riverine food production and recruitment of flow-cued spawning fishes) in the LMR. For this, reinstating key features of the natural flow regime in this region, such as high, in-channel spring–early summer flow pulses (>20,000 ML/d) should be considered a priority for management. Additionally, weir pool lowering could be considered to complement flows, to rehabilitate flowing water habitats. Improved understanding of specific flow (e.g. timing, magnitude and duration) and habitat requirements (including velocity) of flow-dependant species will inform management to maximise ecological outcomes.

Past years have demonstrated that environmental water is critical in supporting barrage releases (i.e. end-of-system flow), particularly during dry years when environmental water can comprise up to 100% of releases. Barrage flows are vital for maintaining freshwater–estuarine habitat connection and facilitating important life history processes (e.g. lamprey migration). Barrage flows are important for exporting salt from the Basin, reducing salt import into the Coorong, and reducing salinity levels in the Coorong. These essential processes maintain critical estuarine habitat (e.g. for fish and aquatic vegetation) and ecosystem function, and prevent detrimental loss of aquatic life from the system.

1 Monitoring and evaluation of environmental water in the Lower Murray

1.1 Background

The Commonwealth Environmental Water Office (CEWO) Monitoring, Evaluation and Research (MER) Project (2019-20 to 2021-22) monitors, investigates and evaluates the ecological outcomes of Commonwealth environmental water delivery in the Murray–Darling Basin (MDB). The project extends the monitoring activities of the Long Term Intervention Monitoring Project (2014-15 to 2018-19) across seven Selected Areas throughout the MDB, including the Lower Murray, to enable evaluation at the Basin and local scales. The aims of the project are to demonstrate the ecological outcomes of Commonwealth environmental water delivery and support adaptive management.

1.2 The Lower Murray and monitoring indicators

The Murray River, downstream of the Darling River junction, is a complex system that comprises the main river channel, anabranches, floodplain/wetlands, billabongs, tributaries and the Lower Lakes, Coorong and Murray Mouth, providing a range of habitats and supporting a diversity of significant flora and fauna. This part of the Murray River is modified by a series of low-level (<3 m) weirs (Figure 1), changing a connected flowing river to a series of 'weir pools' and greatly influencing the character of the ecosystem (Walker 2006).

Figure 1. The Murray River in South Australia comprises various habitats including limestone cliffs in the gorge zone (left) and locks/weir pools (right, Lock 4) (photos: SARDI).

The CEWO MER Project in the Lower Murray focuses on the main channel of the Murray River between the South Australian border and Wellington, with salt/nutrient transport and Coorong habitat modelling extending to the Lower Lakes and Coorong (Figure 2). Nine indicators were used to assess ecological responses to environmental water delivery. *Hydrology*, *Stream Metabolism and Water Quality* and *Fish Community* followed standard protocols to support comparisons across other areas of the MDB and the basin-scale evaluation (Hale *et al.* 2014). *Hydraulic Regime*, *Matter Transport and Coorong Habitat*, *Littoral Vegetation Diversity and Productivity*, *Microinvertebrate Assemblage*, *Murray Cod Recruitment* and *Flow-cued Spawning Fish Recruitment* were developed to address objectives and test a series of Lower Murray-specific hypotheses with respect to biological/ecological response to environmental flows. Additional contingency monitoring of lamprey migration was conducted during winter–summer 2019.

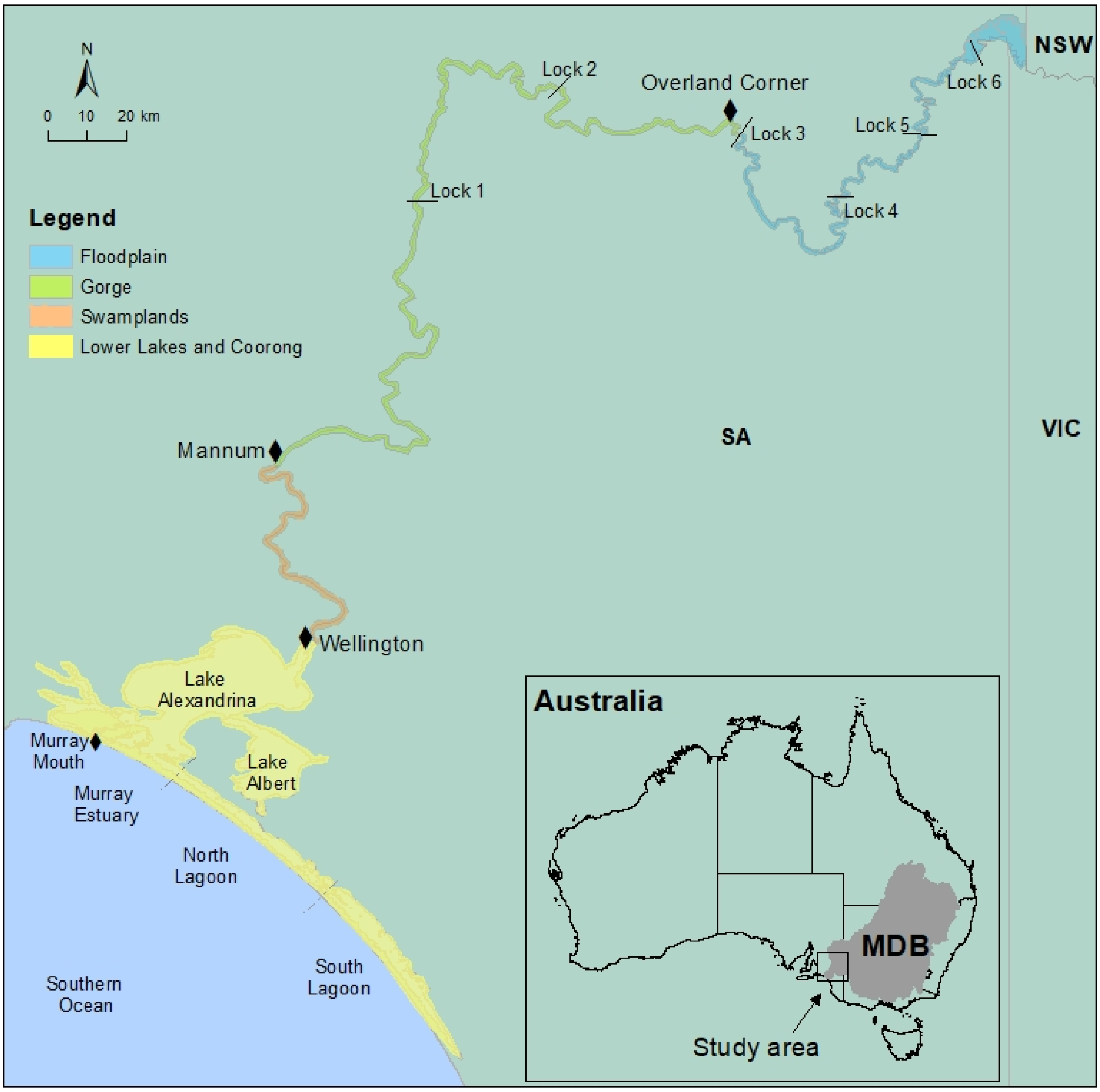


Figure 2. Map of the Lower Murray Selected Area showing the floodplain (blue), gorge (green) and swamplands (orange) river zones, and the Lower Lakes, Coorong and Murray Mouth (yellow).

1.3 Purpose of this summary report

This report provides a summary of environmental water use in the Lower Murray during 2019-20, key outcomes from the watering, and general implications for environmental flow management. The learnings and recommendations build on previous years of monitoring from 2014-15 to 2018-19. Detailed information, including methods, results and evaluation of Commonwealth environmental water, are provided in the technical report (Ye *et al.* 2021, http://www.environment.gov.au/water/cewo/catchment/lower-murray-darling/monitoring).

