Technical information supporting the South Australian Basin Plan Environmental Outcome Evaluation

Eastern Mount Lofty Ranges

Department for Environment and Water
October, 2024

DEW Technical report 2024/13

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Acknowledgement of Country

We acknowledge and respect the Traditional Custodians whose ancestral lands we live and work upon and we pay our respects to their Elders past and present.

We acknowledge and respect their deep spiritual connection and the relationship that Aboriginal and Torres Strait Islanders people have to Country.

We also pay our respects to the cultural authority of Aboriginal and Torres Strait Islander people and their nations in South Australia, as well as those across Australia.

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Summary

The Eastern Mount Lofty Ranges (EMLR) Water Resource Plan Area (WRPA) has several priority environmental assets (PEAs) identified in the Long-term Environmental Watering Plan for the Eastern Mount Lofty Ranges Water Resource Plan Area, based on surface water catchments. The watercourses of these PEAs are generally intermittent or temporary rivers interspersed with permanent pools, supporting a community of aquatic macroinvertebrates, fish, frogs, tortoises and birds, as well as riparian and overstorey vegetation. The management of the water resources of the EMLR is through Water Allocation Plans (WAPs) for the EMLR, and Marne Saunders Prescribed Water Resource Areas (PWRA), which seek to protect water for the environment by limiting the level of development of water resources.

South Australia has assessed the achievement of environmental outcomes relating to ecological objectives and targets outlined in the EMLR Long-term Watering Plan (LTWP) (linked to the WAPs), which identifies objectives and targets in order to "maintain water-dependent ecosystems at an acceptable level of risk for meeting the overall objective of maintaining/restoring self-sustaining populations of aquatic/riparian flora/fauna that are resilient to drought". The assessment and evaluation of environmental outcomes for the PEAs have been collectively assessed and consolidated into two overarching assets, the EMLR and the Marne Saunders PWRA. The aim is to assess the progression towards these outcomes relating to the maintenance or improvement of the health and ecological function of water-dependent ecosystems (WDEs). The assessment of environmental outcomes presents the trend for each measured indicator, along with a detailed evaluation of the contribution of the Basin Plan and other influences on the achievement of these outcomes. A summary of the assessment is shown below:

Theme	Indicator	Trend	Information reliability	Key findings
Flow & Ecosystem Function	Flow regime	Trend **Improved** **EMLR PWRA** Trend **Declined** **Marne Saunders PWRA**	★★☆☆☆ Reliability **Fair**	Outcome **not achieved** – improved in EMLR PWRA but declined in the Marne Saunders PWRA.
Macroinvertebrates	Macroinvertebrate condition within sampling sites	Trend **Declined** **EMLR PWRA** Trend **Declined** **Marne Saunders PWRA**	★☆☆☆☆ Reliability **Poor**	Outcome **not achieved** – only 4 of the 42 sampled sites with moderate or better condition.
Fish	Community condition	Trend **Declined** **EMLR PWRA** Trend **Stable** **Marne Saunders PWRA**	★★★☆☆ Reliability **Good**	Outcome **not achieved** – only 3 of 9 catchments with moderate or better condition.
	Recruitment success (in key species)	NA Trend **Not Applicable**	★★★☆☆ Reliability **Good**	Outcome **achieved** – continuing persistence of key species across the prescribed area, despite lower abundances and less sites where detected.

The following key messages have come from South Australia's assessment and evaluation of the achievement of environmental outcomes in the EMLR WRPA:

- Flow requirements were not achieved, despite overall improvements in flow in the EMLR PWRA, most sites in the Marne Saunders declined.
- Macroinvertebrate communities remain in poor condition and have declined in the EMLR and Marne Saunders PWRAs, primarily due to variability in climatic conditions, pressures on water resources (extraction and diversion) and land use, influencing flow regimes and habitat condition.
- Fish communities are variable across catchments but the majority are in poor condition. Declines in fish community condition are likely due to the deterioration of upper-pool riffle and terminal wetland habitat condition, along with large populations of invasive fish species.
- Successful recruitment of native fish species (southern pygmy perch, and mountain and obscure galaxias) has maintained populations, despite current low abundances.
- Continued restoration of flow regime is critical to achieve environmental outcomes in the EMLR WRPA, including through the delivery of solutions to restore low flows whilst minimising impact on water use and security, through programs such as Flows for the Future.
- The continued controls and policies, including through Water Resource Plans and WAPs, are critical to ensure sustainable water use, taking into account environmental, social and economic needs.

1 Introduction

1.1 Basin Plan Schedule 12

The reporting requirements outlined in Schedule 12 of the Basin Plan provide the Murray–Darling Basin Authority (MDBA) with the information necessary to evaluate the effectiveness of the Basin Plan against its objectives and outcomes (s13.05).

Matter 8 (achievement of environmental outcomes at an asset scale) is a state-based reporting obligation that is central to communicating the environmental outcomes achieved through the implementation of the Basin Plan. Basin states are required to report on Matter 8 on a 5-yearly basis, with the first round of reporting submitted in October 2020. The next round of reporting (of which this report contributes to) is to be submitted in October 2024. Technical reports for the 2025 Matter 8 Evaluation were prepared and submitted a year earlier (four years after the 2020 Evaluation) in order to support the MDBA's Basin-scale evaluation in 2025. The MDBA is required to undertake an evaluation of the Basin Plan against its objectives in 2025, which will draw on the reporting undertaken by the MDBA, and reporting submitted by the Basin states under Schedule 12.

1.2 South Australia's approach to 2025 Basin Plan Environmental Outcome Evaluation and Reporting (Matter 8)

South Australia has identified the following objectives for Matter 8 environmental outcome reporting:

- To meet Basin Plan reporting obligations (Schedule 12, Basin Plan)
- To inform South Australia's, the Australian Government's, and other States' environmental water delivery decision making and adaptive management capacity
- To make a meaningful contribution to MDBA's evaluation of the effectiveness of the Basin Plan (at Basin-scale)
- To communicate outcomes to stakeholders, including the public.

The South Australian Department for Environment and Water (DEW) has developed an approach to reporting on the achievement of environmental outcomes required for the Matter 8 reporting (Imgraben 2023). This approach recognises the linkages between the Basin Plan environmental objectives, environmental watering plans and strategies (state and Basin-wide) and asset-scale environmental outcome reporting (Matter 8). Four key evaluation questions guide South Australia's evaluation of environmental outcomes at an asset scale:

1. To what extent have outcomes been achieved?
2. If outcomes were not achieved, why not?
3. To what extent did the Basin Plan contribute to achieving outcomes?
4. Have there been any unanticipated outcomes?

Reporting for Matter 8 in South Australia is required for three Water Resource Plan Areas (WRPA):

- South Australian River Murray
- Eastern Mount Lofty Ranges
- Murray Region

In line with the Basin Plan, South Australia has developed a LTWP for each of these WRPA. These plans identify PEAs in each area together with environmental objectives, targets, and environmental water requirements (EWRs). The asset scale reporting of Matter 8 is therefore directly linked to the assets identified in the LTWPs and the objectives, targets, and EWRs for each. The evaluation of environmental outcomes in the EMLR WRPA is based on ecological objectives and targets outlined for the PEAs in the EMLR LTWP (DEW 2020a); however, the assessment has been carried out for two overarching assets, the EMLR and Marne Saunders PWRAs.

2 Eastern Mount Lofty Ranges Water Resource Plan Area

2.1 Context

The Eastern Mount Lofty Ranges (EMLR) Water Resource Plan Area (WRPA) covers an area of approximately 3,588 km^2 from the Marne River Catchment in the north to Currency Creek Catchment in the south (Figure 2-1). This area (described as area SW7 in the Basin Plan) is managed as two Prescribed Water Resource Areas (PWRA) under the *Landscape South Australia Act 2019*, the EMLR PWRA and the Marne Saunders PWRA. The watercourses of the area are predominantly intermittent streams with several sections of perennial flow supported by groundwater discharge. The streams arise in the hills at the western edge of the area and flow east towards the River Murray and Lake Alexandrina. The largest and most notable watercourses in the EMLR WRPA include the Finniss, Angas and Bremer confluences in the south, and Reedy Creek and the Marne River in the north. The WRPA is connected to the River Murray through the Marne River (on rare occasions), and to Lake Alexandrina with the Bremer, Angas and Finniss rivers, and Tookayerta and Currency creeks.

The EMLR WRPA represents important stream habitat in the lower reaches of the MDB. There are many WDEs in the EMLR WRPA, including some of national and international significance (VanLaarhoven & van der Wielen 2012). WDEs are defined as "parts of the environment, the species composition and natural ecological processes of which are determined by the permanent or temporary presence of flowing or standing water" (ANZECC & ARMCANZ 2000). Nearly all the watercourses of the EMLR WRPA support permanent pools, which are scoured sections of stream channel that are maintained year-round by the influx of groundwater. These pools provide a vital refuge for obligate aquatic flora and fauna during the typical annual cease-to-flow period and provide a source for re-colonisation when flows and subsequent stream connectivity returns.

The WDEs of the EMLR have changed substantially since European settlement. The clearance of native vegetation, urban and agricultural development and water resource development have altered natural flow regimes. Water resource development in the EMLR WRPA is primarily in the form of farm dams, and the prevalence of these dams provide a passive barrier to the natural flow regime, delaying the onset of flow downstream before the dam fills and spills. This affects the crucial low flow component of the flow regime as reduced runoff during the dry phase of stream flow inhibits the maintenance of permanent pools, affecting WDEs. These collective impacts have been reflected in the South Australia Environment Protection Authority's Aquatic Ecosystem Condition Reports, with most sites assessed in 2010 and 2015 found to be in either poor or fair condition.

The level of demand for water resources in the EMLR WRPA led to the prescription of the EMLR and Marne Saunders PWRAs. The WAP for the Marne Saunders PWRA was adopted in January 2010 and amended in January 2019 (South Australian Murray–Darling Basin Natural Resources Management Board 2019), and the WAP for the EMLR PWRA was adopted in December 2013 and amended in February 2019 (South Australian Murray–Darling Basin Natural Resource Management Board 2019).

There currently is no held environmental water (HEW) in the WRPA. However, Planned Environmental Water (PEW) is established through a range of principles that limit the take or consumptive use of water in order to support the needs of WDEs. This includes the setting of consumptive use limits for management zones and the requirement to return low flows. As these catchments are managed with PEW, they are considered PEAs under the definition in the Basin Plan (refer to Green 2016). The PEAs in the EMLR WRPA are presented in Table 2–1, and have been consolidated into two overarching assets, i.e. the EMLR and the Marne Saunders PWRAs.

2.2 Aquatic ecosystems

Riverine flows of the EMLR WRPA are seasonal and generally commence in autumn and cease-to-flow in late spring to early-mid summer. The flowing season is location-specific, however, local rainfall and groundwater discharge influence the duration of the flowing season in different areas. Groundwater discharge also supports many permanent pools across the WRPA, typically in 3rd order or higher watercourses.

There is a general north to south gradient of increasing rainfall, which has a direct influence on runoff and flow of the watercourses. The catchments in the northern parts of the WRPA are generally drier and have shorter flowing seasons than those in the southern parts. This also impacts the aquatic flora and fauna supported by WDEs, with more tolerant species generally found in the north, while the more sensitive species are restricted to the south.

The physical habitat of the river systems has been altered due to vegetation clearance and erosion whereby many of the watercourses are incised and lacking significant riparian vegetation. Despite the altered environment, the range of conditions present across the rivers, creeks and streams of the EMLR WRPA support a diverse community of aquatic flora and fauna. Across the area there are 29 native fish species, representing more than half of all native species present in the MDB, and eight exotic species (Whiterod 2018). The EMLR region also supports a diverse macroinvertebrate community with over 400 species, supported by EPA monitoring data from 1994 to 1999. For a full description of the aquatic ecosystems of the EMLR WRPA, refer to the WAPs for the EMLR (South Australian Murray–Darling Basin Natural Resource Management Board 2019) and Marne Saunders (South Australian Murray–Darling Basin Natural Resources Management Board 2019).

There is broad diversity in life history, habitat requirements and sensitivities of the 29 native fish species in the EMLR. In the upper reaches of the region's watercourses, there are more sensitive species, including mountain galaxias, obscure galaxias, southern pygmy perch and river blackfish (Whiterod 2018). The remainder of the species are generally found in the terminal wetlands of the river systems reflecting connectivity with the River Murray and Lower Lakes, and for diadromous species broader connection (achieved through barrage fish passage) to the Murray Estuary and Southern Ocean. The most common and widely distributed fish species in the EMLR WRPA is the introduced eastern gambusia.

2.3 Priority environmental assets (PEAs)

There are numerous PEAs outlined in the LTWP for the EMLR WRPA (DEW 2020a), outlined in (Table 2–1). For reporting purposes, these PEAs have been consolidated into two overarching assets: the EMLR and the Marne Saunders PWRAs. Therefore, the achievement of environmental outcomes and assessment of trend for assets (PEAs) are assessed at the overarching PWRA scale.

Table 2–1. The nested PEAs that are identified in the LTWP for the EMLR and the Marne Saunders PWRAs. Note that the PWRAs serve as the overarching assets used to assess environmental outcomes and trend in this report.

PWRA	PEA
EMLR	Angas River
	Bremer River
	Finniss River
	Reedy Creek
	Tookayerta Creek
	Central Lowlands Group (Angas Plains; Ferries-McDonald; Sandergrove Plains)
	Southern Group (Currency Creek and Deep Creek)
	Northern Group (Bees Knees, Long Gully, Milendella Creek, Preamimma Creek, Long Gully Creek and Salt Creek)
Marne Saunders	Marne River
	Saunders Creek

Figure 2-1. Location and extent of the EMLR WRPA. Stream order describes the hierarchy of streams within a catchment, with higher orders having a greater number of in-feeding streams.

3 Objectives, targets and environmental outcomes

The objectives, targets and EWRs for the EMLR WRPA are identified in the EMLR WAP (South Australian Murray–Darling Basin Natural Resource Management Board 2019) and referred to in the EMLR LTWP (DEW 2020a), presented in Table 3–1. These ecological objectives, targets and EWRs informed the development of environmental outcomes that are to be assessed and evaluated for the purpose of Matter 8 evaluation and reporting. The rationale for the selection of these environmental outcomes and the measures to be used for their assessment are shown in Table 3–2.

The environmental outcomes developed are for two timeframes: short-term (2020–2025) and long-term (2025–2048). The short-term (2020–2025) environmental outcome for flow regime is to be assessed as part of this report, however, the long-term (2025–2048) environmental outcomes for macroinvertebrates and the fish community are not expected to be achieved at the time of this assessment (using data to June 2023). Given the long-term outcomes are beyond this assessment period, and that relevant actions will either continue to be implemented (e.g. water management programs and actions relating to the provision and protection of water for the environment) or altered through the revision of the WAPs, achievement of environmental outcomes is defined as *progress towards* these long-term environmental outcomes.

Table 3–1. Ecological objective, targets and EWRs in the LTWP for the EMLR WRPA.

Ecological objective	Ecological targets	Environmental water requirements
Maintain water-dependent ecosystems at an acceptable level of risk for meeting the overall objective of maintaining/restoring self-sustaining populations of aquatic/riparian flora/fauna that are resilient to drought.	Suitable flow regime	85% of the relevant metrics (listed in Appendix C of the EMLR WAP) are passed in the majority of cases.
	Moderate to good macroinvertebrate community condition.	
	Better-than-marginal recruitment in ≥7 out of 10 years for southern pygmy perch and mountain and obscure galaxias.	

Table 3–2. The environmental outcome indicators, measures and data sources used to assess environmental outcomes for the EMLR and Marne Saunders PWRAs in the EMLR WRPA.

Indicator	Environmental outcome	Outcome timeframe	Measure	Rationale
Flow regime	Maintain or improve the number of flowing days.	2020–2025	Number of flowing days per year.	The number of flowing days was selected out of the suite of EWR metrics as it can assess stream intermittency and changes to the low flow component.

Indicator	Environmental outcome	Outcome timeframe	Measure	Rationale
Macroinvertebrates condition within sampling sites	A condition score of moderate or better, considered ≥3.	2025–2048	Condition scores (range: 1 – 6) in sampled sites in the WRPA.	Macroinvertebrates are one of the best indicators of aquatic ecosystem health and are regularly used as indicators for monitoring programs. The environmental water provisions in the WAPs were developed aiming to deliver “moderate to good macroinvertebrate community condition”.
Fish	Moderate or better community condition, considered ≥3.	2025–2048	Condition scores (range: 0–10) in sampled sites in the WRPA, as in Whiterod et al. (2023).	Fish are one of the key ecological assets in the rivers systems of the EMLR, including several species of conservation concern. The environmental water provisions in the WAPs were developed aiming to deliver moderate or better fish community condition.
	Better-than-marginal recruitment in ≥7 out of 10 years for southern pygmy perch and mountain (and obscure) galaxias.	2025–2048	The presence and evidence of recruitment, as in Whiterod et al. (2023).	Successful recruitment of these indicator species is suggested to infer generally self-sustaining populations of fish across the EMLR.

4 Methods

South Australia's key evaluation questions were designed to align with the MDBA's evaluation questions and their reporting guidelines. Answers to SA's key evaluation questions are intended to contribute to the MDBA's Basin-scale evaluation of the Basin Plan against its objectives.

4.1 Assessment

An evaluation methodology was developed to address each of SA's key evaluation questions, and is underpinned by the following assessments and evaluative processes:

- achievement of environmental outcomes
- trend (as described in section 4.3)
- data and information reliability (as described in section 4.4)
- evaluation of environmental outcomes using expert elicitation supported by available data and information, including the identification of actions to achieve environmental outcomes in the future.

An overview of the method followed to address SA's key evaluation questions is shown in Table 4–2.

Table 4–1. Key evaluation questions used for this assessment and evaluation of environmental outcomes in the EMLR WRPA.

SA key evaluation questions	Evaluation method
To what extent have environmental objectives been achieved at the asset scale?	Progress towards ecological objectives and environmental outcomes were quantitatively assessed and reported for each indicator at the asset scale. The data cut-off point for the environmental outcome assessment for all indicators will be 30 June 2023. Trend and change will be assessed where possible: • All available data will be presented to provide a baseline for assessing and reporting trend. • Change since the 2020 evaluation will be assessed using data collected between July 2019 and June 2023.
If outcomes were not achieved, why not?	Qualitative evaluation of achievement of outcomes will be undertaken using: • Contextual datasets and supplementary information • Expert judgement through a structured elicitation process • Assessment of documented assumptions, limitations and contributing factors for environmental outcomes • Outcomes for 2020 Matter 8 reporting.
To what extent did the Basin Plan contribute to achieving outcomes?	Qualitative evaluation of achievement of outcomes will be undertaken using: • Contextual datasets and supplementary information • Expert judgement through a structured elicitation process • Assessment of documented assumptions, limitations and contributing factors for environmental outcomes

SA key evaluation questions	Evaluation method
	• Outcomes for 2020 Matter 8 reporting The evaluation will comment on the contribution of the Basin Plan and will not attempt to provide an attribution of impact.
Have there been any unanticipated outcomes?	Qualitative evaluation of unanticipated outcomes at the asset scale will be undertaken using a structured expert elicitation process.

4.2 Data sources

There was a variety of data sources used in the outcome assessments. Table 4–2 outlines data sources used for each indicator and provides a reference or link to the appropriate method information. More specific details are provided in each indicator section.

Table 4–2. Summary of data sources and references for the evaluation and assessment of environmental outcomes for the EMLR WRPA.

Indicator	Measure	Data source	Reference/Link
Flow regime	Number of flowing days per year	DEW station data, Landscape Board station data, Water Data SA	Water Data (DEW 2023a)
	Annual rainfall	Bureau of Meteorology	Climate data online (BOM 2023)
Macroinvertebrate condition within sampling sites	Condition scores (range: 1–6) in sampled sites in the WRPA	Flows for the Future	Hydro-ecological monitoring, evaluation and reporting plan for the Flows for the Future Program (Maxwell et al. 2017)
		Angas Finniss Bioblitz and Bremer Bioblitz	Angas River Catchment Bioblitz (Miles et al. 2016)
		Marne Saunders Bioblitz	""
Fish	Condition scores (range: 0 – 10) in sampled sites in the WRPA	Aquasave Condition Model, through annual fish monitoring in the EMLR	Whiterod et al. (2023)
	The presence and evidence of recruitment (of southern pygmy perch and mountain and obscure galaxias)	Aquasave annual fish monitoring in the EMLR	Whiterod et al. (2023)

4.3 Trend assessment

A Bayesian modelling approach was used to assess trend in the time series data. Bayesian modelling calculates a probability distribution of coefficient values which estimate some relationship between a predictor (time step) and an outcome. The median coefficient summarises the slope (trend) describing the relationship, whilst the distribution around this estimate provides uncertainty about the true relationship that exists in the population. Bayesian trend analysis was performed in R Studio (R Core Team 2022) (R Core Team 2024), using Generalised Linear Models and

Mixed Models (using the stan_glm and stan_glmer functions) provide by the "rstanarm" package (Goodrich et al. 2020). All models used 4,000 iterations, four sampling chains, and the default (weakly-informative) priors. Specific details on variable specification are provided in the methods for each indicator. Trend direction (sign of median slope) was assessed using calculated probability (modified from Mastrandrea et al. 2010; as per McBride 2019) using a graduated scale to present results, and align with trend categories used for this report, presented in Table 4–3.

Table 4–3. Alignment of trend outcomes based upon the probability of an increase or decrease (modified from Mastrandrea et al. 2010; as per McBride 2019) with the icons used for the evaluation.

Outcome	Probability (%)	Trend category
Virtually certain increase	>+99 to +100	Improved
Extremely likely increase	>+95 to +99	
Very likely increase	>+90 to +95	
Likely increase	>+66 to +90	
About as likely as not	-66 to +66	Stable
Likely decrease	<-66 to -90	Declined
Very likely decrease	<-90 to -95	
Extremely likely decrease	<-95 to -99	
Virtually certain decrease	<-99 to -100	

This trend outcome is summarised as the following:

- Improved: The indicator is improving over the period of assessment
- Stable: The indicator is neither improving nor declining over the period of assessment
- Declined: The indicator is declining over the period of assessment
- Unknown: Data are not sufficient to determine any trend in the status of this indicator.

4.4 Information reliability

The reliability of data to assess the achievement of environmental outcomes and the progression towards the LTWP objectives were scored based upon the method devised Battisti et al. (2014) with modifications to improve its applicability to Matter 8 reporting. This scoring system assesses questions relating to the method used for data collection, representativeness and repetition (

Table 4–4). A scoring system as shown in

Table 4–4 was used to determine a final score for information reliability that ranges between 0 and 12. Final scores are then converted into an information reliability rating that ranges between poor and excellent using the matrix in Table 4–5.

Table 4–4. Scoring system for the reliability of data used to assess and analyse trend, condition and LTWP targets and environmental outcomes for Matter 8 reporting.

Methods	Question	Scoring system		
		Yes	Partially	No
Methods used	Are the methods used appropriate to gather the information required for evaluation?	2	1	0
Standard methods	Has the same method been used over the sampling program?	2	1	0
Representativeness				
Space	Has sampling been conducted across the spatial extent of the PEA with equal effort?	2	1	0
Time	Has the duration of sampling been sufficient to represent change over the assessment period?	2	1	0
Repetition				
Space	Has sampling been conducted at the same sites over the assessment period?	2	1	0
Time	Has the frequency of sampling been sufficient to represent change over the assessment period?	2	1	0
Overall score		**Out of 12**		

Table 4–5. Conversion of the final score (0-12) of information reliability to a rating that ranges from poor to excellent for Matter 8 reporting.

Final score	Information reliability
12	Excellent
11	Very good
10	Good
9	Fair
≤8	Poor

4.5 Expert elicitation workshops

Relevant subject matter experts attended a half-day workshop for each respective indicator to evaluate and review the preliminary data and findings of the assessments as presented in a workshop paper.

5 Flow regime: Number of flowing days

Trend Improved EMLR PWRA

Trend Declined Marne Saunders PWRA

Reliability Fair

Key findings and messages:

- The environmental outcome for flows (number of flowing days) in the EMLR WRPA was not achieved despite overall improvement in the EMLR PWRA, as most sites in the Marne Saunders declined.
- Since 2019, 85% of gauging sites in the EMLR PWRA had an average number of flowing days equal to or greater than average. Only one site in the Marne Saunders PWRA was above average, and there was several significant cease-to-flow events.
- Patterns of regional precipitation is a key driver for the flow regime of the EMLR; changes in seasonality and declines in long-term rainfall impact the length of flowing season and total stream flow.
- Continued restoration of flow regime is critical, including through solutions to restore low flows whilst minimising the impact on water use and security, through programs such as the Flows for the Future.

5.1 Introduction

The flow regime is a fundamental driver of riverine ecosystems, encompassing the seasonality, timing, frequency, duration, magnitude and rate-of-change of the flow in streams (Poff et al. 1997). These components of the flow regime support various hydro-ecological processes, such as keeping stream pool habitats wet (e.g. low flows), flushing streams to oxygenate flows and improve water quality (freshes), and occasional inundation of riparian and floodplain vegetation (overbank flows) (South Australian Murray–Darling Basin Natural Resource Management Board 2019). The ecological integrity of a freshwater stream is dependent on its the natural and dynamic flow characteristics (Poff et al. 1997).

The watercourses of the EMLR WRPA are predominantly intermittent, although some (e.g. Tookayerta Creek) flow near-perennially in most years due to the influence of groundwater (South Australian Murray–Darling Basin Natural Resource Management Board 2019). Flow intermittency is thus a defining feature of the flow regime in many EMLR streams, and the region supports many permanent pools (persistent water bodies, usually scoured pools) which serve as vital refugia for biota during dry phases and extended droughts. As intermittent streams naturally experience variation in flow, non-flowing (pools) and dry hydrological phases (Datry et al. 2018), maintaining hydrological connectivity involves identifying the ecological requirements for WDEs, prioritising and supporting the critical flow components (VanLaarhoven & van der Wielen 2012), especially when a full restoration of the natural flow regime is not possible (Larned et al. 2010).

Stream flow in the EMLR WRPA generally begins in autumn and ceases-to-flow in early-mid summer, predominantly influenced by rainfall and runoff, but also by groundwater discharge (South Australian Murray–Darling Basin Natural Resource Management Board 2019). There is a general north to south gradient of increasing rainfall in the EMLR WRPA; catchments in the northern sections (e.g. Upper Marne Saunders) are generally drier and have shorter flow seasons compared to the rest of the EMLR. Long-term rainfall data suggests that there have been declines in total annual rainfall (since 1900), and a decline in total stream flow (since 1974) in most localities in the EMLR PWRA (Savadamuthu et al. 2023b). There have also been seasonal shifts in rainfall across the Mount Lofty Ranges since the onset of the Millennium Drought (1996–2010), largely due to declines in springtime precipitation (October), and to a lesser degree autumn rainfall (Savadamuthu & McCullough 2024). As variability in runoff influences stream flow, declines in rainfall will impact the frequency, duration and timing components of flow regimes in the EMLR.

Water resource development impacts the flow and water quality in streams. For example, dams capture and divert surface runoff for commercial and industrial uses, which ultimately impacts the infiltration rate of precipitation into the unsaturated zone and water table. Water diversions across the Mount Lofty Ranges have reduced the volume of flows which would otherwise be returned to the environment when flowing periods reoccur. For example, storage capacity in the Upper Marne Saunders catchment doubled during the 1990s, which impacted the median runoff returning to streams (Savadamuthu 2002). This is an important issue for many streams across the EMLR WRPA due to the level of dam development, as crucial low flows are kept in dams impacting downstream WDEs. In the context of a drying climate, greater water resource development elevates the level of risk to WDEs during drought conditions, and there have been approximately 8,000 dams constructed across the region to date (CSIRO 2007; Whiterod 2018).

5.2 Ecological objectives, targets and environmental outcomes

The ecological objective from the LTWP for the EMLR WRPA is given in Table 5–1. There is no ecological target set for flow regime in the LTWP. However, flow regime has been addressed using various EWRs, set out within the WAPs for both the EMLR PWRA and Marne Saunders PWRA (South Australian Murray–Darling Basin Natural Resource Management Board 2019; South Australian Murray–Darling Basin Natural Resources Management Board 2019). The flow regime required to sustain the natural ecological processes with an acceptable level of risk has been defined with these EWRs (South Australian Murray–Darling Basin Natural Resource Management Board 2019). Therefore, to assess an environmental outcome for flow regime, the suite of EWRs were considered.

Table 5–1. Ecological objective for flow regime in the LTWP for the EMLR WRPA.

Ecological objective
Maintain water-dependent ecosystems at an acceptable level of risk for meeting the overall objective of maintaining/restoring self-sustaining populations of aquatic/riparian flora/fauna that are resilient to drought.

5.2.1 Environmental water requirements (EWRs)

The 56 EWR metrics developed for the EMLR and Marne Saunders WAPs cover all aspects of the flow regime and have multiple metrics that address the number of flowing days (South Australian Murray–Darling Basin Natural Resource Management Board 2019; South Australian Murray–Darling Basin Natural Resources Management Board 2019; VanLaarhoven & van der Wielen 2009). Further development of the EWRs has consolidated the number of metrics (Green & Savadamathu 2024, in Review), mainly because there is a high amount of correlation between metrics in the same flow season (Maxwell et al. 2015).

5.2.2 Environmental outcome

As the EWRs from the WAPs are referenced within the LTWP for the EMLR WRPA, a single and simplified metric was used to assess the environmental outcome (Table 5–2) for flow regime. The number of flowing days has been previously used to characterise the flow regime in the context of drought periods and changes to rainfall and runoff (Savadamuthu et al. 2023a); therefore, the number of flowing days was considered sufficient to i) assess progress towards the ecological objective (Table 5–1), ii) detect changes to the low flow component of the flow regime, and iii) assess the variability in stream intermittency.

Table 5–2. The environmental outcome for flow regime in the EMLR WRPA.

Environmental outcome	Outcome timeframe
Maintain or improve the number of flowing days	2020–2025

5.3 Method

5.3.1 Flow datasets

Flow data was sourced from 61 sites with installed flow gauges in the EMLR WRPA (Figure 5-1). A QA/QC process was followed to check whether data from the flow gauges were suitable for inclusion in the environmental outcome assessment. Any data that was identified as missing or interpolated data (i.e., with a code less than 1) was discarded. Sites with insufficient data (28 sites), issues with data collection (two sites) or excessive zeros (one site) were completely excluded from the outcome assessment, with a total of 30 sites (27 sites in the EMLR PWRA; 6 sites in the Marne Saunders PWRA) remaining used in the assessment. The data completeness of the remaining sites was then checked, with any year with less than 95% of a complete record removed to ensure that missing data was not interpreted as non-flowing days. Note that most sites had two to three months of unverified data at the end of the sourced dataset (i.e., April–June 2023). This unverified data was still used in the assessment, considering flow gauges are regularly checked and therefore, the risk around using this data was negligible.

All flow data was extracted from Water Data SA, except for data from the Marne River at Marne Gorge site (A4260605). The Marne Gorge site was upgraded in the late 2000s and the new gauge (A4260605) has data from 2008 onwards. The Water Science and Monitoring Branch of DEW have developed a linked dataset for this gauge that combines the data from the old gauge (A4260529) with the new gauge data.

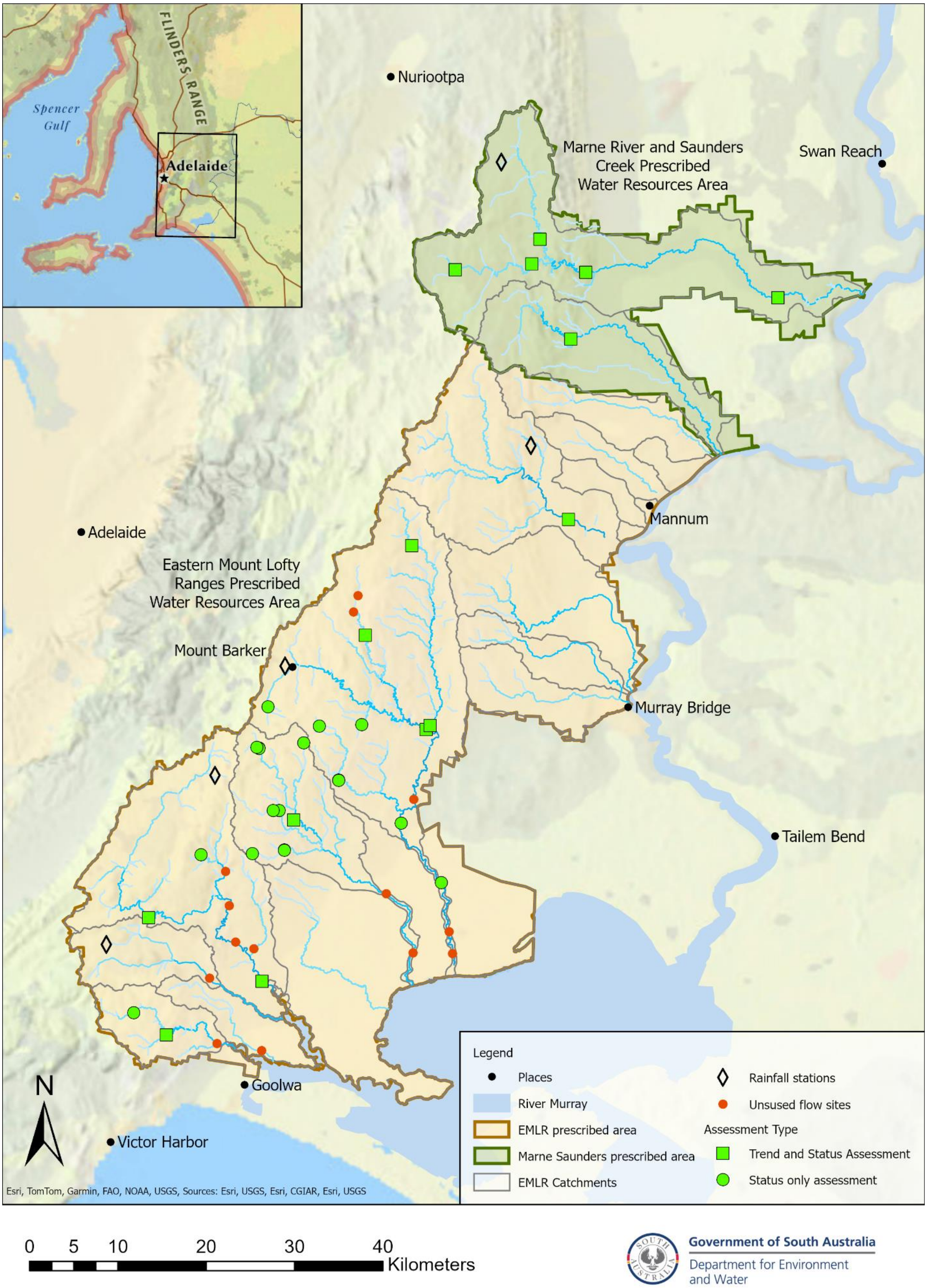

Figure 5-1. Study map of the stream gauges and rainfall monitoring stations used in flow regime assessment for the EMLR WRPA. Light blue lines represent major streams in the area and black lines are the boundaries of water catchments shown in Table 2–1 and Figure 2-1.

5.3.2 Supplementary datasets

The following long-term (1900–2023) rainfall data (Bureau of Meteorology; http://www.bom.gov.au/climate/data/) were used to support the assessment to the environmental outcome for flow regime, in the context of a changing climate:

- Four monitoring stations in the EMLR PWRA in Mount Barker (23733), Palmer (24525), Meadows (23730), and Mount Compass (23735).
- One monitoring station in the Marne Saunders PWRA in Keyneton (23725).

5.3.3 Trend assessment

The analysis was undertaken as per section 4.3 using a Bayesian Generalised Linear Mixed Model. Sites used in trend assessment were required to have a minimum of 7 years of data. All of these sites (15; 9 for the EMLR PWRA; 6 for the Marne Saunders PWRA) had monitoring data before 2016 and data after 2020. Trend was assessed based on the proportion of days with flow recorded at each gauging site per year, using a beta distribution (logit link). Time step was included as a fixed effect, with site used as a random (intercept) factor. Models were performed for both PWRA regions, noting that the limitation in spatial representativeness of catchments (see section 5.3.5). The model specification was:

Proportion of flowing days ~ time step * region + (1|site)

5.3.4 Information reliability

Information reliability was assessed as part of the expert elicitation workshop following the methods outlined in section 4.4.

5.3.5 Limitations of assessment

A limitation with this assessment is that not all major sub-catchments have flow data. Although the EMLR is relatively well gauged compared to some other regions around South Australia, the lack of data from all major sub-catchments means that the assessment needs to consider possible localised effects that may not be accounted for when considering regional results.

Flow monitoring stations are regularly visited and calibrated to ensure that the data is as accurate as possible but uncertainties exist for several reasons including:

1) The uncertainty in measuring low flows (especially on broad crested weir or natural rock bars compared to a v-notch/crump weirs).
2) The degree of validation achieved on the rating curve against actual flows measured in the field.

One of the characteristics of the EMLR WRPA is the localised and often strong influence of groundwater on the surface flows. Therefore, it is understood that the flow observed at a given gauging location may not be representative of the flow conditions of a stream across its reaches. For example, gauges are assumed to represent local flow conditions in the catchment, but there are groundwater inputs within reaches that can support significant biotic communities such as riffle sensitive macroinvertebrates and/or diatoms that may persist where flow gauges indicate zero flow. Additionally, groundwater inputs may vary flow rates in some reaches independent of changes to flow rates upstream. Therefore, no direct comparisons (e.g. collective averages) between flow stations can be made.

This assessment assumes that maintaining the number of flowing days will lead to biotic outcomes for macroinvertebrate and fish communities (among others). A limitation of this metric is that it only considers days that the system is flowing and does not consider if these days are consecutive or not. While there are some processes that require number of days of flow (i.e. water quality management), there are others where stop-start flows may be problematic (e.g. dispersal or breeding triggers). While it is possible to undertake an assessment of both, previous work has identified that all low flow metrics are highly correlated with each other (Maxwell et al. 2015). Based on the assessment undertaken by Maxwell et al. (2015), the total number of flowing days was the selected metric due to the high correlation between the number of flowing days and the number of consecutive flowing days.