2 Environmental watering in the Lower Murray in 2019-20

Since 2014-15, an annual average of 698 gigalitres (GL)[a] of Commonwealth environmental water has been delivered to the Lower Murray, in conjunction with other sources of environmental water (e.g. The Living Murray Initiative) (Ye *et al.* 2020; 2021). Over this six-year period, the Lower Murray was characterised by low flow conditions (i.e. flow <18,000 ML/d at the South Australian border) except for an unregulated, overbank flow (peak ~94,600 ML/d) in spring–summer 2016-17 (Figure 4a). Environmental water contributed to 11–43% of the total flow in the Lower Murray annually, with Commonwealth environmental water contributing 7–33%.

The year 2019-20 was climatically and hydrologically dry. Without environmental water, flow would have been at South Australian Entitlement levels (~3,000–7,000 ML/d), the minimum flow to be delivered to South Australia under Clause 88 of the MDB Agreement. During 2019-20, ~750 GL[a] of Commonwealth environmental water was delivered to the main channel of the Lower Murray (32% of the total flow). Environmental water delivery in the Lower Murray largely consisted of return flows from upstream watering events (e.g. in the Murray and Goulburn rivers) and promoted a winter flow pulse peaking in late July 2019 (11,000 ML/d) and a spring flow pulse peaking around mid-October 2019 (15,600 ML/d) (Figure 4b). Environmental water was delivered to the Lower Murray, largely via direct trades from summer–late autumn, mainly to support continuous low flows to the Lakes and Coorong. Barrage flows in 2019-20 were comprised of 100% Commonwealth environmental water (Figure 3). Commonwealth environmental water also supported other complementary management, including weir pool manipulations and wetland watering by pumping[a].

Figure 3. Flows through the barrages from the Lower Lakes into the Coorong (photo: SARDI).

[a] Annual average volumes exclude off-channel watering (e.g. wetland pumping). In addition to ~750 GL of Commonwealth environmental water delivered to the South Australian border in 2019-20, approximately 10 GL was used to water off-channel wetlands and for net losses associated with other infrastructure events (e.g. weir pool manipulation) (source: CEWO).

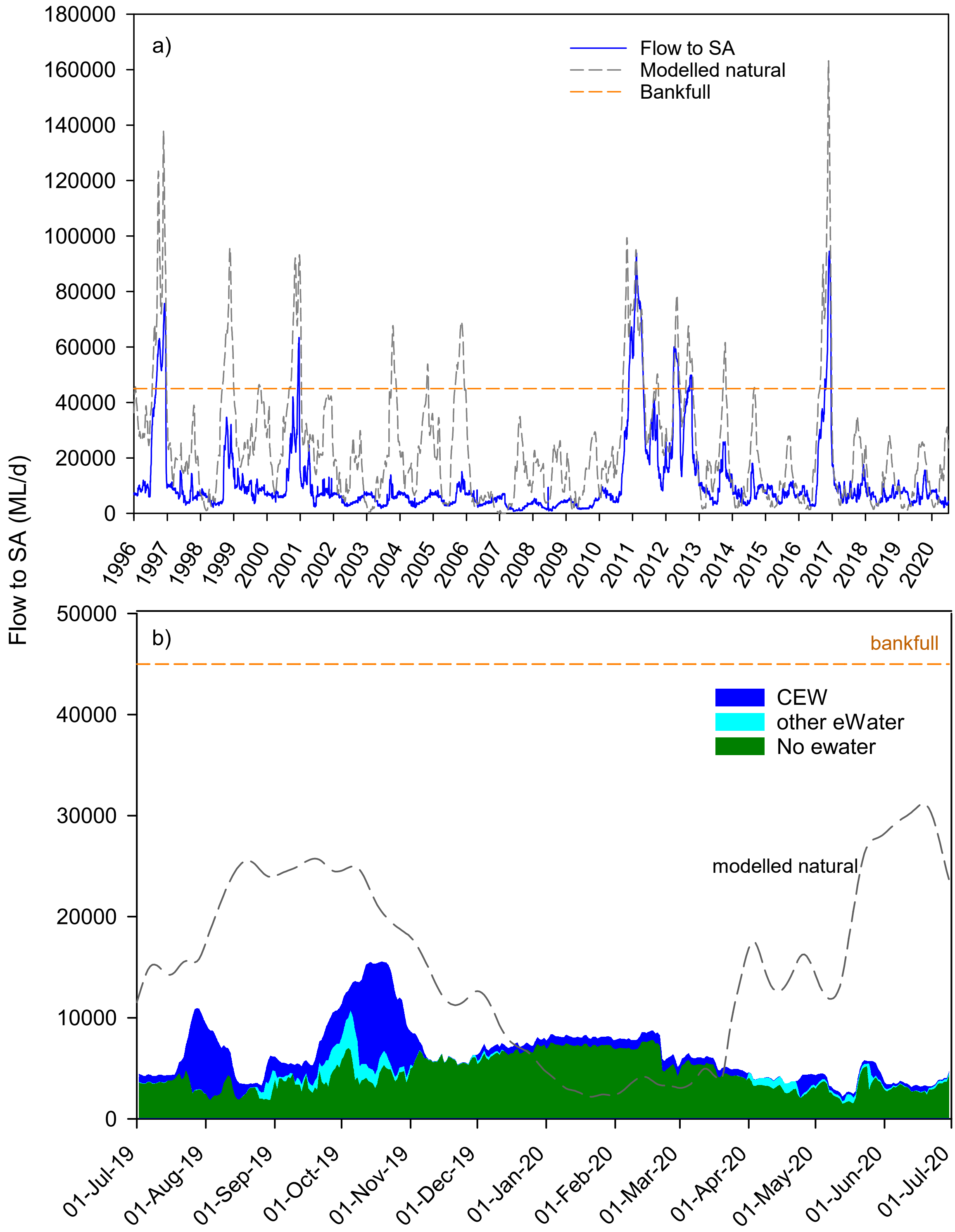


Figure 4. Murray River flow to South Australia (SA) (a) from January 1996 to July 2020 and (b) the contribution of environmental water to flow to South Australia in 2019-20. Observed flow is compared to modelled flow under natural conditions without weirs and extraction (grey dashed line) (source: MDBA). Orange dashed line represents the flow (45,000 ML/d) required to reach the bank in the Lower Murray River. CEW = Commonwealth environmental water. Other eWater = The Living Murray (TLM), Victorian Environmental Water Holder (VEWH) and River Murray Increased Flows (RMIF). The 'no eWater' component includes the South Australian entitlement held by the Commonwealth Environmental Water Holder and TLM. Note: change in y-axis scale between the two figures.

3 Key outcomes from environmental water use

3.1 Expected outcomes

In 2019-20, Commonwealth environmental water use in the Lower Murray contributed to elevated base (low) flows and pulses of flow within the Murray River channel, and provided flow to the Lower Lakes and Coorong (see Section 2). Expected outcomes of these flows related to fish, birds, vegetation, river function, Lower Lakes water levels, salt export and connectivity between freshwater, estuarine and marine environments, although only some of these were monitored through this project (also see Ye *et al.* 2021 (Appendix A) and https://www.mdba.gov.au/issues-murray-darling-basin/water-for-environment/lower-lakes-coorong-murray-mouth-report-card).