5.4 Results

5.4.1 Environmental outcome assessment

The environmental outcome of the number of flowing days for the EMLR WRPA was considered not to have been achieved, as most assessment sites in the EMLR PWRA have remained stable or improved since July 1999 (Figure 5-2; Figure 5-3; Figure 5-4; **Figure** 5-5; Table 5–3), while most sites in the Marne Saunders PWRA have not remained stable or improved (Figure 5-6; Table 5–4).

EMLR PWRA

In general, the variable start date for sites in the EMLR PWRA, as well as years of insufficient data, make the interpretation of the changes in the number of flow days difficult. However, there was a notable reduction in the proportion of EMLR PWRA sites meeting or exceeding their average over the period from 2007 to 2010 (associated with the Millennium Drought), as well as during some notable drier years (i.e. 2015–16 and 2018–19) during the assessment period (Table 5–3).

Most gauging sites (all upper catchment sites) for the Angas River have maintained or improved the number of flowing days over the assessment period, including since 2018–19 (Figure 5-2). Similarly, sites in upper reaches and creeks for the Bremer River have also maintained or improved the number of flowing days, apart from one site (A4261402) with no flows on record (Figure 5-3). One site (A4260558, Dawsons Creek) in the upper reaches for the Bremer River and one site (A4260688, Bremer River) in the middle reaches for the Bremer River have experienced a decline in the rolling average of the number of flowing days, although both sites are currently at their average for the assessment period (Figure 5-3). One site (A4260679; Mount Barker Creek) upstream of Bremer River confluence has had perennial flow since 2008–09 (Figure 5-3). Similarly, one upper catchment site (A4260504) for the Finniss River has had permanent flow since 2009–10, and another upper catchment site (A4261269) since 2016–17 (Figure 5-4). The lower catchment monitoring station for the Finniss River has also seen perennial flow since 2016–17 (Figure 5-4). One site (A4260530) in the middle catchment area for Currency Creek has had near-perennial flow since 2010–11, while the other upper catchment site is currently above the assessment average but largely lacks data in intervening years (Figure 5-4). Data available from one site in Reedy Creek indicates there has been some natural variability in the number of flowing days, but has largely remained close to the assessment period average (**Figure** 5-5).

Since 2018–19, and based on monitoring data present here, 90% of sites for the Angas River have had an average number of flowing days which has equaled or exceeded the site-specific assessment period average. Approximately 73% of monitoring sites for the Bremer River have equaled or exceeded the assessment period average. All sites in Currency Creek (two sites), Finniss River (three sites) and Reedy Creek (one site) have met or exceeded their assessment period average. Approximately 85% of gauging sites in the EMLR PWRA presented here have had an average number of flowing days which has equaled or exceeded the site-specific assessment period average.

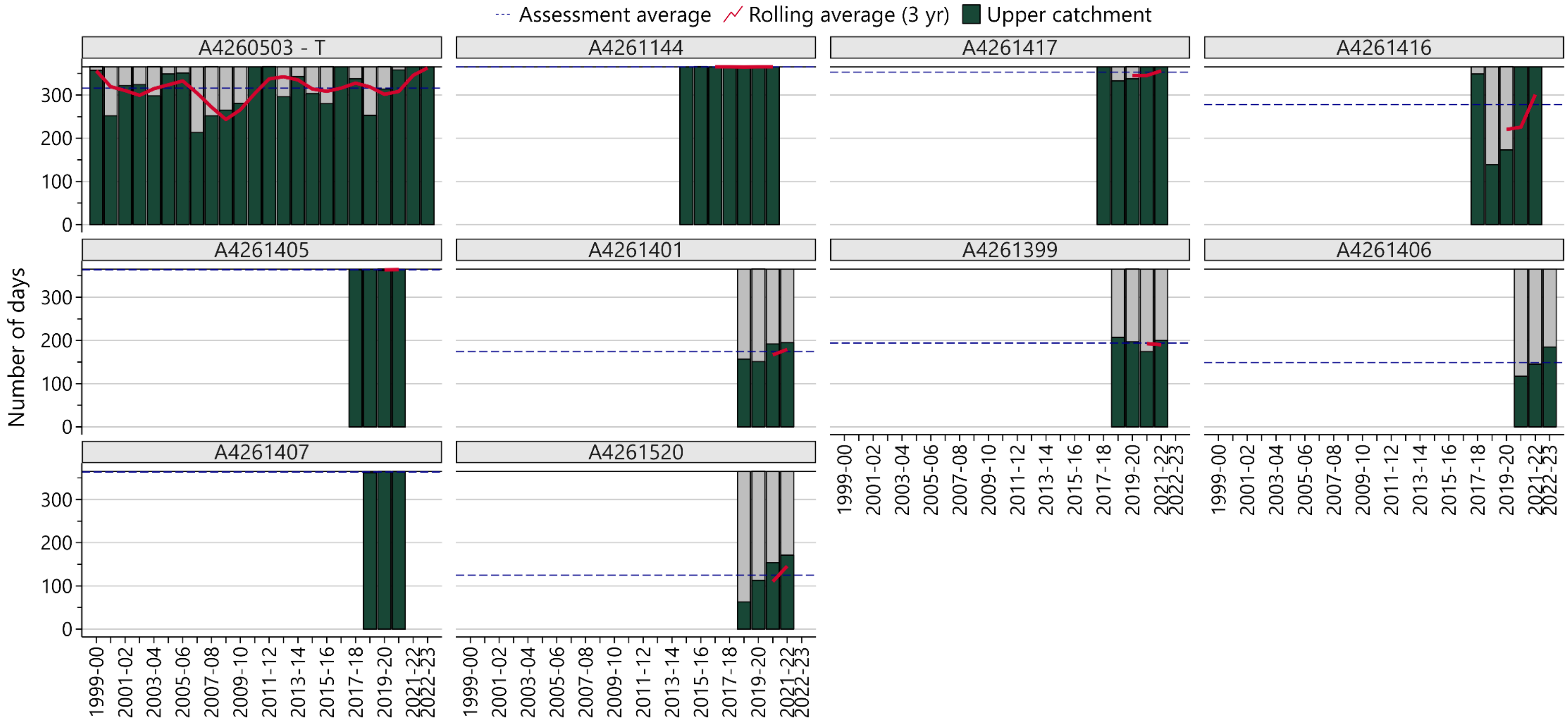

Figure 5-2. The number of flowing days observed at ten monitoring sites for the Angas River in the EMLR PWRA during the assessment period (July 1999 – June 2023). Data for each site are referenced to their position (upper, middle or lower) in the catchment, the three-year rolling average (if available; red line) and overall assessment period average (dashed blue line). The letter "T" in site labels indicates that the site was used in the trend assessment.

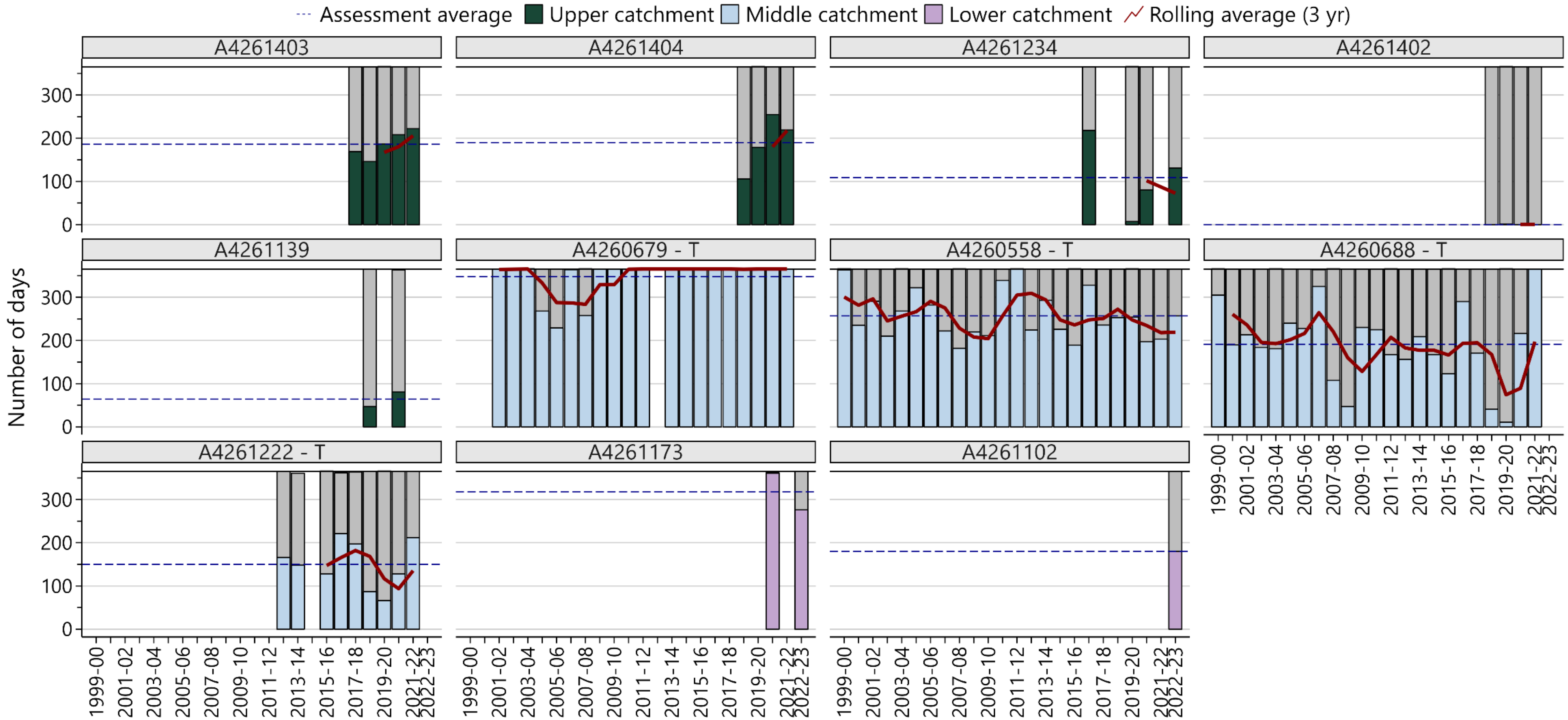

Figure 5-3. The number of flowing days observed at eleven monitoring sites for the Bremer River in the EMLR PWRA during the assessment period (July 1999 – June 2023). Data for each site are referenced to their position (upper, middle or lower) in the catchment, the three-year rolling average (if available; red line) and overall assessment period average (dashed blue line). The letter "T" in site labels indicates that the site was used in the trend assessment.

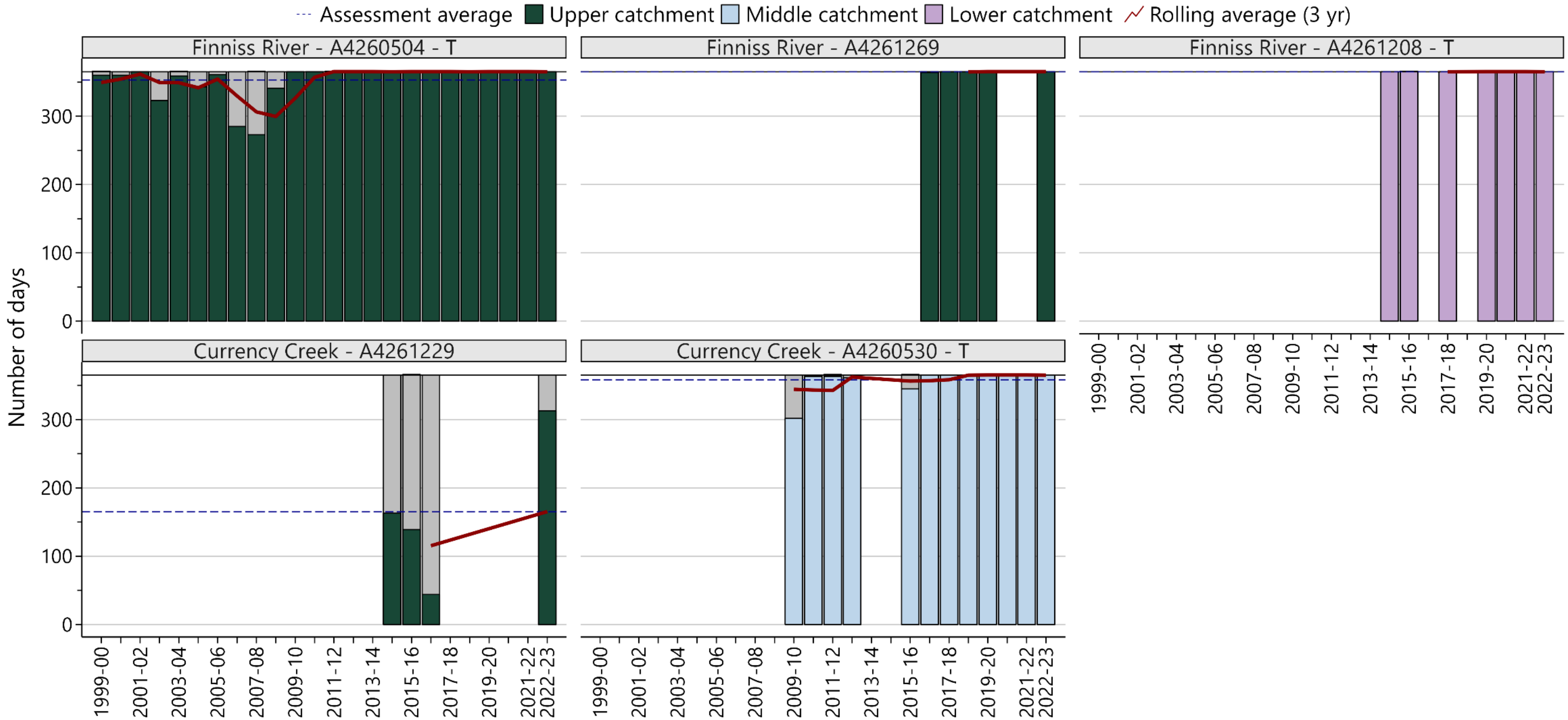

Figure 5-4. The number of flowing days observed at three and two monitoring sites for the Finniss River and Currency Creek, respectively, in the EMLR PWRA during the assessment period (July 1999 – June 2023). Data for each site are referenced to their position (upper, middle or lower) in the catchment, the three-year rolling average (if available; red line) and overall assessment period average (dashed blue line). The letter "T" in site labels indicates that the site was used in the trend assessment.

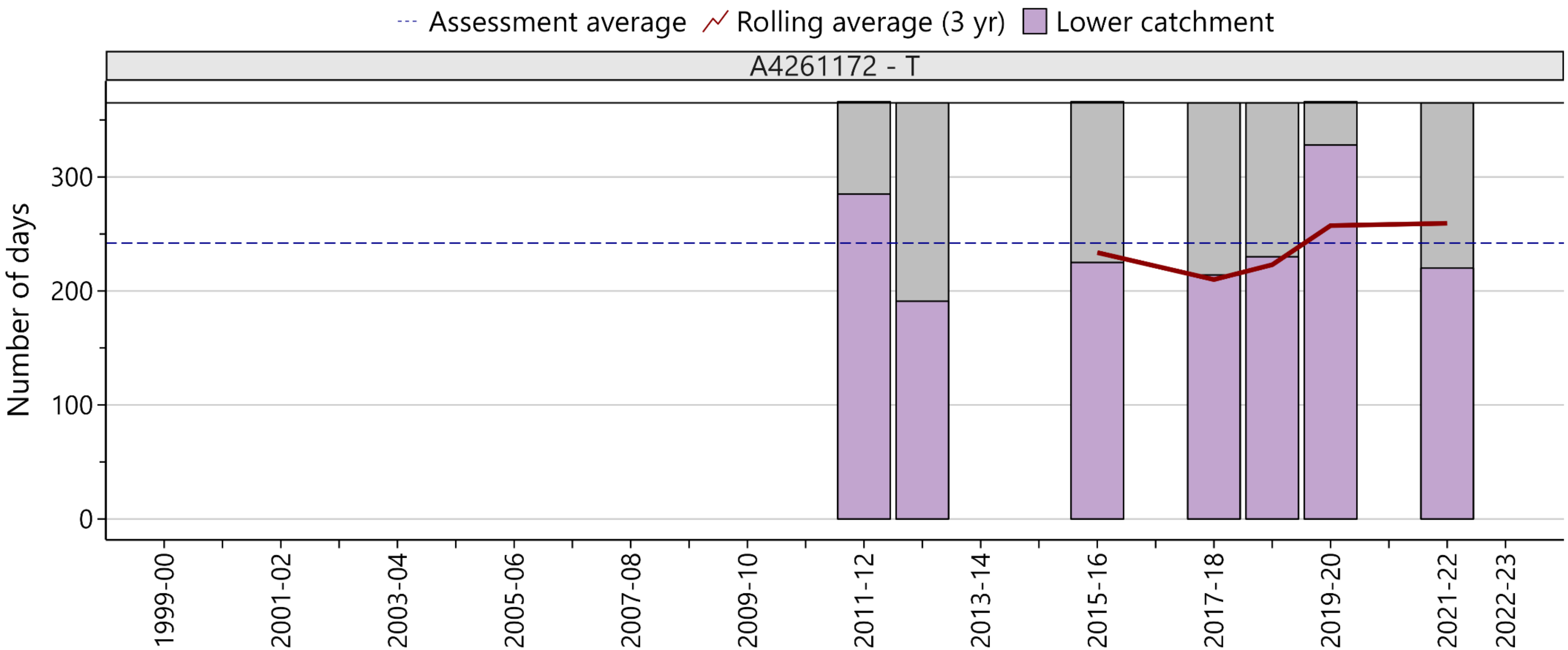

Figure 5-5. The number of flowing days observed at one monitoring site for Reedy Creek in the EMLR PWRA during the assessment period (July 1999 – June 2023). Data for each site are referenced to their position (upper, middle or lower) in the catchment, the three-year rolling average (if available; red line) and overall assessment period average (dashed blue line). The letter "T" in site labels indicates that the site was used in the trend assessment.

Table 5–3. Deviation from the average (2000–2023) number of flowing days per water year (July – June) for sites in the EMLR PWRA. Green represents years above the assessment period average, light red denotes below this average, and blue represents no change. Dark red shows years with complete cease-to-flow (zero days).