3.2 Monitoring

Lower Murray River: spring flow pulse

Increased flowing habitat

Improving riverine hydraulics (e.g. water velocity (speed) and turbulence) is critical for restoring the ecology of the Lower Murray. Pre-regulation, the Murray River downstream of the Darling River, was characterised by flowing, riverine habitats, with average water velocities of >0.3 m/s, even at low flows <10,000 ML/d (Bice *et al.* 2017). Many native plants and animals that are adapted to a flowing river have suffered major declines due to the largely non-flowing weir pool environments now present in this region (Mallen-Cooper and Zampatti 2018). In 2019-20 due to the Commonwealth environmental water delivery, there was an extra 74 km (22%) of river between Lock 1 and Lock 6 transformed to flowing habitat (i.e. velocities exceeding 0.3 metres per second, m/s) for at least 14 days, or 34 km (10%) of river for 30 days (Figure 5). This may have benefited riverine ecological processes for ~2–4 weeks at a spatial scale of 10–22% of the river's length. The velocity increase in 2019-20 remained a moderate improvement in contrast to substantial increases in flowing water habitat throughout the Lower Murray in 2016-17, due to unregulated, overbank flows (Ye *et al.* 2020).

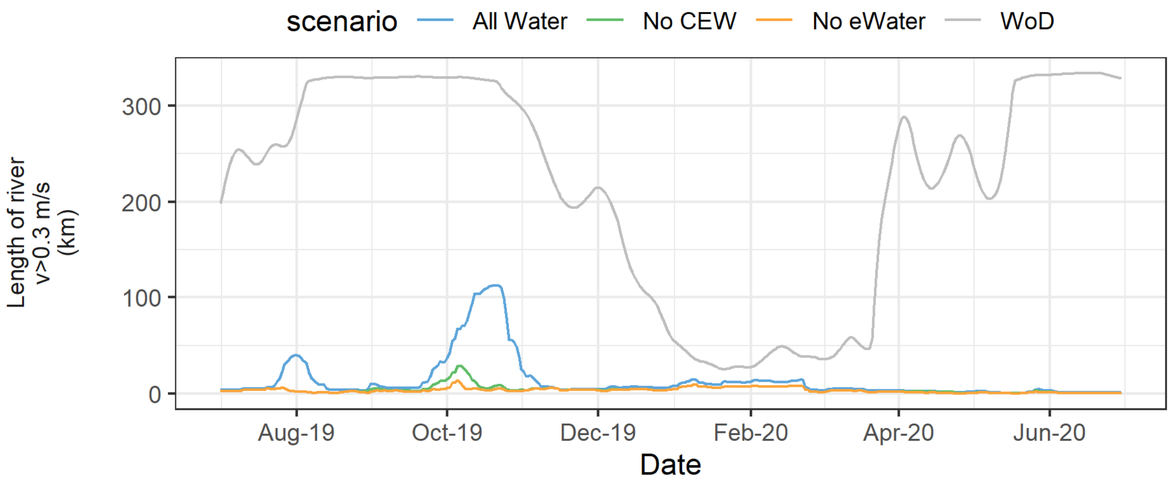


Figure 5. Length of the Lower Murray between Locks 1 and 6 with flowing water habitat, defined as a velocity greater than 0.3 metres per second. Total length of river assessed = 345 km. Coloured lines represent the modelled environmental water scenarios. The grey line represents the modelled natural (without development, WoD) scenario.

Reduced risk of low dissolved oxygen: Like other low flow years (e.g. 2017-18), in spring–summer 2019-20, environmental water decreased the likelihood of low dissolved oxygen levels in the Lower Murray by increasing water mixing and oxygen exchange at the surface (Figure 6). It was estimated that Commonwealth environmental water contributed to reducing the risk of low oxygen levels by 30 extra days, when Commonwealth environmental water contributed to increasing water velocities above 0.18 m/s. Favourable dissolved oxygen concentrations (generally >5 mg/L) in water are critical for the survival of aquatic biota. The consequences of low oxygen on the survival of larger aquatic animals are evident from the flood year in 2016-17, when dissolved oxygen levels fell to zero in the Lower Murray for a short period (Ye *et al.* 2018) and resulted in extensive Murray cod deaths.

Figure 6. Loggers that are deployed in the Lower Murray to measure dissolved oxygen concentrations (left) and the typical mooring station (right) (photos: SARDI).

Enhanced recruitment of Murray cod: Spawning of Murray cod occurs in spring–early summer, irrespective of flow (Rowland 1998), but recruitment in the Lower Murray main channel may be more successful with increased flow and lotic habitat (Ye *et al.* 2000; Zampatti *et al.* 2014). In recent years (2015–2019) under predominately in-channel flows <18,000 ML/d, regular recruitment of Murray cod was observed in the Lower Murray (Figure 7). During 2019-20, there was a strong recruitment event, indicated by an increase in the relative abundance of juveniles (<1 year old) throughout the Lower Murray. Peak spawning in 2019-20, back-calculated from daily ages, was from mid-October to mid-November 2019. The greater extent and duration of lotic habitat (Figure 5) may have benefited Murray cod during their reproductive season (spring–early summer), potentially by enhancing spawning habitat area and survival of early life stages. The mechanisms that influence the recruitment success need further investigation and are currently being explored via the Selected Area research (Section 3.3).

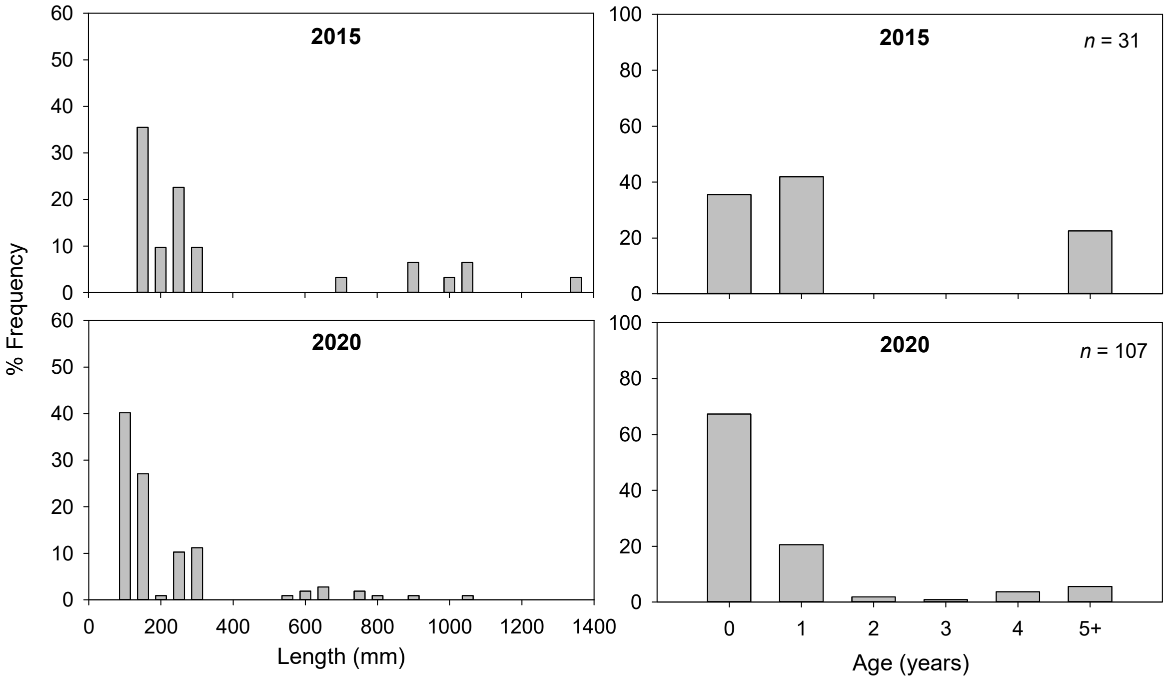


Figure 7. Lengths (left) and estimated ages (constructed using age–length relationships, right) of Murray cod, expressed as a percentage of the sampled population from the Lower Murray River during electrofishing in autumn 2015 and 2020 (photo: SARDI). Note: change in y-axis scale between figures.

Increased water level variability

The combination of environmental water delivery and weir pool manipulation created variability in water levels that would not have occurred otherwise, particularly during spring–summer at the upstream end of weir pools (tailwaters) (e.g. Weir Pool 2, Figure 8).

In 2019-20, the interquartile range (a measure of variation) in water level increased by 0.13 m in the tailwaters across Weir Pools 1–5, due to Commonwealth environmental water. This variability tended to mimic the seasonal timing of the without development pattern of river height, albeit at a smaller magnitude (Figure 8). Without environmental flows, water levels would have been stable throughout most of the year.

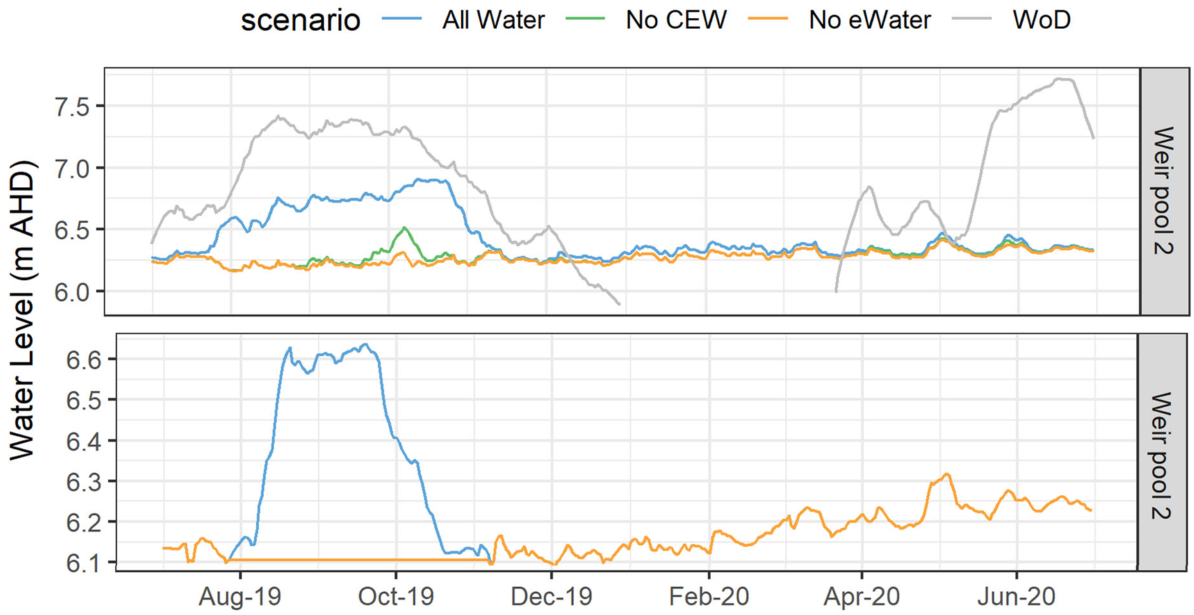


Figure 8. Modelled water level (metres relative to the Australian Height Datum) at the upstream (top) and downstream end (bottom) of the Lock 2 weir pool in the Lower Murray. Coloured lines represent the modelled environmental water scenarios. Note the different scaling on the y-axis.

Increased littoral vegetation diversity: Vegetation monitoring in December 2019 demonstrated increased native plant species diversity at multiple spatial scales following the inundation of littoral zones by increased water levels from spring flows in the Lower Murray, supported by environmental water. Furthermore, river red gum germination was observed exclusively in inundated areas of the floodplain geomorphic zone (Figure 9). In addition, the spring flow pulse produced conditions suitable for the recruitment of specialised riparian species (e.g. Australian mudwort, lesser joyweed, spreading nut-heads) that are adapted to fluctuating water levels, therefore increasing plant functional diversity.

Figure 9. Newly germinated river red gum seedling in the Lock 4 reach (photo: SARDI).

Slightly increased food production: Increased flow and water levels from environmental water deliveries widened the river, increasing the volume of water available for aquatic plant and animals. As a result, the rates of food production (measured as cross-sectional gross primary production) increased slightly (by ~1–2% each year from 2014-15 to 2019-20, and by 1% for 2019-20), indicating a marginally increased food supply from primary producers (e.g. algae and plants) in the food web. The influence of environmental water on riverine food production in the Lower Murray was only minor due to the largely ‘fixed’ water levels set by regulation (weirs).

Increased microinvertebrate abundance: Despite the marginal outcomes in primary production from 2014-15 to 2019-20, environmental flows were estimated (through modelling) to increase aquatic microinvertebrate abundance and diversity in the Lower Murray by an average of 18 and 9% per year, respectively. Microinvertebrates (Figure 10) are a major food source for larger animals, including larger invertebrates (Schmid-Araya and Schmid 2000) and early life stages of fish (i.e. larvae) (Tonkin *et al.* 2006). Therefore, a diverse and abundant microinvertebrate community may be important for the survival and growth of larval fish and in turn, fish recruitment.

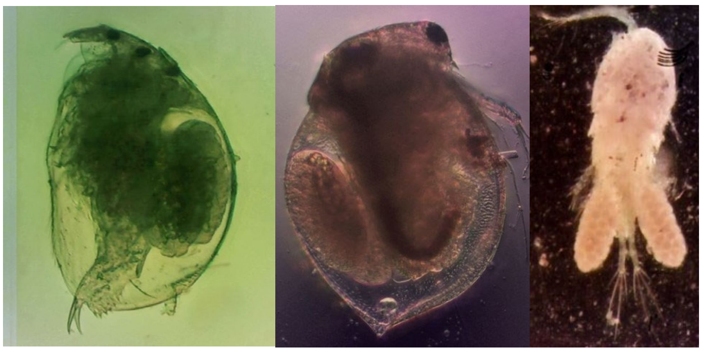


Figure 10. Microinvertebrates of the Lower Murray River that are prey for large-bodied fish larvae. Left: Cladocera (Chydoridae), middle: Cladocera (Daphniidae), right: Copepoda (Cyclopoida: Cyclopidae) (photos: University of Adelaide).

In 2019-20, this included an increase, specifically, in the density of microinvertebrates dependent upon lateral (river channel–off-channel) connectivity (30%) and those transported downstream through longitudinal connectivity (27%). Lateral exchange from increased water levels and longitudinal transport through returned flows of environmental water from upstream sources (e.g. Goulburn River/Upper Murray) likely promoted the microinvertebrate community in the main channel of Lower Murray. It was estimated that the density of preferred microinvertebrate prey of large-bodied native fish larvae increased by 37% during spring 2019 due to environmental water delivery in the Lower Murray. This may have contributed to the enhanced recruitment of Murray cod through increasing food resources during early life stages.

Negligible golden perch recruitment: Spawning and recruitment of golden perch in the southern MDB typically corresponds with increases in water temperature and river flow that occur in spring–summer (Zampatti and Leigh 2013a; 2013b). In the Lower Murray, the population may be comprised of fish derived from local spawning, and immigrants from other spawning sources, such as the Darling River (Figure 11).

In the Lower Murray from 2014–2020, golden perch spawning occurred annually, at low levels, during spring–summer and often in association with in-channel flow pulses. Nevertheless, the absence of juvenile (<1 year old) golden perch in annual autumn electrofishing surveys suggested negligible recruitment. It is possible that in-channel flows (<18,000 ML/d) were insufficient to support significant golden perch spawning and/or recruitment in the Lower Murray during dry years, whereas in 2016-17, low oxygen levels, associated with blackwater during the spring–early summer spawning season, impacted the survival of eggs and larvae.