						Last assessment period																				Current assessment period			
Site	**Stream**	**PWRA**	**Long-term average**	**Average (2000–23)**	**C.V**	**1999–00**	**2000–01**	**2001–02**	**2002–03**	**2003–04**	**2004–05**	**2005–06**	**2006–07**	**2007–08**	**2008–09**	**2009–10**	**2010–11**	**2011–12**	**2012–13**	**2013–14**	**2014–15**	**2015–16**	**2016–17**	**2017–18**	**2018–19**	**2019–20**	**2020–21**	**2021–22**	**2022–23**
A4260503	Angas River	EMLR	225	316	0.145	41	-64	6	8	-18	33	35	-103	-64	-51	-35	49	50	-20	27	-13	-36	49	22	-63	-2	42	49	49
A4260504	Finniss River	EMLR	356	353	0.071	7	7	12	-30	6	-10	8	-68	-80	-12	12	12	13	12	12	12	13	12	12	12	13	12	12	12
A4260530	Southern Cluster	EMLR	362	358	0.051											-56	6	6	4			-12	8	8	8	9	8	8	8
A4260558	Bremer River	EMLR	270	257	0.213	106	-22	34	-47	11	65	25	-35	-75	-37	-46	82	108	-33	36	-31	-68	71	-21	-4	-3	-60	-54	0
A4260679	Bremer River	EMLR	350	348	0.121			17	17	18	-80	-119	16	-90	17	17	17	18		17	17	18	17	17	17	18	17	17	
A4260688	Bremer River	EMLR	195	191	0.459	114	-1	22	-7	-10	49	37	134	-83	-144	39	34	-24	-35	18	-24	-68	99	-20	-150	-180	25	174	
A4261102	Bremer River	EMLR		180	NA																								0
A4261139	Bremer River	EMLR		64	0.376																				-17		17		
A4261144	Angas River	EMLR		365	0.001																0	1	0	0	0	1	0		
A4261172	Reedy Creek	EMLR		242	0.196													43	-51			-17		-28	-12	86		-22	
A4261173	Bremer River	EMLR		318	0.189																						42		-42
A4261208	Finniss River	EMLR		365	0.001																0	0		0		1	0	0	0
A4261222	Bremer River	EMLR		150	0.359														16	-2		-22	71	47	-63	-84	-22	62	
A4261229	Southern Cluster	EMLR		165	0.676																-2	-26	-121						148
A4261234	Bremer River	EMLR		109	0.814																		109			-102	-29		22
A4261269	Finniss River	EMLR		365	0.002																		-1	0	0	1			0
A4261399	Angas River	EMLR		194	0.073																				12	2	-20	6	
A4261401	Angas River	EMLR		174	0.132																				-17	-23	18	21	
A4261402	Bremer River	EMLR		0	2																				0	1	0	0	
A4261403	Bremer River	EMLR		186	0.162																			-17	-40	1	22	36	
A4261404	Bremer River	EMLR		190	0.337																				-84	-11	65	29	
A4261405	Angas River	EMLR		364	0.004																			0	1	-2	1		
A4261406	Angas River	EMLR		149	0.229																						-32	-4	36
A4261407	Angas River	EMLR		364	0.005																				-2	1	1		
A4261416	Angas River	EMLR		278	0.404																			71	-139	-105	87	87	
A4261417	Angas River	EMLR		353	0.046																			12	-20	-15	12	12	
A4261520	Angas River	EMLR		125	0.384																				-62	-12	29	46	
Proportion of sites ≥ assessment period average						**1.0**	**0.25**	**1.0**	**0.4**	**0.6**	**0.6**	**0.8**	**0.4**	**0**	**0.2**	**0.5**	**1.0**	**0.86**	**0.43**	**0.83**	**0.5**	**0.36**	**0.82**	**0.73**	**0.33**	**0.5**	**0.74**	**0.78**	**0.91**
Total sites						**4**	**4**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**6**	**6**	**7**	**7**	**6**	**8**	**11**	**11**	**15**	**21**	**22**	**23**	**18**	**11**

Marne Saunders PWRA

There was a low proportion of monitoring sites during the Millenium Drought between 2006–07 and 2008–09 where the number of flowing days was equal to or exceeded the assessment period average (Table 5–4), likely due to drier-than-average conditions (Figure 5-7). Between 2015–16 and 2018–19, there were some notable cease-to-flow events, especially in 2018–19 where no sites maintained or improved the number of flowing days (Table 5–4).

One site (A4261233) in the upper catchment area of the Marne River has seen an improvement in the number of flowing days (Figure 5-6). By contrast, the three monitoring sites in the middle catchment reaches of the Marne River have experienced a general decline in the number of flowing days, supported by a three-year rolling average (Figure 5-6). One site (A4261011) in the lower catchment section of the Marne River has maintained its average number of flowing days (4 days, 2002–03 to 2021–22), but has experienced a complete cease-to-flow since 2011–12 (Figure 5-6), 38 days after a wet period in 2010–11 (see Figure 5-7). The one gauging site for Saunders Creek (middle catchment) has experienced a similar decline in the number of flowing days over the assessment period as the middle-catchment sites for the Marne River (Figure 5-6).

Since 2018–19, only one site (A4261233) in the Marne River has had an average number of flowing days which has equaled or exceeded the site-specific assessment period average.

It is important to note that the average number of flowing days for sites in the Marne Saunders PWRA may not be reflective of the natural and historical flow regime (see long-term average in Table 5–4).

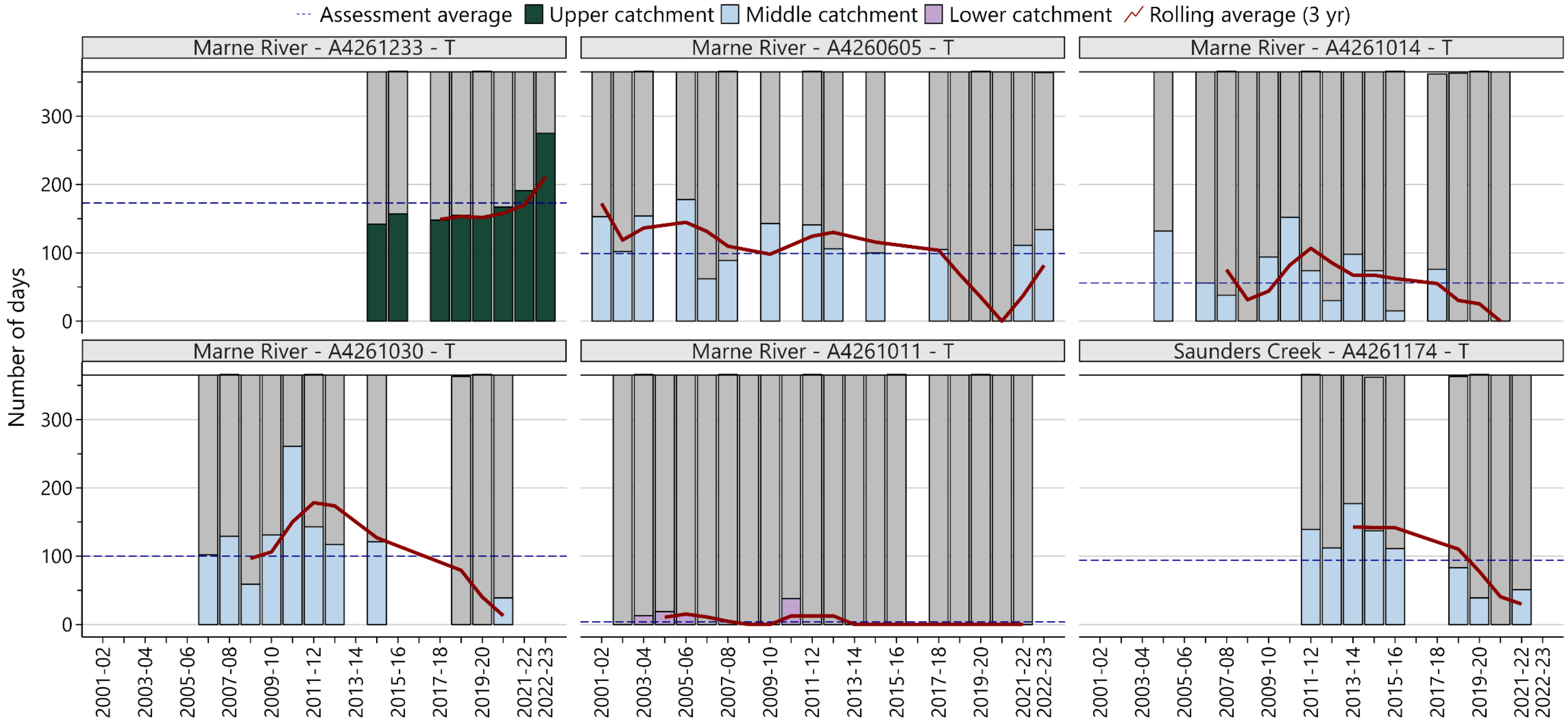

Figure 5-6. The number of flowing days observed at five and one monitoring site(s) for the Marne River and Sanders Creek, respectively, in the Marne Saunders PWRA during the assessment period (July 1999–June 2023). Data for each site are referenced to their position (upper, middle or lower) in the catchment, the three-year rolling average (if available; red line) and overall assessment period average (dashed blue line). The letter “T” in site labels indicates that the site was used in the trend assessment.

Table 5–4. **Deviation from the average (2000–2023) number of flowing days per water year (July–June) for sites in the Marne Saunders PWRA. Green represents years above the assessment period average, light red denotes below this average, and blue represents no change. Dark red shows years with complete cease-to-flow (zero days). Contextual data:**

						Last assessment period																		Current assessment period			
Site	**Stream**	**PWRA**	**Long-term average**	**Average (2000–23)**	**C.V**	**2001–02**	**2002–03**	**2003–04**	**2004–05**	**2005–06**	**2006–07**	**2007–08**	**2008–09**	**2009–10**	**2010–11**	**2011–12**	**2012–13**	**2013–14**	**2014–15**	**2015–16**	**2016–17**	**2017–18**	**2018–19**	**2019–20**	**2020–21**	**2021–22**	**2022–23**
A4260605	Marne River	MS	201	99	0.575	54	3	55		79	-37	-10		44		42	7		1			6	-99	-99	-99	12	35
A4261011	Marne River	MS		4	2.261		-4	9	15	10	-4	-4	-4	-4	34	-4	-4	-4	-4	-4		-4	-4	-4	-4	-4	
A4261014	Marne River	MS		56	0.887				76		0	-18	-56	38	96	18	-26	42	18	-41		20	-56	-56	-56		
A4261030	Marne River	MS		100	0.745						2	29	-41	31	161	43	17		21				-100	-100	-61		
A4261174	Saunders Creek	MS		94	0.595											45	18	83	43	17			-11	-55	-94	-43	
A4261233	Marne River	MS		173	0.252														-31	-16		-25	-18	-21	-6	18	102
Proportion of sites ≥ assessment period average						**1.0**	**0.5**	**1.0**	**1.0**	**1.0**	**0.5**	**0.25**	**0.0**	**0.75**	**1.0**	**0.8**	**0.6**	**0.67**	**0.67**	**0.25**	**N/A**	**0.5**	**0.0**	**0.0**	**0.0**	**0.5**	**1.0**
Total number of MS sites						**1**	**2**	**2**	**2**	**2**	**4**	**4**	**3**	**4**	**3**	**5**	**5**	**3**	**6**	**4**	**0**	**4**	**6**	**6**	**6**	**4**	**2**

5.4.2 Influence of rainfall

Annual precipitation during the assessment period in the Marne Saunders upper headwaters has mostly been below the long-term rainfall average, especially evident during drier years such as during the Millennium Drought, 2018–19 and 2019–20 (Figure 5-7). Similarly, rainfall across the EMLR PWRA also shows a long-term decline in total annual rainfall recorded at most stations, besides Palmer (Figure 5-8; Figure 5-9; Figure 5-10; Figure 5-11). During the assessment period, most water years were below the station-specific long-term average in annual rainfall, supported by the 10-year rolling averages.

For context, it should be noted that while the total amount of rainfall is important, the distribution and intensity of rainfall across the year has the most influence on the number of flowing days, and local climate is dependent on changes to the seasonality of rainfall (see section 5.5.1).

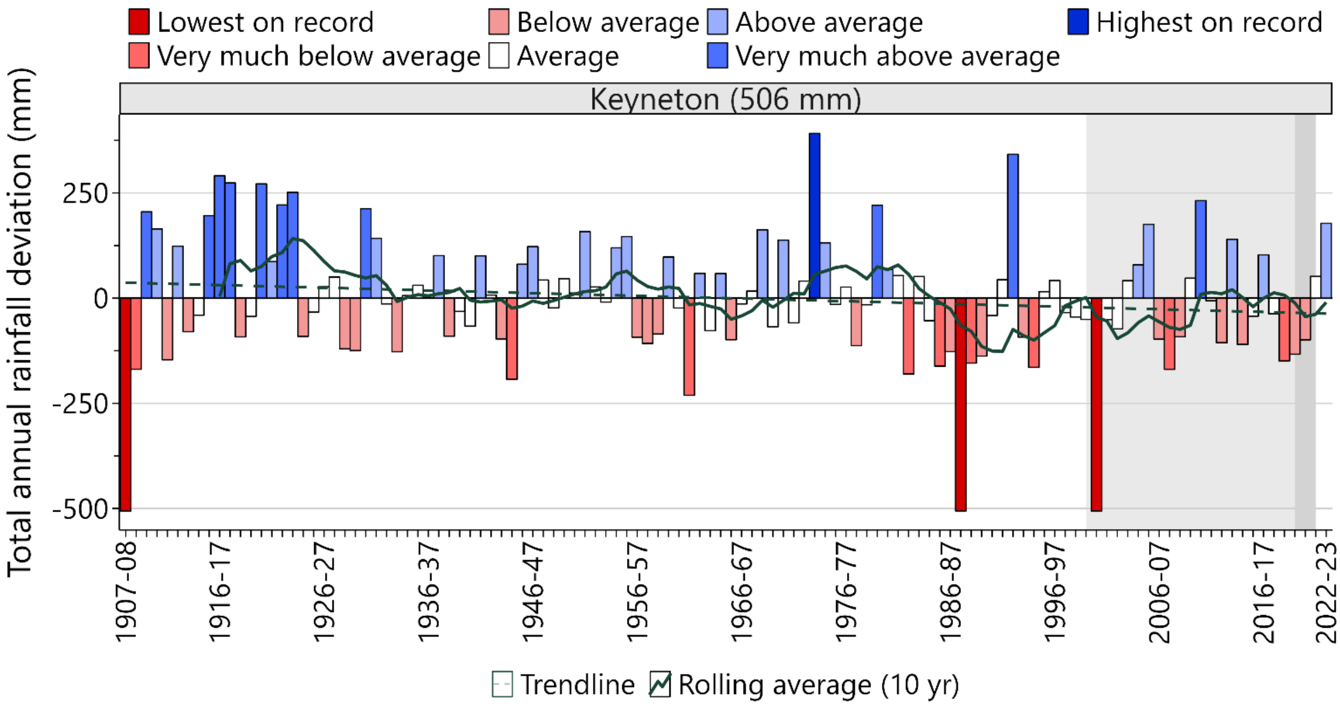

Figure 5-7. Long-term rainfall patterns (deviation from the average: 1907–08 to 2022–23) from the Keyneton station (23725) in the Marne Saunders PWRA. Data sourced from BOM (2023).

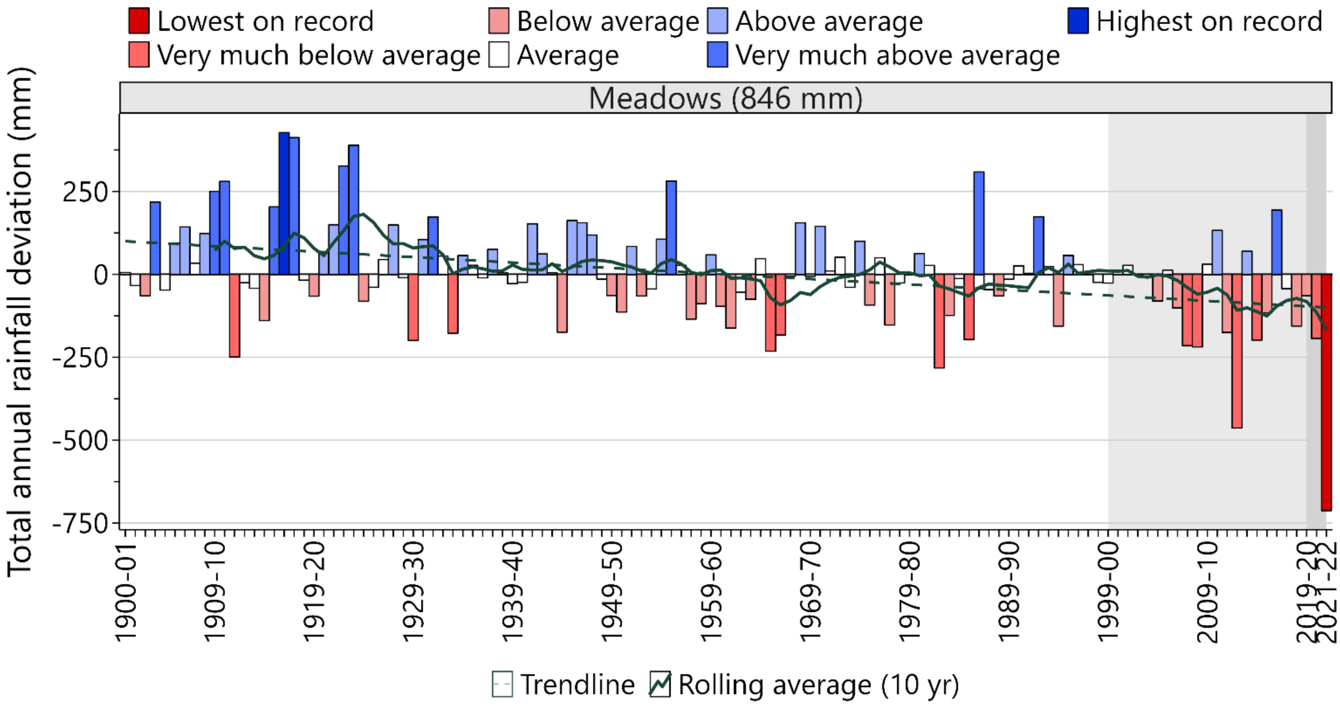

Figure 5-8. Long-term rainfall patterns (deviation from the average: since 1900-01) from the Meadows (Finniss River) station (23730) in the EMLR PWRA. Data sourced from BOM (2023).

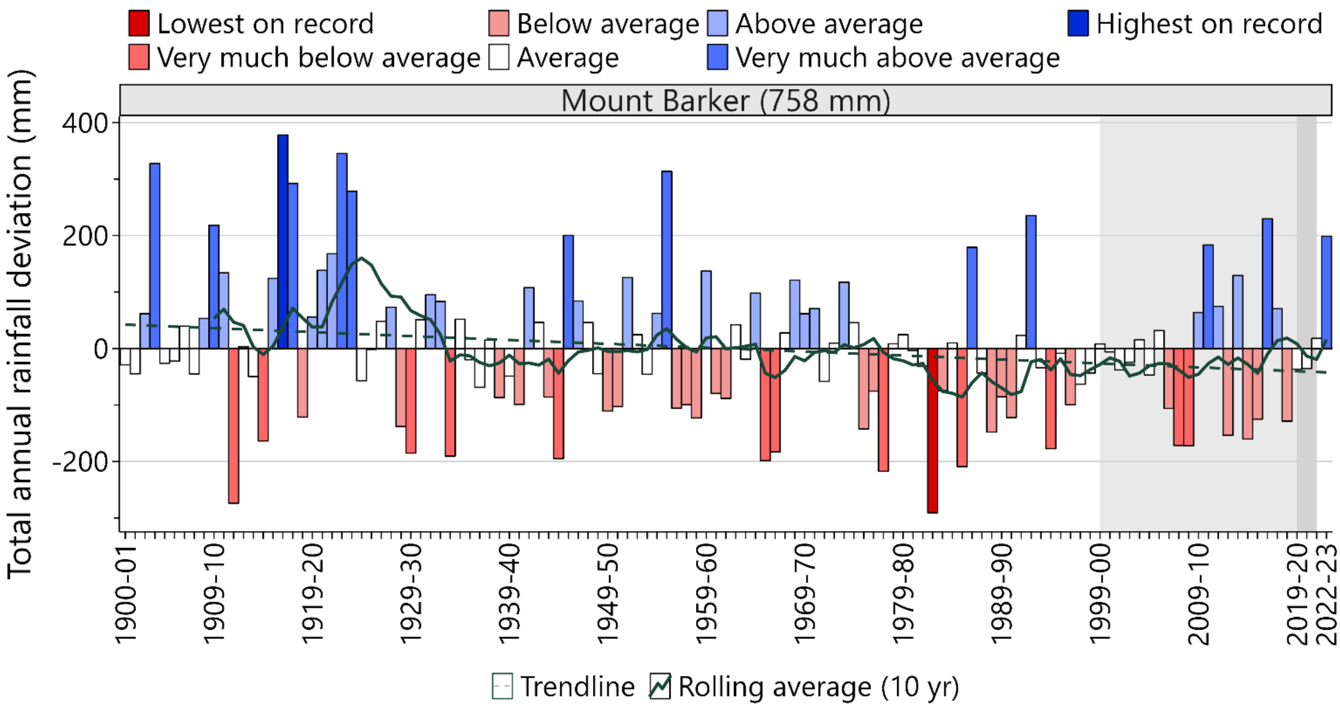

Figure 5-9. Long-term rainfall patterns (deviation from the average: since 1900–01) from the Mount Barker (Bremer River) station (23733) in the EMLR PWRA. Data sourced from BOM (2023).