Poor reproductive success of golden perch in the Lower Murray over the last six years has resulted in a lack of young golden perch (<5 years old) in the population (Figure 11). In 2020, the population was comprised mainly of older fish (8 to 10 years old) that were recruited at the end of the Millennium Drought and the wet years that followed (2009–2012). A lack of younger cohorts and the low number of age classes in the population of this long-lived species (>23 years) indicates low resilience to environmental disturbances (e.g. drought).

Fish assemblage: In 2019-20, the fish community was characteristic of low river flows (Bice *et al.* 2014), and similar to the communities documented in 2015 and 2016. This was due to the lack of recent recruitment of native, large-bodied flow-cued spawning species (e.g. golden perch and silver perch), a decline in common carp abundance (post-flooding in 2016-17) and continued high abundances of small-bodied species (e.g. carp gudgeon).

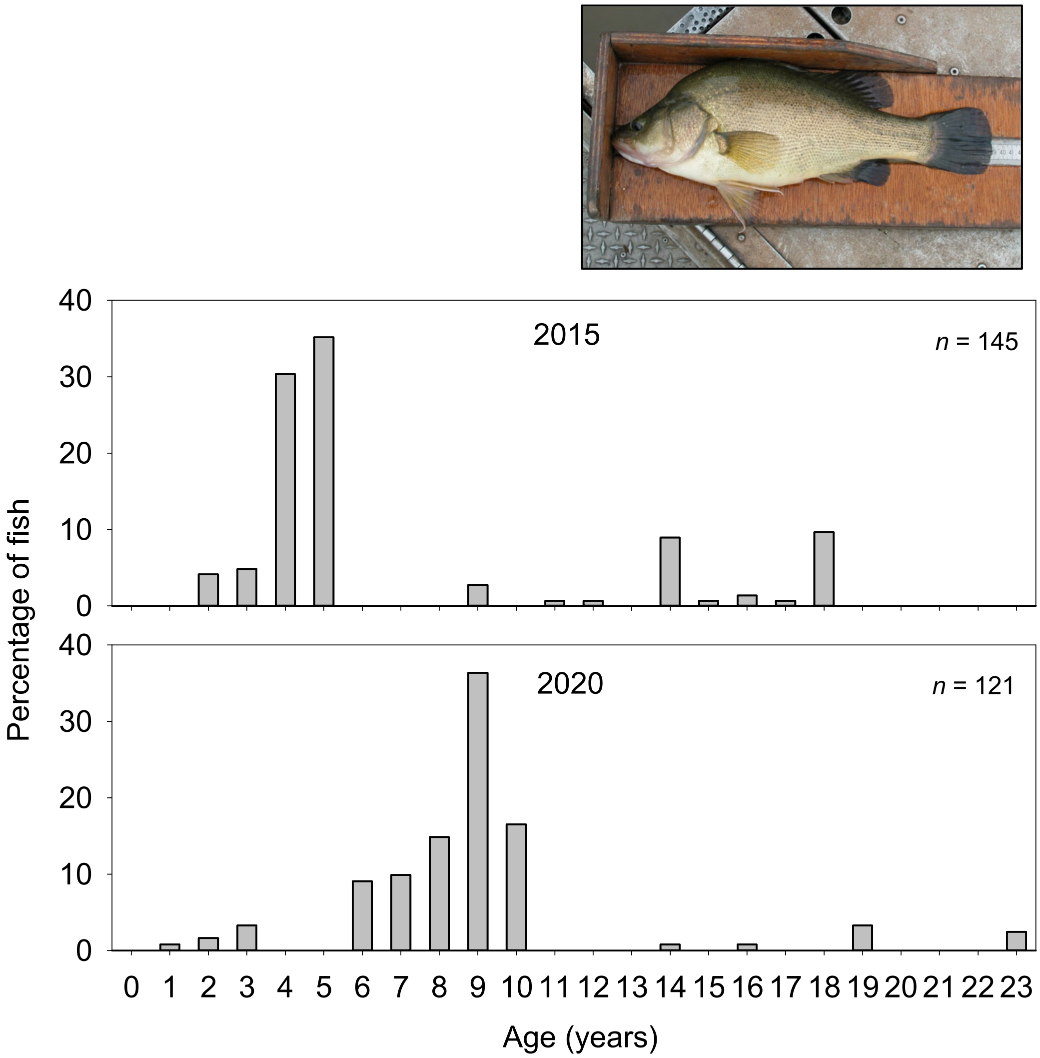


Figure 11. Ages of golden perch, expressed as a percentage of the overall population, from the Lower Murray in 2015 and 2020 (photo: SARDI).

Lower Lakes and Coorong

Winter flow pulse

Lamprey migration: Pouched lamprey and short-headed lamprey are the only 'anadromous' fishes native to the MDB. Their lifecycles include a parasitic marine phase, upstream spawning migrations into freshwaters followed by adult mortality, freshwater larval and juvenile development, and subsequent downstream migration to the ocean. Historically, lamprey were common in the Murray River with spawning migrations potentially extending up to 2,000 km upstream, but they are now rarely encountered, suggesting barriers to migration and flow regulation have impacted these species.

In winter–spring 2019, releases of Commonwealth environmental water from the Murray barrages represented 100% of discharge, including that for fishway operation. This facilitated connectivity between freshwater, estuarine and marine environments, and promoted lamprey migration. This included moderate–high abundances of pouched (n = 45) and short-headed lamprey (n = 15) passing the Murray barrages (Figure 12), relative to previous monitoring years, and migrations that continued for 100's of kilometres upstream up to Lock 10 (825 km from the river mouth) (Bice *et al.* 2020).

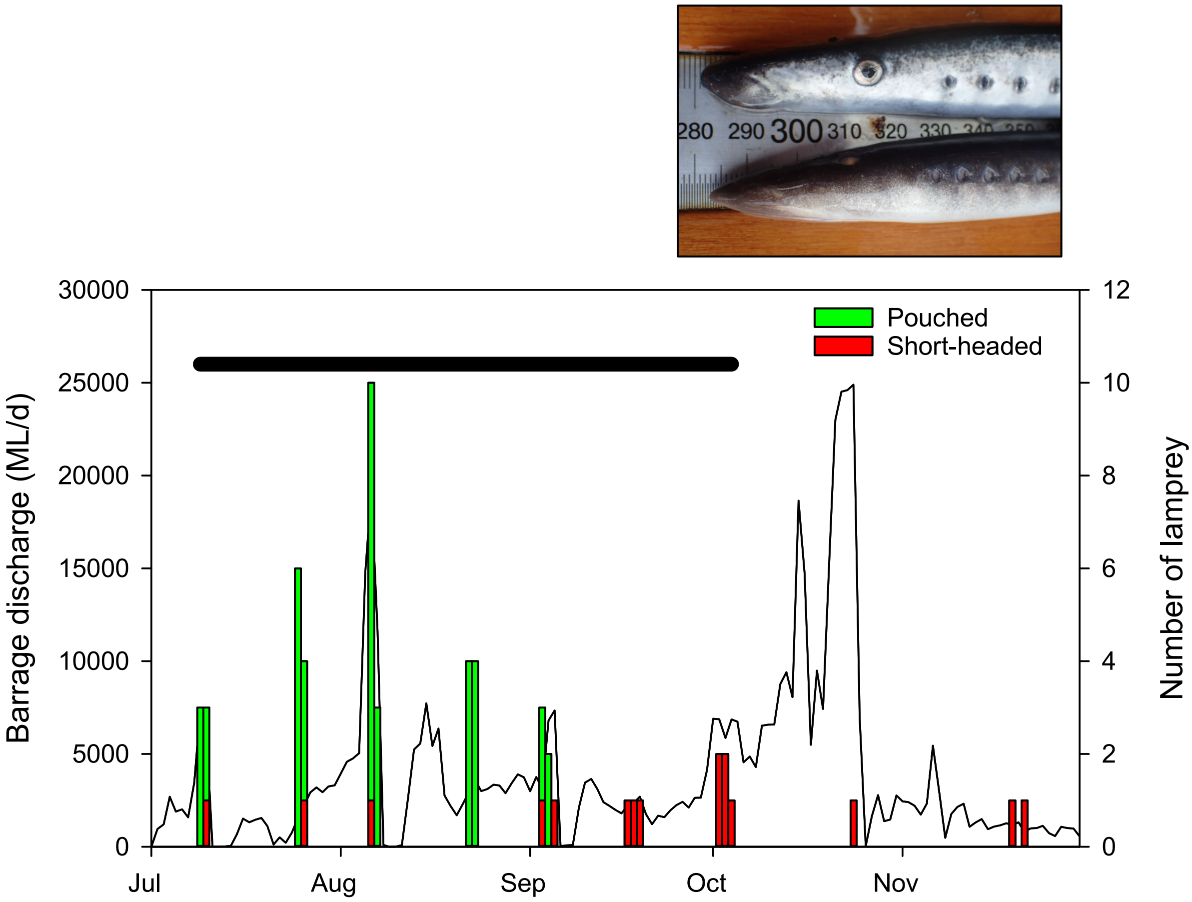


Figure 12. Numbers and date of capture for pouched and short-headed lamprey in winter–spring 2019, presented with total daily barrage discharge (ML/d). Horizontal black bar represents period of targeted lamprey sampling (photo: SARDI).

Annual barrage flow

Increased salt export: There is approximately 100 billion tonnes of salt in groundwater in the MDB and an additional 1.5 million tonnes of salt is deposited in the MDB each year by rainfall (Herczeg *et al.* 2001). Unless salt is exported from the basin with flow, there will be an accumulation of salt, potentially leading to salinisation of habitats, particularly wetlands. In the high flow year (2016-17), when annual barrage flow was ~7,161 GL, >1.5 million tonnes of salt was exported from the MDB and Commonwealth environmental water contributed 8% of salt export (Ye *et al.* 2020). In low flow years (e.g. 2017-18, 2018-19 and 2019-20), however, Commonwealth environmental water played a vital role in salt export from the MDB, contributing to 88–100% of export (Ye *et al.* 2021) (Table 1).

Table 1. Modelled salt export (tonnes) through the barrages to the Coorong from 2017-18 to 2019-20, using the high-resolution Coorong only model. CEW = Commonwealth environmental water, eWater = environmental water. Note the results are based on modelled barrage flows, eWater and CEW for matter transport modelling.

Scenario	2017-18	2018-19	2019-20
With all water	496,936	532,333	623,999
Due to CEW	436,848	532,333	623,999
Due to eWater	436,848	532,333	623,999

Reduced salt import and enhanced Coorong habitat: Commonwealth environmental water has also been critical in reducing salt import via the Murray Mouth (Figure 13), particularly during the low flow years (Figure 14). Without environmental water, an additional ~5.5 million tonnes of salt would have entered the Coorong via the Murray Mouth over the period 2017-18 to 2019-20, producing salinities (~3.5 times seawater) in the South Lagoon reminiscent of the Millennium Drought that led to detrimental loss of aquatic life. Maintaining suitable salinity levels in the Coorong is crucial for supporting estuarine habitats, species diversity and ecosystem function. In 2019-20, modelling indicated a 40% increase in the area of suitable habitat for mulloway due to reduced salinity by environmental water delivery to this region from 2017-18 to 2019-20. Over these three years, environmental flows also led to some improvements in habitat suitability for seed production and life-cycle completion of the aquatic plant *Ruppia tuberosa* in the southern Coorong.

Figure 13. The Coorong estuary (and Murray Mouth) of the Murray–Darling River system connecting the river to the Southern Ocean (photo: Adrienne Rumbelow, DEW).

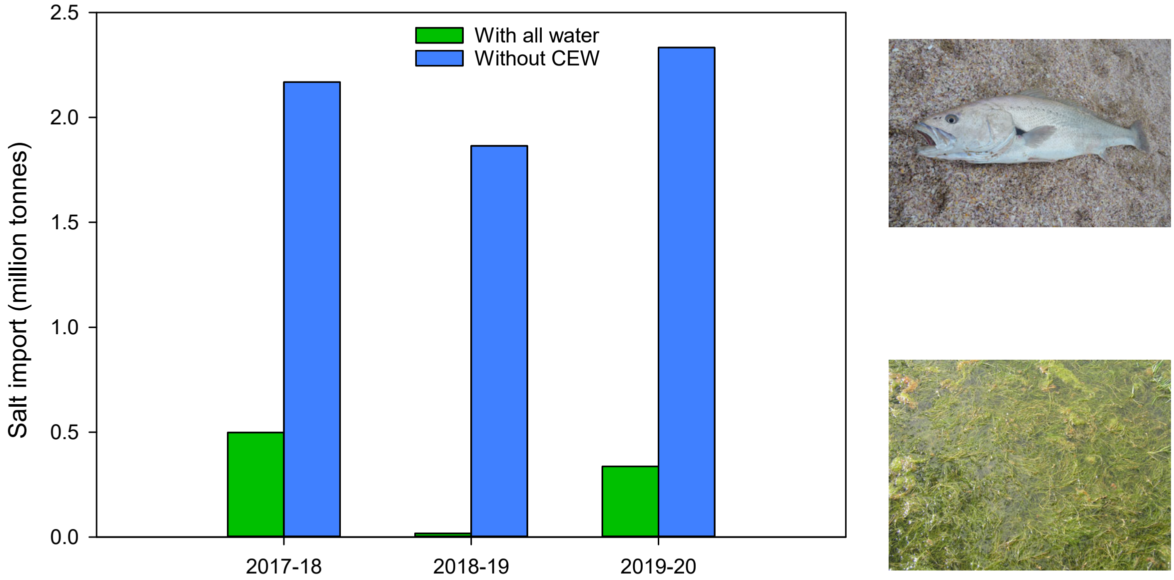


Figure 14. Modelled salt import (million tonnes) into the Coorong through the Murray Mouth during low flow years from 2017-18 to 2019-20. CEW = Commonwealth environmental water (photos: SARDI).

3.3 Research

The objective of the research project in the Lower Murray is to investigate how energy transfers through the aquatic food web to higher predators (e.g. juvenile Murray cod), and ultimately how flow (hydrology and hydraulics) affects energy sources and transfer (Figure 15). Specific questions are:

- What is the diet of larval and juvenile Murray cod?
- What 'basal sources' of the food web (e.g. river channel vs. floodplain, micro-algae vs. plants) support the growth of early life stage Murray cod?
- How do these flow-related food web processes relate to Murray cod growth, body condition and recruitment?

Understanding what drives improved growth rates, condition, survival and ultimately recruitment of Murray cod, is key knowledge required to inform environmental water delivery and flow management in the Lower Murray.