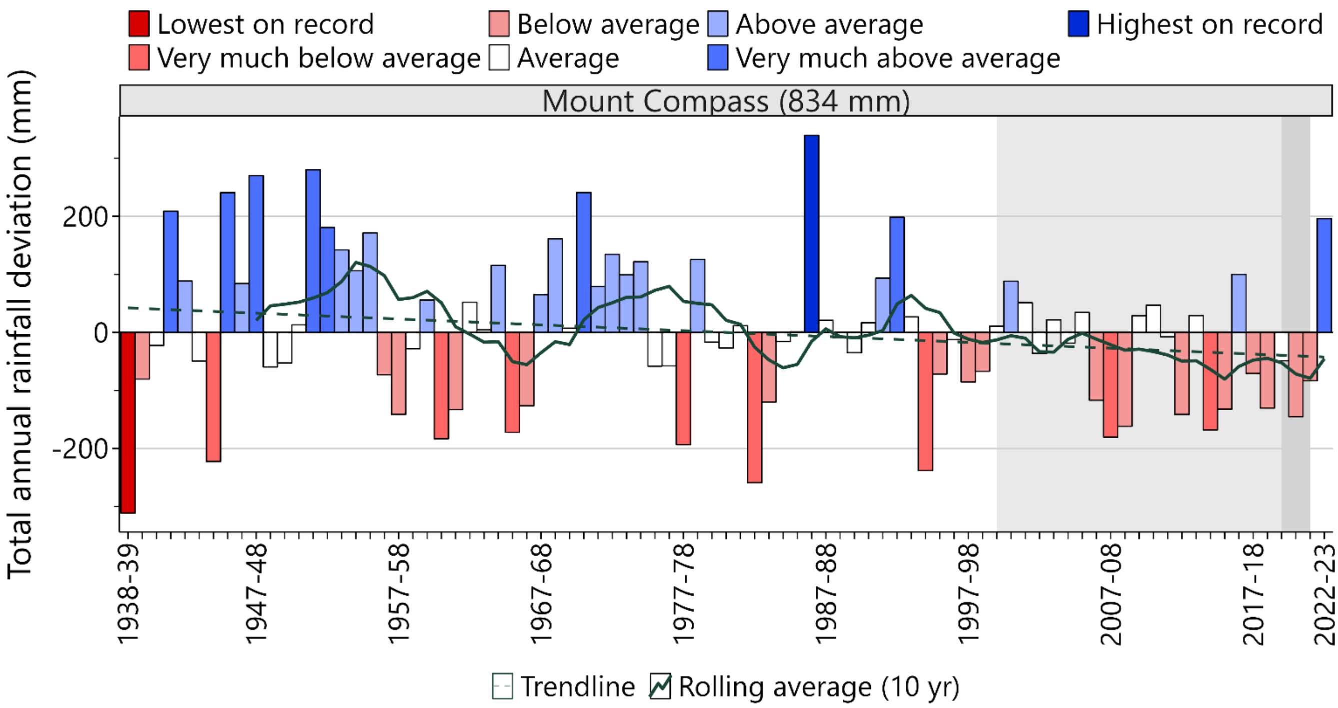

Figure 5-10. Long-term rainfall patterns (deviation from the average: since 1938-39) from the Mount Compass (Tookayerta Creek) station (23735) in the EMLR PWRA. Data sourced from BOM (2023).

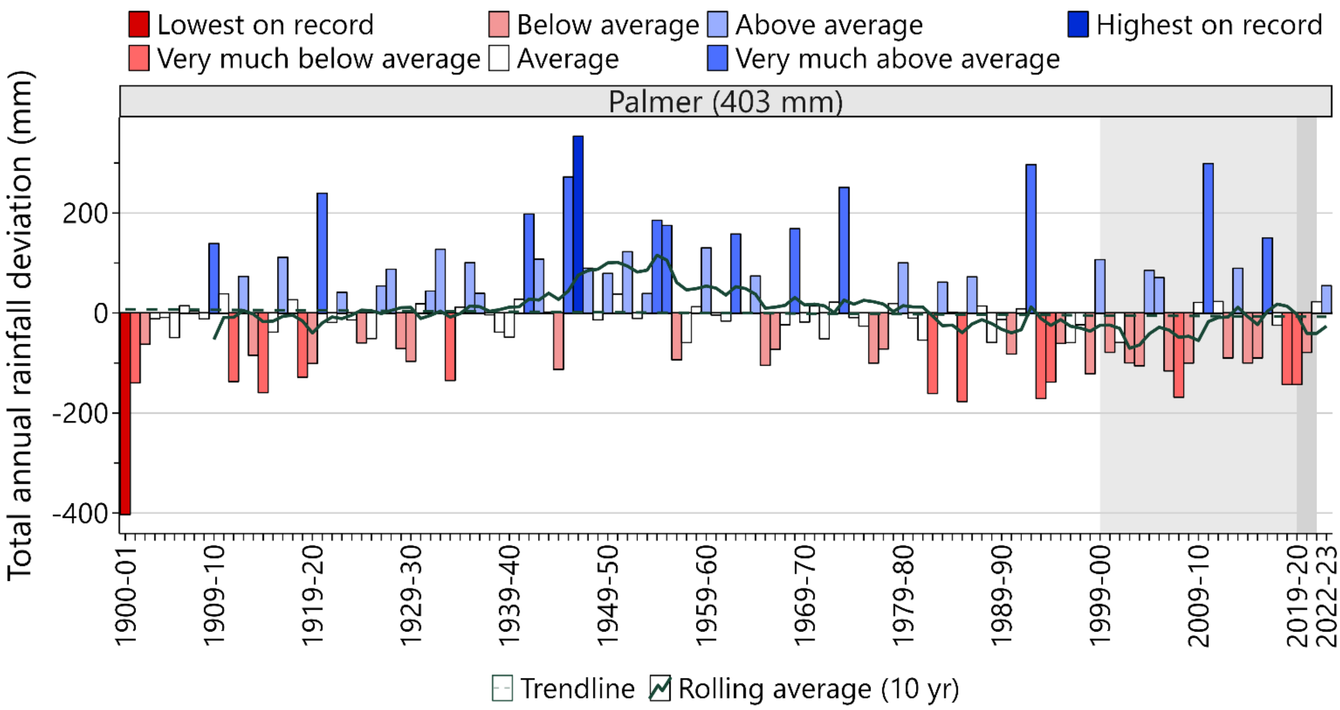

Figure 5-11. Long-term rainfall patterns (deviation from the average: since 1900-01) from the Palmer (Reedy Creek) station (24525) in the EMLR PWRA. Data sourced from BOM (2023).

5.4.3 Trend assessment

The number of flowing days across 13 sites in the EMLR PWRA was virtually certain (100% probability) to have **improved** (median slope, 0.037) (Figure 5-12). By contrast, the number of flowing days across 5 sites in the Marne Saunders PWRA is virtually certain (100% probability) to have **declined** (median slope, -0.116) (Figure 5-13). Note that while the assessment period is from 2000–2023, not all sites were assessed from 2000 and individual site commencement varied between 2000 to 2013.

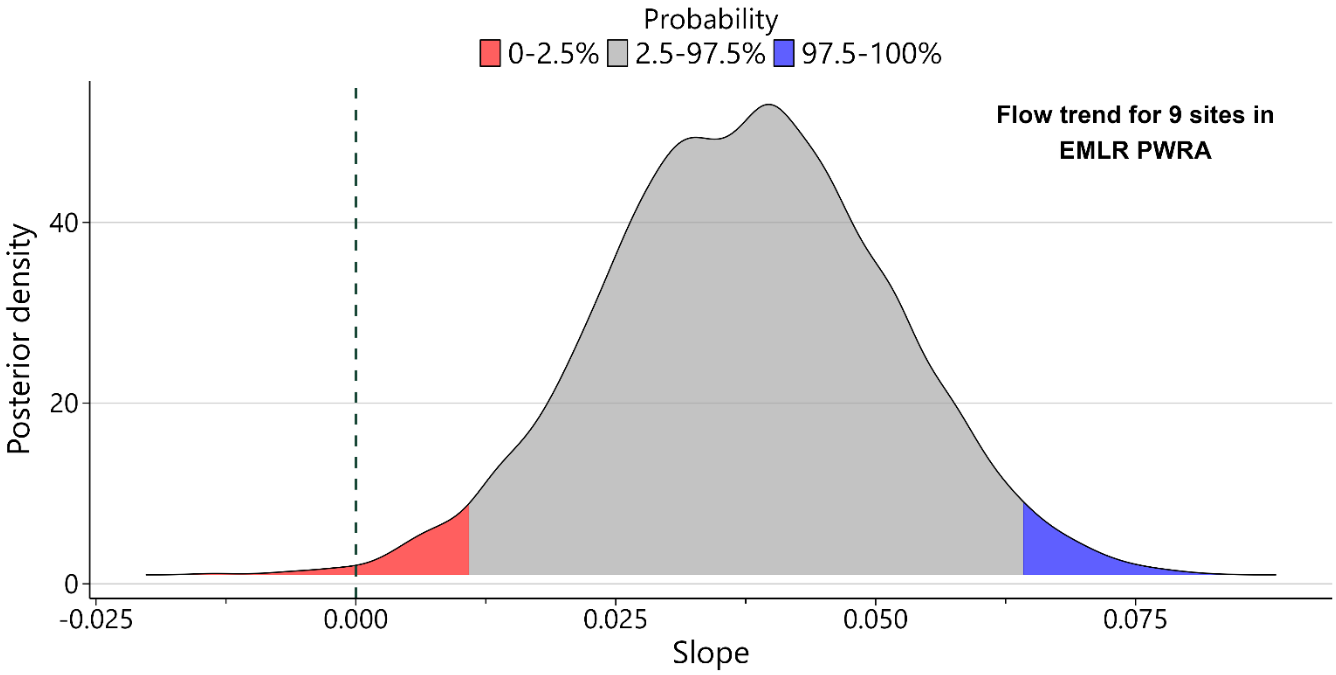

Figure 5-12. Estimated values for the slope generated from Bayesian modelling the number of flowing days for 9 sites in the EMLR PWRA. Posterior slope values >0 infer a positive trend (improved) and values <0 infer a negative trend (declined).

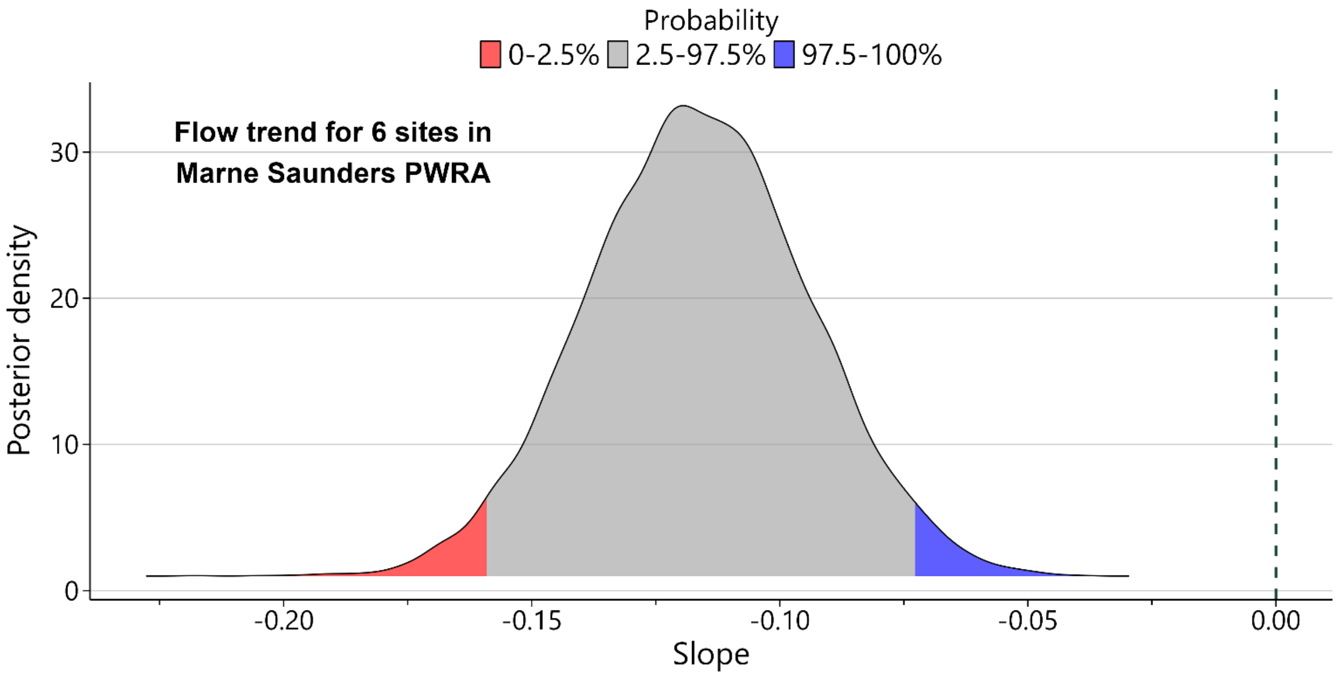

Figure 5-13. Estimated values for the slope generated from Bayesian modelling the number of flowing days for 6 sites in the in the Marne Saunders PWRA. Posterior slope values >0 infer a positive trend (improved) and values <0 infer a negative trend (declined).

5.4.4 Information reliability

The information reliability for the assessment of the flow regime was evaluated as **fair** (final score of 9). Justification for the scoring is detailed in Table 5–5. The ratings reflect discussions within the staff and experts present for the evaluation workshop.

Table 5–5. Information reliability used to assess environmental outcomes and trend the number of flowing days. The methods used in data collection as well as the representativeness and repetition of data were scored based on the answers to questions regarding each facet of data collection. Answers to questions on the method, representativeness and repetition of data collected were scored 2 points – Yes, 1 point – Partially and 0 points – No.

Methods	Question	Answer and justification	Score
Methods used	Are the methods used appropriate to gather the information required for evaluation?	**Partially.** Flow monitoring network specifically designed to assess flow conditions across the state. However, detectability of the number of non-flowing days difficult to measure, leading to potential errors.	**1**
Standard methods	Has the same method been used over the sampling program?	**Yes.** Standard method used as applied to State Water Resource Assessments and other peer reviewed reporting products.	**2**
Data representativeness			
Space	Has sampling been conducted across the spatial extent of the assets with equal effort?	**Partially.** There are several ungauged catchments in the WRPA in this assessment, and there is an over representation of perennial or near-	**1**

Methods	Question	Answer and justification	Score
		perennial sites. Trend in flow condition may only represent the trend observed at the gauging sites presented here, and zero flow may not reflect persistent biotic communities in dry reaches.	
Time	Has the duration of sampling been sufficient to represent change over the assessment period?	**Partially.** Flow monitoring data is available are varying times since the assessment period began. There are only site gauging sites which have data available since the early 2000s.	1
Repetition			
Space	Has sampling been conducted at the same sites over the assessment period?	**Yes.** Flow monitoring at fixed locations.	2
Time	Has the frequency of sampling been sufficient to represent change over the assessment period?	**Yes.** Continuous monitoring.	2
Final score			**9**
Information reliability			**Fair**

5.5 Evaluation

The environmental outcome for flow regime in the EMLR WRPA was not met, considering that most gauging sites in the Marne Saunders PWRA have declined in the number of flowing days (see section 5.4.1), reflected by the average trend across these sites (see section 5.4.3). By contrast, it was clear that most gauging sites in the EMLR PWRA displayed either a stable or improving number of flowing days (see section 5.4.1), with the average trend across these sites indicated as improved (see section 5.4.3), but this might be due to an overrepresentation of perennial or near-perennial gauging sites. Since 2019, approximately 85% of presented gauging sites in the EMLR PWRA have had an average number of flowing days which has equaled or exceeded the site-specific assessment period average, whereas only one site (A4261233) in the Marne River has had an average number of flowing days which has equaled or exceeded the site-specific assessment period average.

There are multiple factors that contribute the number of flowing days at a given location including: the influence and patterns of rainfall on runoff; changes in land use; changes to water demand and use; and water diversions or interceptions. While these factors are important, the long-term declining rainfall and the presence of interception activities are identified as the two key factors influencing the environmental outcome.

5.5.1 Climate and rainfall

Long-term rainfall data suggests that there have been declines in total annual rainfall in most localities in the EMLR WRPA (see section 5.4.2), contributing to a long-term decline (since 1974) in total stream flow in some areas of the EMLR PWRA (Savadamuthu et al. 2023b). The change in annual rainfall has been greatest since the onset of the Millennium Drought (1996–2010), and this has been driven mainly by changes to the seasonality of rainfall (Savadamuthu & McCullough 2024). For example, the strongest decline in seasonal rainfall has been spring-time precipitation (mainly October) since the early-to-mid-2000s, whilst autumn rainfall has also declined but has seen a greater recovery since the end of the Drought (Savadamuthu & McCullough 2024). This suggests that regional precipitation has been compressed into the winter season (Savadamuthu & McCullough 2024), having implications for the number of flowing days, considering that this metric will be influenced by the spread of rainfall across the year. This may also increase the risk to future droughts, as earlier cease-to-flow periods have implications for biological life histories (e.g. macroinvertebrate emergence).

The reduction in rainfall is likely not uniform across the WRPA, considering that there is distinct north-south gradient for precipitation. The Marne Saunders is experiencing some extreme reductions in flow through the system, as illustrated in the results presented in this assessment, whilst the number of flowing days at EMLR PWRA sites has been maintained or improved. The management of the water resources of the EMLR WRPA is passive and currently principally based on the use of low flow bypasses (see section 5.2.2), where a small portion of the flow is returned the environment. However, these devices require flows into dams to be sufficient. Therefore, the flow regime and the number of flowing days in the WRPA still remains largely dependent on rainfall.

5.5.2 Water resource development

Water resource development impacts the flow and water quality within stream as dams capture and divert surface runoff. One of the most important components affected by water resource development are low flows, and in the context of a drying climate, greater water resource development elevates the level of risk to WDEs during drought conditions. There have been approximately 8,000 dams constructed across the EMLR WRPA (CSIRO 2007; Whiterod 2018), whilst storage capacity in the Upper Marne Saunders doubled during the 1990s, impacting the median runoff returning to streams (Savadamuthu 2002).

To progress towards the environmental water provision objective (pass 85% of metrics), as outlined in the WAPs for the EMLR and Marne Saunders, it is recommended that all licensed dams and watercourse extractions plus stock and domestic dams over 5 ML in volume return or not capture flows at or below a certain threshold flow rate (low flows). The restoration of low flows (a form of PEW) is currently underway in the EMLR WRPA, with bypass devices aiming to reduce the impact of dams on the flow regime by allowing a portion of the flow to bypass a dam rather than be captured. In particular, this allows low flows to continue through the system unimpeded rather than requiring the dam to fill and spill, increasing the number of flowing days per year.

5.6 Conclusion

Overall, the environmental outcome for flow regime in the EMLR WRPA was not considered to have been met, due to the decline in the number of flowing days at sites in the Marne Saunders PWRA. Decreasing rainfall experienced across the EMLR WRPA and the presence of water interception/capture activities has contributed to this outcome. By contrast, gauging sites in the EMLR PWRA have maintained or improved the number of flowing days, however there is potential that this is influenced by overrepresentation of perennial or near-perennial sites. This is consistent with the 2020 evaluation that also identified that the flow regime outcome had not been achieved (DEW 2020b). The restoration of low flows continues through the Flows for the Future program. The Flows for the Future program contributes to the maintenance or improvement in the number of flowing days and reduces risks to WDEs; however, the number of flowing days across the year is primarily influenced by rainfall.

6 Macroinvertebrate condition

Trend **Declined** **EMLR PWRA**

Trend **Declined** **Marne Saunders PWRA**

★☆☆☆☆ Reliability **Poor**

Key findings and messages:

- The environmental outcome for macroinvertebrate condition was not achieved as only four sampled sites had a moderate or better community condition – the majority of sampled sites were assessed as in poor condition.
- Changes in climate, rainfall, and stream flow continue to impact an already degraded system, exacerbated by water quality and land use pressures in the EMLR WRPA.
- The continued implementation of low flow devices through the Flows for the Future program will contribute to maintenance of an improved flow regime for macroinvertebrate communities.

6.1 Introduction

Macroinvertebrates are a large and diverse group of organisms including insects, crustaceans, worms, snails, and mites that are vital to freshwater food webs. Macroinvertebrates respond strongly to changes in stream flow, water quality and habitat condition and are thus good indicators for inclusion in aquatic monitoring and evaluation programs. The foundation of these assessments are changes to community composition and the presence of key taxa to make biological inferences on the condition of watercourses (Botwe et al. 2015).

The EMLR supports a diverse community of macroinvertebrates with over 400 species recorded, supported by EPA monitoring data from 1994 to 1999. Macroinvertebrates that are commonly regarded as responsive to flow regime, water quality and habitat disturbances include mayflies, stoneflies and caddisflies. Common tolerant taxa include amphipods (*Austrochiltonia*), snails (*Potamopyrgus*, *Physa*, and *Austropygrus*), certain mites (Hygrobatidae, Hydryphantidae, Limnesiidae, and Pionidae), and chironomids (*Procladius*, *Paramerina*, *Chironomus*, and *Tanytarsus*).

Communities of macroinvertebrates are often defined with taxa that live in surface waters. However, there are some macroinvertebrate taxa that persist within and below the streambed (hyporheic fauna) and in groundwater aquifers (stygofauna), for which knowledge is limited (South Australian Murray–Darling Basin Natural Resource Management Board 2019; South Australian Murray–Darling Basin Natural Resources Management Board 2019). Monitoring macroinvertebrates during dry phases in intermittent streams is difficult (Steward et al. 2018), and sampling of macroinvertebrates in the EMLR largely tends to target sites with permanent pools at the start and end of the flowing season (spring and autumn). Therefore, inferences of the broader macroinvertebrate across the EMLR region (i.e. locations without permanent pools, only seasonal flows, and other non-surface water macroinvertebrates) can be challenging.

Water resource development has negatively affected WDEs across South Australia (VanLaarhoven & van der Wielen 2009). Some significant environmental drivers of macroinvertebrate condition related to water resource development include; flow (Datry et al. 2014), salinity (Botwe et al. 2015) and oxygen (Jacobsen 2008). In streams in hilly catchments, flow dynamics and dissolved oxygen concentrations are often closely correlated. Many insects, such as mayflies and stoneflies, are sensitive to low dissolved oxygen and therefore rely on habitats such as riffles (Connolly et al. 2004). As such, the presence and composition of macroinvertebrate communities is often associated with the function of these freshwater stream ecosystems (Jonsson et al. 2017; Múrria et al. 2017).

6.2 Ecological objectives, targets and environmental outcomes

The ecological objective and target from the LTWP for the EMLR WRPA is given in Table 6–1, and aims to achieve a community in moderate to good condition, assumed to provide enough resilience for future droughts.

Table 6–1. Ecological objective and target for macroinvertebrates in the LTWP for the EMLR WRPA.

Ecological objective	Ecological target
Maintain water-dependent ecosystems at an acceptable level of risk for meeting the overall objective of maintaining/restoring self-sustaining populations of aquatic/riparian flora/fauna that are resilient to drought.	Moderate to good macroinvertebrate community condition

The environmental outcome for the macroinvertebrate community condition was based on the LTWP target and is a long-term outcome (2025–2048). Macroinvertebrate community condition scores (continuous) were calculated from several community attributes and were continuous numbers ranging from 1 (very poor) to 6 (excellent) (see section 0). Therefore, it was considered that an environmental outcome set at community condition score of 3 or greater was sufficient to evaluate the LTWP ecological target of moderate to good community condition (Table 6–1).

Table 6–2. The environmental outcome for macroinvertebrates in the EMLR WRPA.

Environmental outcome	Outcome timeframe
A condition score of moderate or better, considered ≥ 3.	2025–2048

6.3 Method

6.3.1 Data sources

Macroinvertebrate presence/absence data was collected between 2016 and 2022 from 42 sites (31 sites in the EMLR PWRA; 11 sites in the Marne Saunders PWRA) Figure 6-1. Two key sources for this data were the Flows for the Future hydro-ecological monitoring program (Maxwell et al. 2017) and the BioBlitz Program (Miles et al. 2016 unpublished). As the data cut-off for this assessment was June 2023, sampling Autumn 2023 was omitted, as it would provide incomplete data for seasonal community structure in macroinvertebrate populations.

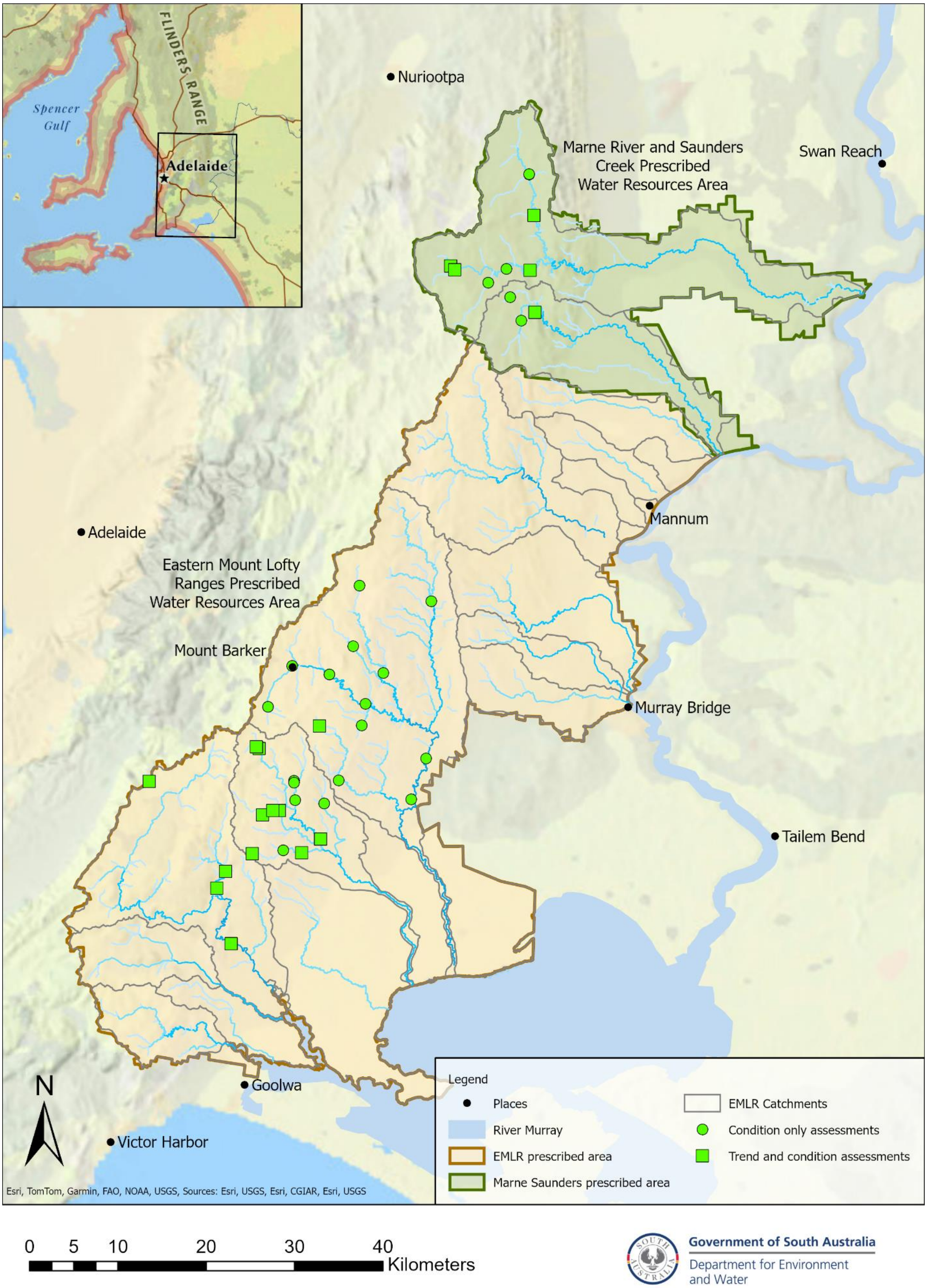

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Figure 6-1. Study map of the sampled sites used in the macroinvertebrate assessment for the EMLR WRPA. Light blue lines represent major streams in the area and black lines are the boundaries of water catchments shown in Table 2–1 and Figure 2-1.

Some attributes used in the condition modelling process considered frequency classes (e.g. rare or common taxa) and/or an "expected" community (i.e. the total expected pool of taxa potentially encountered at a site; see section 6.3.3). For this purpose, the macroinvertebrate dataset from the EPA's Aquatic Ecosystem Condition Reports (AECRs) program was used due its greater length and spatial extent. The EPA provided these data to improve the information available on the rarity, frequency and expected values of taxa to help with the development of the contemporary macroinvertebrate condition model (CMCM) for Matter 8 reporting purposes. However, these data are not part of the presented results nor are they reflected in the assessment of the environmental outcome for macroinvertebrates in this report. Results here do not reflect the condition scores determined through the EPA's AECRs program (available here), which collect significantly more site data (i.e. water and habitat qualities, and riparian and vegetation information) in addition to the macroinvertebrate sampling, and uses an expert panel approach following the original biological condition modelling approach (Davies & Jackson 2006).

6.3.2 Site sampling

The sampling process was developed based on the procedure utilized by the EPA's AECRs program, but is undertaken twice per year (spring and autumn) where possible. Sites are identified per 100 m stretch of a watercourse, and sampling is performed using a 30 cm dip net with a mesh size of 250 µm. Two samples are collected (where possible), one from the still water (or pool) habitat and the other from the flowing water (or riffle) habitat. Each sample is made up of a collective 10 m of the respective habitat representing the relative proportions of all microhabitats present. For example, if a pool habitat comprises of 60% macrophytes, 30% bare sediment and 10% bedrock, the pool sampling is performed in 6 m of macrophytes, 3 m of bare sediment and 1 m of bedrock. Riffle sampling is generally undertaken by kick-sampling 10 m of riffle habitat. Note that the sampling does not need to be continuous and may be collected from multiple pools or riffles across the 100 m stretch of the watercourse which defines a site. General site descriptions and basic water quality data are collected at the same time.

Sample processing is conducted onsite (for the Flows for the Future sampling) or at a central location (for BioBlitz sampling). The sample is processed for 30 to 60 minutes depending on the number of taxa being identified and one or several of each morphologically distinct taxa are preserved for later identification under microscope. Taxa are generally identified to family level or genus level where possible, while key taxa are identified to species level where possible (including Ephemeroptera, Trichoptera, Plecoptera and Odonates). All data presented here is converted to presence/absence data, and the pool and riffle samples for a given site in each year were pooled.

6.3.3 Contemporary macroinvertebrate condition model (CMCM)

A CMCM was used to assess the condition of macroinvertebrate communities present at each site. This condition model uses the biological condition framework (Davies & Jackson 2006) to describe macroinvertebrate community condition along a gradient relating to anthropogenic impacts. The CMCM model assesses nine different attributes, out of ten defined in Davies and Jackson (2006), to assess macroinvertebrate communities, each with a score ranging from one (very poor) to six (excellent) (Table 6–3). Attribute scores were then combined for a final score per sample, aiming to provide a condition statement for sites sampled over time to detect potential impacts on macroinvertebrate communities.

Table 6–3. Overview of attribute information used in the calculation of macroinvertebrate condition scores. *Note that frequency classes and observed/expected (O/E) ratios were derived using assessed data plus an additional data source (i.e. SA EPA AECRs dataset).

	Definition	Measure used
Attribute 1	Historical, sensitive, long-lived, or endemic taxa	O/E ratios using sensitivity scores and frequency* since 2008
Attribute 2	Sensitive-rare taxa	O/E using sensitivity scores and frequency* since 2008

	Definition	Measure used
Attribute 3	Sensitive-ubiquitous taxa	O/E using sensitivity scores and frequency* since 2008
Attribute 4	Intermediate-tolerant taxa	O/E using sensitivity scores
Attribute 5	Tolerant taxa	O/E using sensitivity scores
Attribute 6	Invasive species	Proportion of invasive species from the number of presence taxa within the same order
Attribute 8	Functional diversity	O/E of unique trait combinations
Attribute 9	Spatial detrimental effects	% of photosynthetic vegetation in the riparian zone
Attribute 10	Ecosystem connectivity	Water resource development

Ecological attributes

Scores for Attribute 1 to 5 were determined by the observed versus expected (O/E) ratios of attribute-specific taxon. Taxa were assigned to each attribute based on their frequency class (defined as the sum of presences across all samples) and/or a sensitivity score which was derived through expert elicitation and referenced to the SIGNAL2 scores (Chessman 2003). Attribute 1 to 3 used both frequency classes, classified as either "extremely rare" (<6), "very rare" (<11), "rare" (<21), "uncommon" (<51), "common" (<101), or "very common" (>101), as well as sensitivity scores, classified as either "sensitive", "intermediate", or "tolerant". Attribute 4 to 5 only used sensitivity scores to select taxa. The observed number (O) within each attribute was the sum of all presences in a sample (i.e., site and year), while the expected number (E) within each attribute was the sum of all presences in the surrounding region but across all samples (i.e., all sites and years). A region was defined as either a zone (e.g., Upper Bremer or Lower Bremer), a catchment (e.g., Finniss), or a biome (e.g., North-east), selected depending on the number of sites in each category. The O/E ratios were calculated and multiplied by 6 to derive a final attribute score.

Scores for Attribute 6 were based on the proportion of invasive species to non-invasive species within the same order. The maximum proportion evident in each site was taken and multiplied by 6 to derive a final attribute score.

Scores for Attribute 8 were determined by the number unique trait combinations (Keyel & Wiegand 2016). Twenty-five categorical traits were chosen (with 74 modalities) from an integrated macroinvertebrate trait database (Kefford et al. 2020), derived originally in Botwe et al. (2018). This method measures functional richness by counting the number of unique traits combinations from taxa present in a sample. As with Attributes 1 to 5, an O/E ratio was determined for Attribute 8 by counting the number of unique trait combinations in the surrounding region (either zone, catchment, or biome). These O/E ratios were multiplied by 6 to derive a final attribute score.

Spatial attributes

The score for Attribute 9 was based on the proportion of photosynthetically active vegetation along the riparian corridor over summer as a surrogate measure for the level of riparian vegetation. The photosynthetically active vegetation was estimated using the normalized difference vegetation index (NDVI) for a 50 m buffer around all mapped watercourses within each management zone or sub-catchment, and then divided by the total area within the buffer. NDVI information was extracted from time series data covering the period 2000–2018 (Modified Copernicus Sentinel data 2023). The resulting proportion was assessed against modified criteria developed for DEW (DEW 2023). A proportion greater than 50% was generally considered to be reflective of a fully vegetated riparian corridor.

The score for Attribute 10 was based on the estimated level of impact to the connectivity of the system due to the impact of dam development. The level of dam development was estimated based on surface area to volume ratios and then assessed against the modelled runoff generated for the same zone (DEW, unpublished. data). Results were presented for management zones or sub-catchments where appropriate. The development level considered all development within the zone as well as all upstream zones. The attribute score was calculated by assigning development levels greater than 25% to 6 (very poor) based on development level assessments undertaken for the development of local water resource management plans (VanLaarhoven 2012; VanLaarhoven & van der Wielen 2009; VanLaarhoven & van der Wielen 2012). For zones with development between 0% and 25%, the score was calculated by scaling the volume of the development level to a scale of 1-6 (Equation 1).

Equation 1: conversion of the development level (range from 0-0.25) for management zones or sub-catchments to CMCM score.

$$CMCM_9 = 7 - (20 * Dev + 1)$$

Final scoring

The final scoring for the CMCM was the average of all ten Attribute scores, as the overall and per annum distributions of site scores were largely normal. This final (continuous) score was then grouped into six condition categories:

- Very poor – 1 to 1.49
- Poor – 1.5 to 2.49
- Fair – 2.5 to 3.49
- Good – 3.5 to 4.49
- Very good – 4.5 to 5.49
- Excellent – 5.5 to 6

As per the environmental outcome (see section 6.2), a final score of ≥ 3 was considered to represent "moderate to good" community condition.

6.3.4 Trend assessment

The analysis was undertaken as per section 4.3 using a Bayesian Generalised Linear Mixed Model. Sites used in trend assessment (19; 14 for the EMLR PWRA; 5 for the Marne Saunders PWRA) required to have a minimum of 5 years of data between 2016 (or 2017) to 2022. Trend assessed the macroinvertebrate condition scores (1–6) for the EMLR and Marne Saunders PWRA, using a Gaussian distribution (identity link). Time step was included as a fixed effect. A random (intercept) factor was used, which makes the interpretation the average trend in macroinvertebrate community condition for the 14 and 5 sampled sites for EMLR and Marne Saunders PWRAs, respectively. The model specification was:

Condition score ~ time step * region + (1|site)

Note that this trend assessment does not provide a condition state on macroinvertebrate communities across the PWRAs nor the WRPA. The sites used in this assessment are part of targeted monitoring programs, limiting the ability to infer trends outside of these sites (see section 6.3.6).