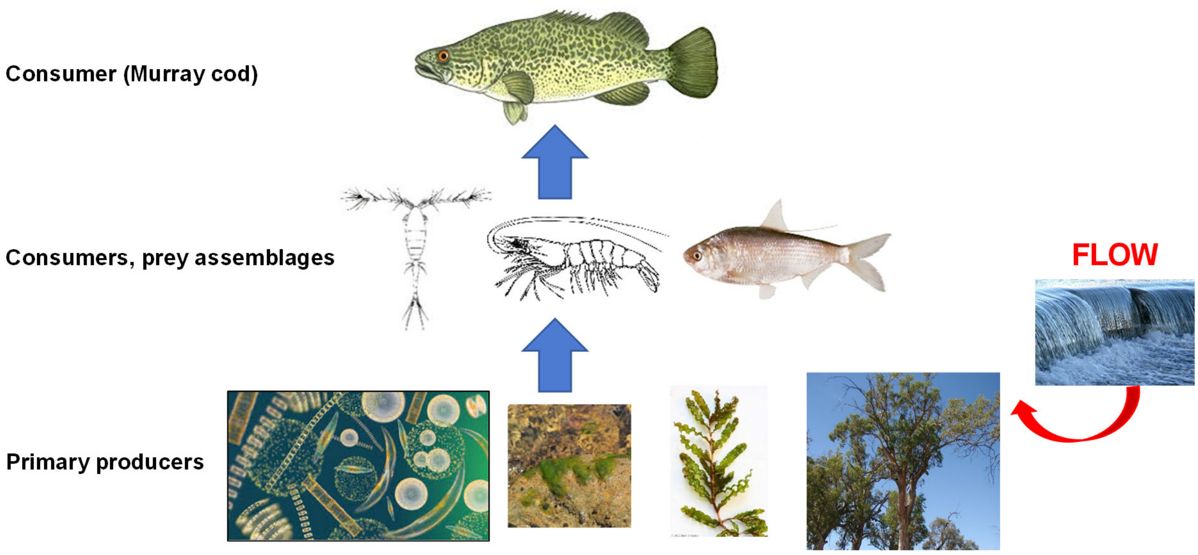


Figure 15. Basic conceptual understanding of how river flow may drive energy flow in Lower Murray food webs.

Techniques

This research project integrates the monitoring from several indicators of the CEWO MER Project in the Lower Murray (Section 0). Multiple laboratory techniques are used to answer our research questions:

- **Gut-content analysis** of larval/juvenile Murray cod to assess diet
- **Molecular analyses** to characterise prey communities, and the diet of larval/juvenile Murray cod
- **Compound-specific stable isotope analysis** (CSIA) to investigate the contribution of different basal food sources (e.g. river red gum, microalgae) in supporting juvenile Murray cod growth.

Preliminary findings – gut-content analysis

- The diet of larval (~10 mm) Murray cod collected from 2014–2019 was almost entirely microcrustaceans (i.e. copepods and cladocerans)
- In contrast, the diet of juveniles (~150 mm) in autumn from 2015–2020 was dominated by decapod crustaceans, such as shrimp
- In 2019-20, there was little difference in diet among juveniles collected from January (~40 mm) to May (~150 mm) – they mostly ate shrimp (Figure 16).

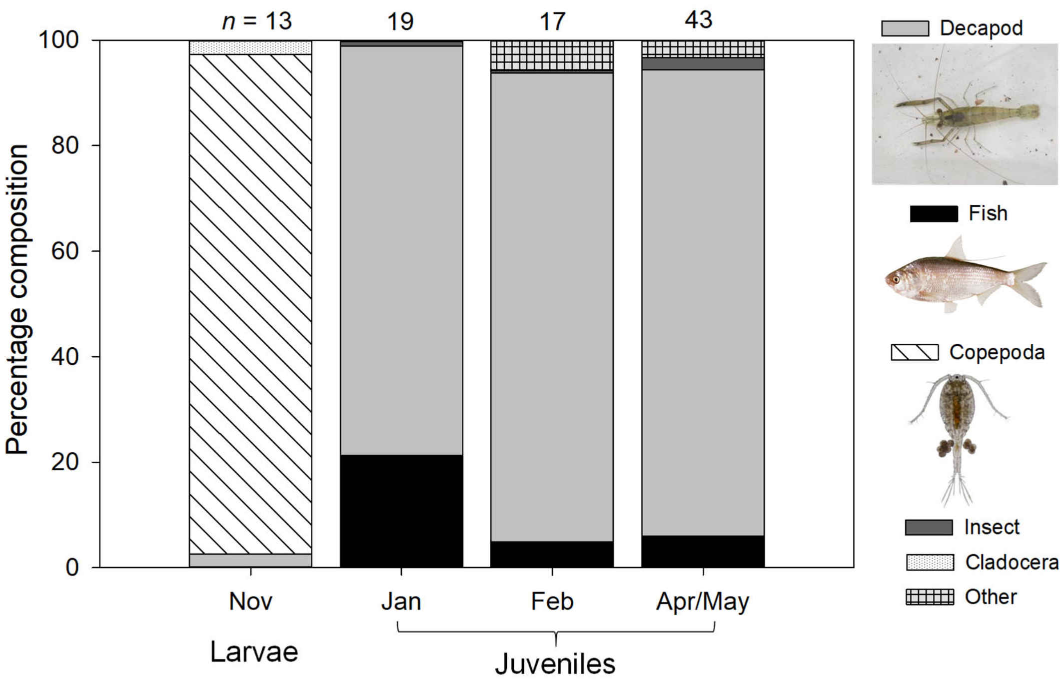


Figure 16. Percentage composition of major prey in the guts of Murray cod larvae (November, by number) and juveniles (January–May, by weight) from the Lower Murray in 2019-20. Sample numbers are presented above each bar. Other = other crustaceans, rotifers, vegetation and unidentified material.

3.4 Communications and engagement

The Engagement and Communication (E&C) activities in the Lower Murray aim to strengthen the existing communication with managers/stakeholders and broaden engagement with the general public, focusing on recreational fishing and indigenous groups. Building on our existing relationship and ongoing communication with CEWO and other key stakeholders (e.g. the Selected Area Working Group), we have implemented a range of additional E&C activities and developed multiple communication products over the last year, including:

- Lower Murray webpage on the Flow-MER website as a key communication tool, with frequent updates in the form of highlight stories (seven stories, spotlight on the electrofishing story)
- Many marketing collaterals materials (hard copy and online) (Figure 17). Spotlight on the ‘Fish, Flows and the Future’ animation video (Figure 18)
- Quarterly outcome newsletters featured on the CEWO and Flow-MER websites
- Capacity building workshop with Siwan Lovett, on how to be a good communicator (oral presentations and storytelling/writing)
- Consulting and co-designing future activities with indigenous and recreational fishing groups (Figure 19).

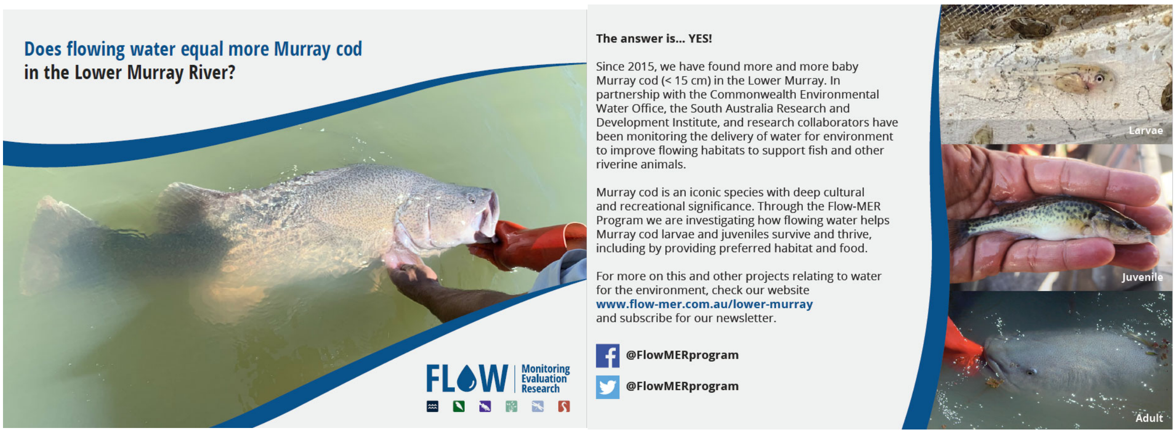


Figure 17. Front and back of postcard targeted to recreational fishing communities.