6.3.5 Information reliability

Information reliability was assessed as part of the expert elicitation evaluation workshop following the methods outlined in section 4.4.

6.3.6 Limitations and assumptions

Monitoring data are collected from targeted sites with permanent pools and site selection may differ between data sources. Sites are repeatedly sampled, which facilitates the assessment of change through time for a given site but does not provide sufficient randomization of regional site selection. Therefore, inference of community condition outside of these sites and across either the PWRAs or the WRPA is limited. Moreover, macroinvertebrate data was sourced from various sampling programs (see section 6.3.1), which may introduce a bias of site selection. Therefore, inferences about macroinvertebrate community condition in, and generalization, including trend assessment, across the region is limited.

Macroinvertebrate data was sourced from various sampling programs, which may impose differences in the underlying taxonomic interpretation of data. These datasets may have differences in taxonomic levels that identified taxa were resolved to; where different observers identified macroinvertebrates to different taxonomic resolutions within the bounds of the sampling guidelines. To overcome this issue, taxonomic resolution was corrected to the level set in sampling guidelines. The limitation here is that additional diversity may be missed by the higher levels of taxonomic resolution, especially considering rarer species in a common genus.

The CMCM was developed to provide a quantitative assessment of macroinvertebrate community condition based on sampled taxa and expert opinion of the classification of these taxa. However, a limitation with this process is that macroinvertebrate data were collected using categorical abundance levels that were not able to be translated across into the CMCM. The data used for the CMCM is presence/absence and therefore, is coarser than it would be otherwise if it included abundance level data. It is unknown whether a change in the condition of macroinvertebrate community condition is detectable over the assessment period (2016–2022) using only presence/absence data.

6.4 Results

6.4.1 Environmental outcome assessment

The environmental outcome for macroinvertebrate community condition for sites sampled in the EMLR WRPA was considered not met, as only four out of 42 sampled sites were found to have a macroinvertebrate community in moderate or good condition (score ≥ 3) in their last year of sampling (Table 6–4 and Figure 6-2). Two of these sites were in the EMLR PWRA (Upper Rodwell Creek and Bull Creek Tributary), whilst two were in the Marne Saunders PWRA (Upper Saunders Creek and One Tree Hill Creek, near Springton). Approximately 14% of sampled sites each year, on average, have had a moderate or better (≥ 3) condition score since 2016.

Direct comparisons and evaluation of change between this assessment and the previous ecological assessment in the 2020 evaluation is difficult. However, based on retrospective condition scores calculated here, about 16% of sampled sites, on average, have met the outcome each year during the last assessment period (2016–2019), compared to 11% since 2020.

Table 6–4. Sampled sites that were identified as meeting the environmental outcome of moderate or better macroinvertebrate community condition (CMCM score ≥3) in the most recent sampling year. Note that "fair" (2.5–3.5) and moderate or better condition (≥3) are different.

Catchment	Site	PWRA	Last sampled	CMCM Score	Condition
Bremer	Upper Rodwell Creek	EMLR	2022	3.32	Fair
Finniss	Bull Creek Tributary	EMLR	2022	3.62	Good
Saunders	Upper Saunders Creek	Marne Saunders	2022	3.07	Fair
Saunders	One Tree Hill Creek, near Springton	Marne Saunders	2021	3.17	Fair

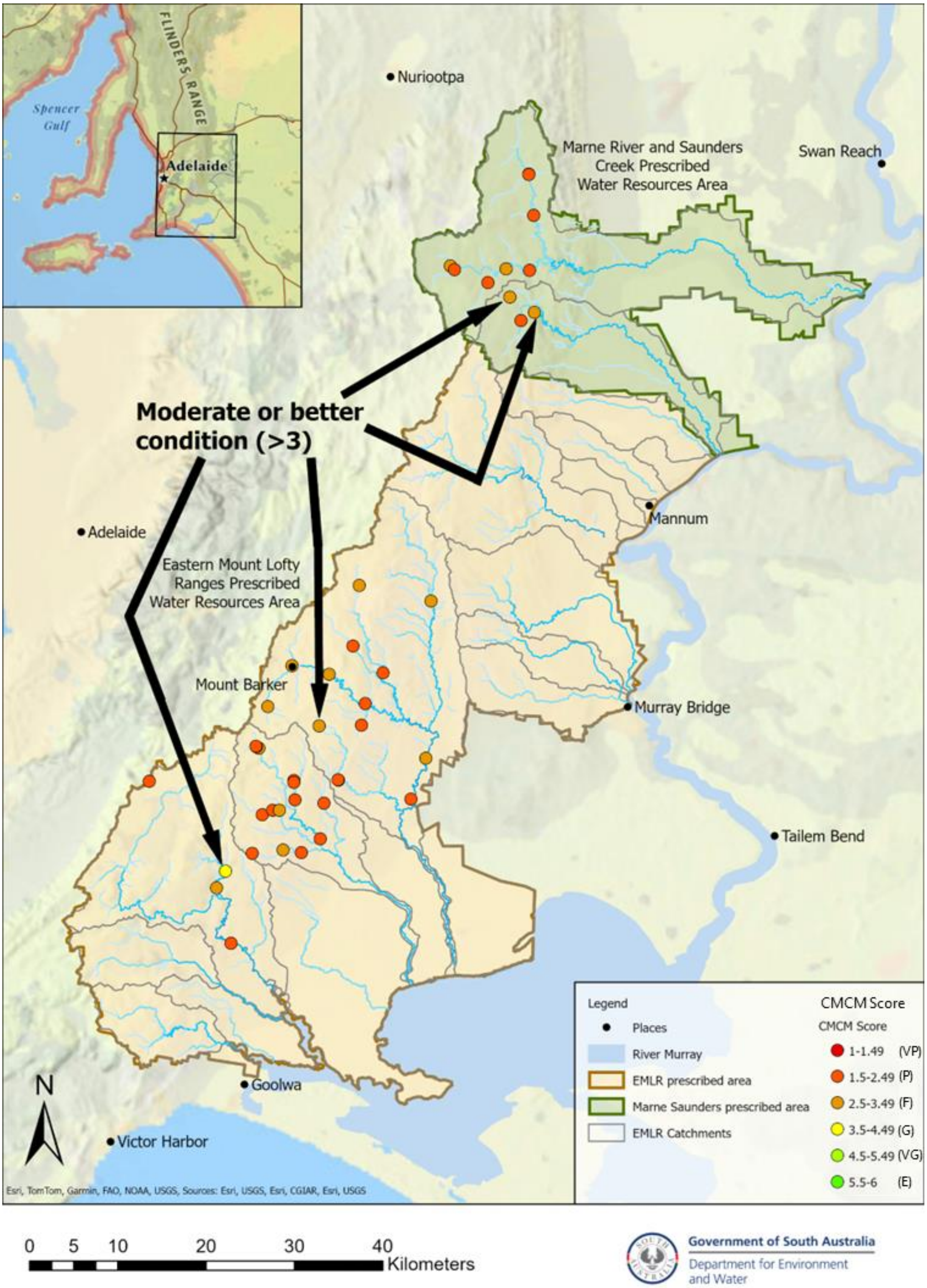

Figure 6-2. The latest macroinvertebrate community condition scores based on sampled sites. The latest assessment year varies by site but are generally from 2021 and 2022. Light blue lines represent major streams in the area and black lines are the boundaries of water catchments shown in Table 2–1 and Figure 2-1.

6.4.2 Macroinvertebrate community condition scores

Macroinvertebrate community condition scores at sampled sites in the EMLR WRPA between 2016 and 2022 were estimated using the CMCM (see Appendix A). It was found that the majority of sites were in "poor" or "fair" condition between 2016 to 2022 (Table 6–5; Figure 6-3). There has been a slight decline in the overall mean score for catchments between these years (Table 6–6), while the median has varied just above and below the threshold value (2.5) between poor and fair condition. The highest score (3.7) was recorded in the Bremer catchment (Upper Rodwell Creek, 2018), whilst the lowest score (1.4) was recorded in the Saunders catchment (Upper Saunders Creek 002, 2019). The Finniss and Bremer catchments were generally in better condition, whilst more intermittent or saline sites, such as in the Saunders catchment, were generally in poorer condition (Table 6–6).

Table 6–5. The number of sampled sites in the EMLR WRPA estimated within each respective macroinvertebrate community condition class from 2016 to 2022.

Category	Score	2016	2017	2018	2019	2020	2021	2022
Very poor	<1.5				1			
Poor	1.5 to <2.5	2	10	13	8	15	11	14
Fair	2.5 to <3.5	7	17	12	15	13	14	10
Good	3.5 to <4.5			1				1
Very good	4.5 to <5.5							
Excellent	≥5.5							

Table 6–6. The average macroinvertebrate condition scores within sampling sites for five catchments in the EMLR WRPA from 2016 to 2022. Colours indicate the condition category for continuous scores (see key legend in Figure 6-2).

Catchment	2016	2017	2018	2019	2020	2021	2022	Mean
Angas	**2.6**	**2.9**	**2.4**	**2.5**	**2.6**	**2.5**	**2.4**	**2.5**
Bremer		**3.0**	**2.5**	**2.5**	**2.5**	**3.2**	**2.5**	**2.7**
Finniss	**2.8**	**3.0**	**2.6**	**2.8**	**2.9**	**2.6**	**2.4**	**2.7**
Marne		**2.4**	**2.8**	**2.6**	**1.9**	**2.1**		**2.4**
Saunders		**2.1**	**2.0**	**1.6**	**2.0**	**2.4**	**3.1**	**2.2**
Overall	**2.7**	**2.7**	**2.4**	**2.4**	**2.4**	**2.6**	**2.6**	**2.5**
	Fair	**Fair**	**Poor**	**Poor**	**Poor**	**Fair**	**Fair**	**Fair**

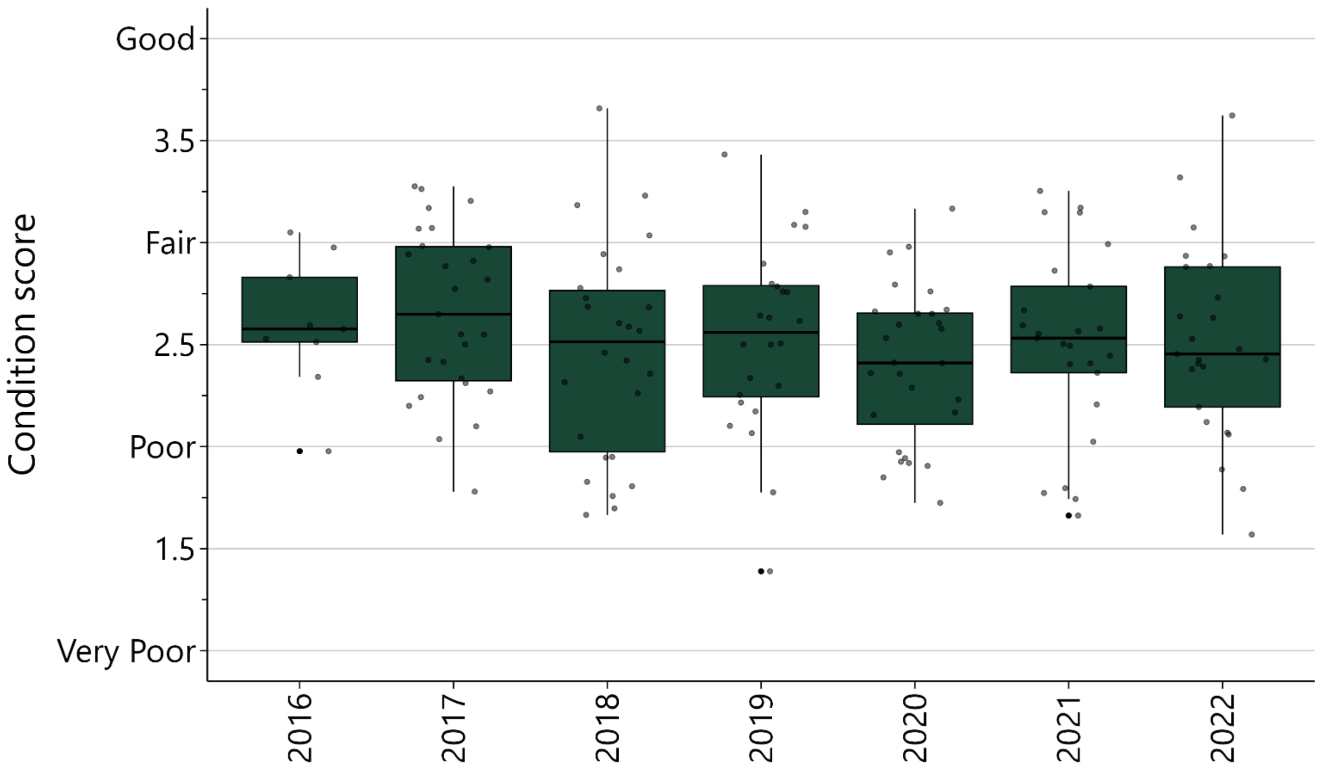

Figure 6-3. The distribution of macroinvertebrate community condition scores in the EMLR WRPA between 2016 and 2022.

6.4.3 Macroinvertebrate community

A total of 268 macroinvertebrate taxa were observed over 42 sites across the EMLR between 2016 and 2022. Amphipods were present in the highest percentage (85%) of samples of any taxa, while water beetles (Dytiscidae) were present over the greatest percentage (67%) of sites (Table 6–7).

Other notable taxa found included the mayflies of *Baetidae; Cloeon sp*. (17%) and *Leptophlebiidae; Thraulophlebia inconspicua* (21%), the caddieflies Leptoceridae; *Triplectides australis* (33%) and *Hydroptilidae; Hellyethira simplex* (24%), and the stonefly Gripopterygidae; *Illiesoperla mayii* (17%). Illiesoperla mayii was present mostly at sites in the Upper Finniss and Angas catchments.

Table 6–7. The most common (≥50% of sites) macroinvertebrate taxa sampled across the 42 sites in the EMLR WRPA. Note that taxa relate to the varying resolutions that macroinvertebrates were identified to.

Taxa	Identified level	Taxon code	Percentage (%) of sites	Percentage (%) of samples
Water beetle	Dytiscidae	QC0920_A	67	75
Amphipod		OP0201	64	85
Non-biting midge	Chironominae/Chironomus	QDAI04_L	64	81
Non-biting midge	Chironominae	QDAI06_L	57	66
Backswimmer	Notonectidae	QH6704_A	57	63
Water boatmen	Corixidae/Micronecta	QH6505	52	60
Bladder snail	Physidae		50	61

6.4.4 Trend assessment

Trend assessment indicates that macroinvertebrate community condition at sampled sites in the EMLR PWRA was likely (77% probability) to have **declined** (median, -0.016) since 2016 (Figure 6-4). Similarly, condition scores at sampled sites in the Marne Saunders PWRA was likely (90% probability) to have **declined** (median, -0.063), although the median slope was slightly higher (Figure 6-5). However, both trend estimates for sampled sites in the PWRAs were considered minor. This trend applies only to the community condition observed in these monitoring sites, considering they are part of targeted programs.

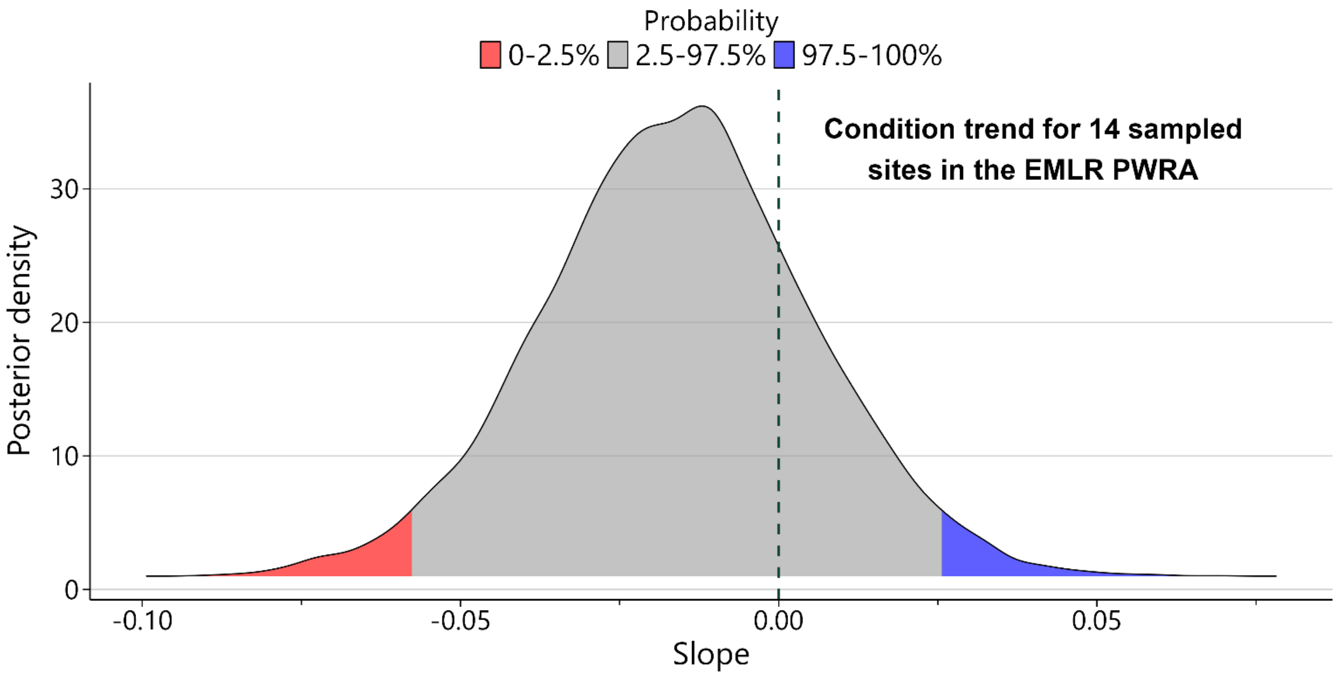

Figure 6-4. Estimated values for the slope generated from Bayesian modelling the macroinvertebrate community condition scores for 14 sampled sites in the EMLR PWRA. Posterior slope values >0 infer a positive trend (improved) and values <0 infer a negative trend (declined).