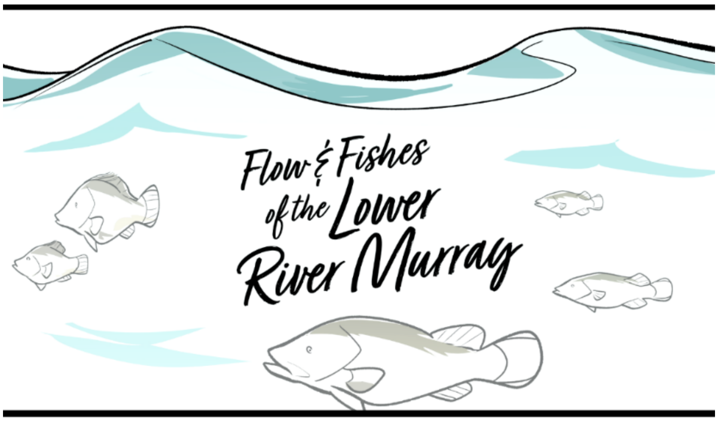


Figure 18. Still image of animation video.

Figure 19. Calperum station visit, meeting with station manager and indigenous ranger (left) and recreational fisher (right).

Looking back

Undoubtably, last year was challenging with COVID-19. Many activities had to be modified. During tight restrictions, we focused more on providing online communication products to keep the community engaged. We also filmed our field teams in action and are planning to release "*In-field* videos". Yet, we acknowledge the importance of face-to-face community engagement. We continued to engage with indigenous and recreational fishing groups, even if it was virtually when in-person meetings were not possible. We appreciate that building relationships and trust takes time and have been carefully managing and continue to strengthen the established relationships with key indigenous and recreational fishing groups.

4 Implications for future management of environmental water

In 2019-20, another dry year, 931 GL of environmental water, including 750 GL of Commonwealth environmental water, was delivered to the main channel of the Lower Murray through coordinated watering events across the southern MDB. This supported a winter and a spring in-channel flow pulse (up to 15,600 ML/d) that contributed to a range of ecological outcomes in the Lower Murray, including increased area of flowing water habitat and increased Murray cod recruitment, and more variable water levels and increased native plant species diversity.

While environmental water promoted a spring flow pulse (up to ~35% of bankfull level in 2019) in the LMR, the magnitude and duration of the flow remained well below modelled flow under natural (pre-regulation) conditions (Figure 4). The presence of weirs also exacerbated the hydraulic conditions by fragmenting the river and promoting still water patches, and thus the river only had small discontinuous stretches of flowing habitat for most of the year (Figure 5). Pre-regulation, the Murray River, downstream of the Darling River, was characterised by flowing habitats, with average water velocities commonly >0.3 m/s, even at flows <10,000 ML/d; whereas currently much greater flow (>20,000 ML/d) is required to reinstate a 'flowing river' due to the weirs (Bice *et al.* 2017). Many native plants and animals, adapted to riverine habitats, are now extinct or suffered major declines due to the largely weir pool environment in this region (Walker 2006; Mallen-Cooper and Zampatti 2018).

Environmental water to support the restoration of flowing water habitats will help to restore ecosystem function and rehabilitate riverine plants and animals in the LMR. In recent years, spring–early summer flows of 10,000–18,000 ML/d have increased the extent of flowing habitats in individual weir pools (10s of km), which may have contributed to the observed Murray cod recruitment in the LMR, as the life history of this species operates over similar spatial scales. However, more extensive increases in flow and the reinstatement of key features of the natural flow regime, such as high, in-channel spring–early summer flow pulses (>20,000 ML/d), is likely required to achieve greater ecological outcomes (e.g. riverine food production and recruitment of flow-cued spawning fishes), and should be considered a priority for management. With existing volumes of environmental water and delivery constraints, during dry years, reaching and sustaining flows >20,000 ML/d in the LMR is largely reliant on coordinating flow deliveries across the southern connected Basin, including flows from tributaries (e.g. Goulburn, Murrumbidgee, Darling rivers). Additionally, weir pool lowering could be considered as an action to complement flows and further rehabilitate flowing water habitats. For example, hydraulic modelling suggests that at flows of 15,000 ML/d, lowering weir pools by 1 m could result in a similar extent of flowing water habitat to flows of 20,000 ML/d in the main channel of the LMR (Figure 20). Further understanding of specific flow (e.g. timing, magnitude and duration) and habitat requirements (including velocity) of flow-dependant species will underpin future environmental water and flow management to maximise ecological outcomes.

In past years, environmental water has been important in supporting barrage releases (i.e. end-of-system flow), particularly during dry years (e.g. 100% flow support). Barrage flows are critical in maintaining connectivity (including fishway operations) and facilitating key life-history processes (e.g. lamprey migration). Barrage flows are crucial in exporting salt from the MDB, reducing salt import and maintaining suitable salinity levels in the Coorong. These are essential in maintaining estuarine habitat (e.g. for fish and aquatic vegetation, i.e. *Ruppia tuberosa*), avoiding demise of aquatic life and mitigating Coorong ecosystem degradation.

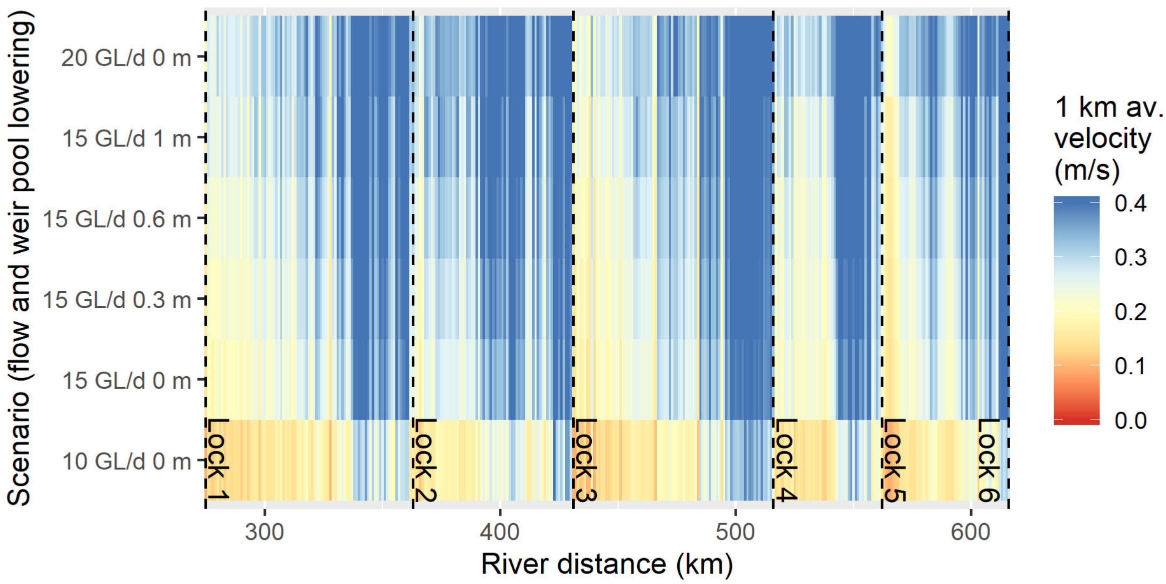


Figure 20. 1 km average velocity from Lock 1 to Lock 6 for scenarios of different flows to South Australia and weir pool lowering.

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