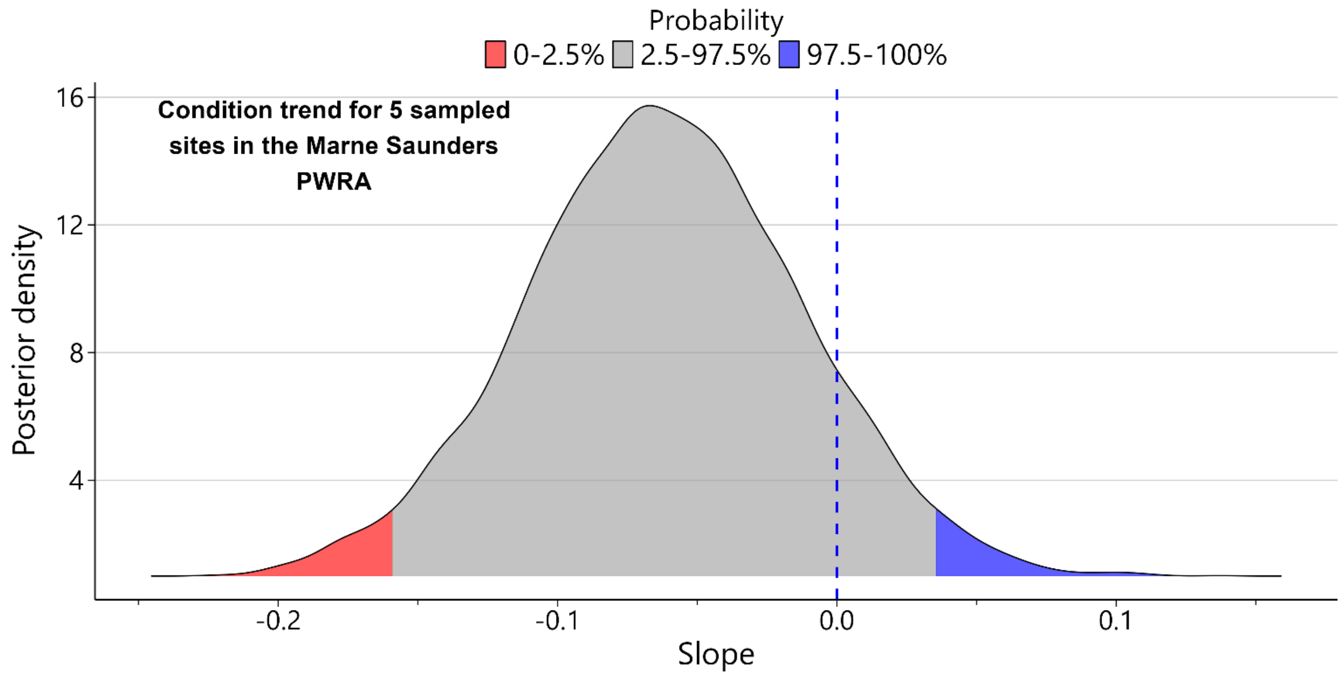

Figure 6-5. Estimated values for the slope generated from Bayesian modelling the macroinvertebrate community condition scores in 5 sampled sites in the Marne Saunders PWRA. Posterior slope values >0 infer a positive trend (improved) and values <0 infer a negative trend (declined).

6.4.5 Information reliability

The information reliability rating for macroinvertebrates in the EMLR WRPA was **poor** (final score of 8). Justification for the scoring is provided in Table 6–8.

Table 6–8. Information reliability used to assess environmental outcomes and trend for macroinvertebrate community condition. The methods used in data collection as well as the representativeness and repetition of data were scored based on the answers to questions regarding each facet of data collection. Answers to questions on the method, representativeness and repetition of data collected were scored 2 points – Yes, 1 point – Partially and 0 points – No.

Methods	Question	Answer and justification	Score
Methods used	Are the methods used appropriate to gather the information required for evaluation?	**Yes.** Sampling method developed is consistent across programs including rigorous QA/QC.	**2**
Standard methods	Has the same method been used over the sampling program?	**Yes.** Sampling method has been consistent since 2016 across programs.	**2**
Data representativeness			
Space	Has sampling been conducted across the spatial extent of the assets with equal effort?	**Partially.** Sampling is limited across catchments. Sites sampled are part of targeted monitoring programs and site selection is not randomised; therefore, inference of macroinvertebrate community condition across the PWRAs or the WRPA is very limited.	**1**

Methods	Question	Answer and justification	Score
Time	Has the duration of sampling been sufficient to represent change over the assessment period?	**Partially.** Sampling since 2016 at some sites. Other sites only have a single year of data.	1
Repetition			
Space	Has sampling been conducted at the same sites over the assessment period?	**Partially.** Most sites have data annually since 2016 or 2017 but some sites only have single records.	1
Time	Has the frequency of sampling been sufficient to represent change over the assessment period?	**Partially.** Annual sampling occurs in spring and autumn each year for some sites – some have had single visits.	1
Overall score			**8**
Information reliability			**Poor**

6.5 Evaluation

The environmental outcome for macroinvertebrate community condition was not achieved in this assessment. Based on the sampled sites, there was only four sites (two in each PWRA) with a moderate or better community condition in the most recent sample collected (see section 6.4.1). Approximately 14% of sites, on average, were observed to have had a moderate or better community condition each year between 2016 and 2022. Similarly, the trend in condition scores of most sampled sites in the Marne Saunders and the EMLR PWRAs were found to have had a minor decline since 2016; however, the distribution of site scores has remained largely between poor and fair community condition. Since 2019, only 11% of sampled sites, on average, have been observed to have a moderate or better community condition each year, and therefore, the majority of sampled communities are currently in (and have been since 2016) a degraded state with an average condition score of fair (2.5; see Table 6–6).

The factors that have impacted the condition of macroinvertebrate communities are climate (see Section 6.5.1), flow regime (see Section 6.5.2), water quality regime (see Section 6.5.3), land use (see section 6.5.4) and invasive fish species (see Section 6.5.5).

6.5.1 Climate and rainfall

Climate directly impacts the condition of macroinvertebrate community, primarily through precipitation patterns, which affect runoff entering streams. Moreover, increased temperature-extremes, greater evapotranspiration, and demand for water resources for consumptive purposes can reduce the availability of water and the health of regional confluences, combining to intensify the impacts on macroinvertebrate communities. Long-term rainfall data suggests that there have been declines in total annual rainfall (since 1900) in most localities in the EMLR PWRA (Savadamuthu et al. 2023a) (see section 5.4.2), which may have contributed to the degraded community condition observed in the sites present in this report. There has also been recent seasonal shifts in rainfall across the Mount Lofty Ranges since the early 2000s, with declines in springtime and autumn precipitation (Savadamuthu & McCullough 2024). As macroinvertebrate sampling was conducted in these seasons, and typically the emergence season occurs in the spring-to-early-summer period, the decline in rainfall may have impacted community condition at these sites.

6.5.2 Flow regime

The only site that achieved the environmental outcome of moderate or better macroinvertebrate community condition which could be compared to an upstream flow gauge presented in section 5 was Bull Creek Tributary (mean score of 3.62; good). The A4261269 (Ti Tree Creek Near Prospect Hill) flow gauge station has had perennial flow since records began (see section 5.4.1).

Flow regime and stream intermittency are key factors that influence macroinvertebrate community condition in seasonal rivers (Datry et al. 2014). Riverine flows have a direct effect on macroinvertebrate community condition through the provision of suitable habitats (e.g. riffles) and corridors for the dispersal and downstream drift of macroinvertebrates from permanent pools to flowing streams. Flow regime can influence (directly or indirectly) water quality (see section 6.5.3) and stream-channel geomorphology, as well as the maintenance of riparian vegetation, which protects freshwater environments.

Declines in total stream flow has been observed in some localities in the EMLR PWRA since 1974 (Savadamuthu et al. 2023a), which may have contributed to the site condition scores, indicative of an already degraded macroinvertebrate community. The length of the flowing period (number of flowing days) in a watercourse is a primary component for the flow regime. Prolonged cease-to-flow events contribute to a reduction in available water habitats and permanent pools, for which low flows are crucial in maintaining. This may increase predator-prey interactions and the overall vulnerability of WDEs to extreme events. A decline in the number of flowing days may have impacted the condition of macroinvertebrates in sampled sites in the Marne Saunders PWRA. Conversely, an improvement in stream flow from some localities in the EMLR PWRA may not have significantly influenced macroinvertebrates, when considering changes to the seasonality of rainfall (see section 5.5.1 and 6.5.1).

6.5.3 Water quality

Water quality exerts a strong influence on the species composition of macroinvertebrate communities (Chessman 2003). The variability in water quality across each year can also impact macroinvertebrates, principally due to cease-to-flow periods. Water quality impacts are caused mainly by diffuse pollution in regional catchments, influenced by urban and agricultural land uses (see section 6.5.4) and exacerbated by clearance of riparian vegetation (EPA 2023).

The river systems of the EMLR WRPA are naturally high in salt and other dissolved solids due to the weathered nature of the catchments (South Australian Murray–Darling Basin Natural Resource Management Board 2019; South Australian Murray–Darling Basin Natural Resources Management Board 2019). Increased freshwater runoff during the flowing season allows the streams and surrounding floodplains to be flushed, reducing salinity and leading to improved water quality conditions. Once naturally reoccurring cease-to-flow periods return, aquatic organisms like macroinvertebrates retreat to a series of permanent pools which are sustained by groundwater inputs. Groundwater-fed flows are often more saline, contributing to an increase in salinity over summer (along with greater evapotranspiration rates). The salinity levels within permanent pools are dependent on these factors, as well as the time between flushing events (e.g. summer storms, environmental flows or the commencement of flowing season).

Nutrient enrichment is also a significant stressor which can lead to excessive algal growth. The impacts of excessive algae can impact macroinvertebrates through a loss in or smothering of habitats, such as rocky or cobble environments relied upon by clinger species (e.g., *Tasmanocoenis* mayflies). Moreover, full eutrophication can occur when the level of algal biomass in the water column reduces light attenuation and dissolved oxygen rates, severely impacting the benthic environment. Algal growth is also enhanced by a lack of riparian vegetation and shading which contributes to higher water temperatures through increased sunlight.

Water quality is also impacted by stock access into the watercourse. Stock access to watercourses and permanent pools can physically impact the habitat by pugging the ground, increasing turbidity and increasing nutrient input. It can also lead to the loss of fringing riparian and aquatic vegetation which limits habitat diversity within the pool.

The installation of devices to allow low flows of environmental water (a form of PEW) to pass around dams and return to the downstream catchment during natural flow periods (e.g., rainfall, runoff etc.) brings forward the timing and commencement of flow and increases the volumes of water flowing to nearby permanent pools early in the flow season (Alcorn 2011). As a result, restoring low flows can improve or maintain hydrological connectivity and keep permanent pools wet, contributing to improvements in water quality regime and aquatic biotic communities.

6.5.4 Land use

Land use in the EMLR WRPA is dominated by grazing, cropping, horticulture and urban environments, with only approximately 5% of remnant native vegetation remaining (South Australian Murray–Darling Basin Natural Resource Management Board 2019; South Australian Murray–Darling Basin Natural Resources Management Board 2019). These land uses are water-use intensive and expose freshwater environments to decreased water quality, directly impacting stream biota (see section 6.5.3). Factors associated with land use in the catchment, such as the extent of riparian vegetation and erosion, influence the condition of macroinvertebrate communities (DEW 2023). Bank erosion can lead to sediment runoff and impact the characteristics of aquatic habitats (Mueller-Warrant et al. 2012). Land uses that increase the rate and accumulation of fine sediment deposition adversely affects macroinvertebrate species which are associated with particular types of substrates. Fine sediment deposition in the benthic environment leads to reductions in the abundance and diversity of mayfly, stonefly, and caddisfly species (Kaller & Hartman 2004; Larsen & Ormerod 2010; Townsend et al. 2008).

Riparian vegetation provides protective corridors or buffers for freshwater streams, and land use has contributed to significant clearance of this vegetation in the EMLR WRPA. Riparian vegetation has been identified as one of the more important catchment characteristics for macroinvertebrate community condition (DEW 2023), as healthy riparian areas provide several key functions including: filtering runoff from surrounding landscape, improving stream water quality; providing diverse habitats for winged adult stages of aquatic macroinvertebrates; and allowing shading for streams, reducing water temperatures and inhibiting algae growth (Connolly et al. 2016). The riparian corridor in the WRPA is typically characterised by sparse remnant river red gum and an understory structure of exotic grasses, native sedges, and in wetter areas, monospecific stands of *Phragmites* and *Typha*.

6.5.5 Invasive fish species

Invasive or introduced fish in the Mount Lofty Ranges, which are found in virtually all reaches in the EMLR WRPA impact on macroinvertebrate communities. Invasive fish species are typically large-bodied pelagic predators, such as trout or redfin perch, and therefore, exert a top-down pressure on the macroinvertebrate community in these watercourses. Eastern gambusia is an aggressive, invasive species and the most prevalent fish in the EMLR WRPA, making up nearly a third of all fish caught between 2014 and 2023 (Whiterod et al. 2023). Eastern gambusia directly predate on and attack smaller macroinvertebrates, frog offspring, and other native fishes, their presence can also negatively impact water quality during cease-to-flow periods (Rowe et al. 2008). Common carp can also negatively impact water quality by increasing turbidity in stream reaches, which impacts the visual hunting mechanisms of certain macroinvertebrates.

Currently, stocking of rivers in the WRPA with rainbow and brown trout is not permitted and ceased in 2018.

6.6 Conclusion

The environmental outcome for macroinvertebrate communities to be in moderate or better community condition was not achieved in this assessment period, as only four of 42 sampled sites had a recent assessment score that met the outcome. Since 2016, the majority of sampled sites have had between poor and fair condition, with an average of 14% of sampled sites per year having a moderate or better community condition. The trend indicates that condition at sampled sites has declined since 2016, and 11% of sites have been observed with moderate or better condition annually since 2019. The factors that have contributed to condition include, change in flow regime, climate, water quality, landscape degradation associated with land use and decline of native fishes. Climate and the presence of water interception activities were considered the major factors in the environmental outcome being achieved. Overall, the restoration of flows will benefit macroinvertebrates through the vital maintenance of permanent pools, with implementation occurring through the Flows for the Future program.

7 Fish

Trend **Declined** **EMLR PWRA**

Trend **Stable** **Marne Saunders PWRA**

★★★☆☆ Reliability **Good**

Key findings and messages:

- Fish community condition was considered poor in 2023, despite several above average years since 2019.
- Lower scores in 2023 compared to 2022 are likely due to a deterioration in upper pool-riffle and terminal wetland condition, as well as high abundances of common carp relative to native fish.
- The trend in fish community condition was considered to have declined in the EMLR PWRA between 2014 and 2023, whereas trend is stable in the Marne Saunders PWRA.
- Fish recruitment was found to be sufficient to maintain populations of mountain (and obscure) galaxias and southern pygmy perch in the EMLR WRPA, despite declining abundances.

7.1 Introduction

The EMLR WRPA supports a fish community that has both regional and national importance. The seasonal rivers of the EMLR WRPA provide critical habitat for many of the native fish species, especially some of the smaller bodied fish (Hammer 2009). Fishes occurring in streams and pools in the EMLR represent almost 60% of small-bodied fish species that occur in the MDB, several of which are considered either regionally or nationally (e.g. Murray Hardyhead) threatened or endangered (South Australian Murray–Darling Basin Natural Resource Management Board 2019; Whiterod et al. 2015). Fish species in the EMLR WRPA can broadly be defined as either resident freshwater species (e.g. southern pygmy perch, mountain galaxias, river blackfish) or migratory freshwater species (e.g. diadromous species like congolli, climbing galaxias) (Hammer 2004; South Australian Murray–Darling Basin Natural Resource Management Board 2019).

Freshwater fish are reliant on the aquatic habitats that are provisioned by the condition of flowing streams and the natural flow regime (i.e. the seasonality, timing, frequency, duration, magnitude and rate-of-change) will impact the ecological integrity in streams. For example, changes to the timing and duration of flowing season in seasonal rivers can disrupt the cues for spawning, rates of egg hatching, and the migration period of fish species (Poff et al. 1997). The low flow component of the flow regime helps to maintain pool habitats in freshwater streams, providing refugia for fish species. Critical components such as low flows and/or groundwater inputs in the EMLR help to maintain refuge habitats for fish species (Hammer et al. 2009). Water resource development can have negative impacts on the flow components in seasonal rivers (see section 5.1), and changes to flow volume, seasonality and duration have led to significant reductions in the community condition of EMLR fish species (Whiterod et al. 2015).

7.2 Ecological objectives, targets and environmental outcomes

The ecological objective and target from the LTWP for the EMLR WRPA (DEW 2020a) is given in Table 7–1. Due to their relatively short life span (~3 years) and naturally adapted strategies to persist in consecutive years of poor to marginal breeding events, expert opinion suggests that “better-than-marginal” recruitment in at least 7 out of 10 years is sufficient to maintain their populations (South Australian Murray–Darling Basin Natural Resource Management Board 2019; VanLaarhoven & van der Wielen 2012). By contrast, marginal to poor recruitment in southern pygmy perch and mountain galaxias species has been shown to have a negative correlation with the number of EWR metrics successfully passed (VanLaarhoven & van der Wielen 2012).

Table 7–1. Ecological objective and target for fish in the LTWP for the EMLR WRPA.

Ecological objective	Ecological target
Maintain water-dependent ecosystems at an acceptable level of risk for meeting the overall objective of maintaining/restoring self-sustaining populations of aquatic/riparian flora/fauna that are resilient to drought.	Better-than-marginal recruitment in ≥7 out of 10 years for southern pygmy perch and mountain galaxias.

The environmental outcomes for the fish were based on the LTWP target and are considered long-term outcomes (2025–2048), outlined in Table 7–2. The environmental outcome for recruitment was qualitatively assessed by Whiterod et al. (2023). An additional environmental outcome was also assessed by Whiterod et al. (2023), aiming to achieve a moderate or better community condition to support the assessment of the LTWP ecological target (Table 7–1).

Table 7–2. The environmental outcomes for fish in the EMLR WRPA. Asterisk (*) indicates outcome that was qualitatively assessed.

Environmental outcome	Outcome timeframe
Better-than-marginal recruitment in ≥7 out of 10 years for southern pygmy perch and mountain (and obscure) galaxias.*	2025–2048
Moderate or better community condition, considered ≥3.	2025–2048

7.3 Method

7.3.1 Fish monitoring

The methodology used to sample fish over the EMLR WRPA is described by Whiterod et al. (2023), shown below:

> *"Between 2014 and 2023, 556 site visits were conducted across nine assessed catchments of the EMLR to provide information on the condition of previously identified ecological assets (Hammer 2009; Whiterod & Hammer 2014a). Typically, annual sampling occurred in Autumn at 50–60 sites (with 46 sampled in 2014) (Table 1), with more than 33 sites sampled opportunistically over the sampling period. Sampling methods matched prevailing conditions (and were consistent with previous monitoring) and predominantly included fyke netting as well as electrofishing, bait trapping, day observations and dip netting (matched to the target species and habitat). All sampled fish were identified to species level and enumerated, with threatened native species sampled measured for length (mm, total length, TL). At each site, broad habitat (type and size, flow connectivity, water level), and water quality (pH, electrical conductivity, water temperature, dissolved oxygen, transparency) were recorded along with assessment of aquatic habitat (submerged physical, biological and emergent cover)".*

Monitoring was funded by the Hills and Fleurieu Landscape Board, the Murraylands and Riverlands Landscape Board and the former Natural Resource Management Boards. Monitoring locations are shown in Figure 7-1.

Figure 7-1. Study map of the sampled reach types in each catchment used in the fish assessment for the EMLR WRPA. Light blue lines represent major streams in the area and black lines are the boundaries of water catchments shown in Table 2–1 and Figure 2-1.

7.3.2 Condition assessment

Fish community condition was quantified using a condition model developed for the EMLR and Marne Saunders, referred to as the Aquasave Fish Condition Model (Whiterod & Hammer 2014a). The Condition Model considers different aspects of the fish community depending on the site. Sites with notable species of concern have bespoke assessments for those species on top of general community condition. Sites with only single species expected to be present will only have species-specific assessments, acknowledging that multiple species are not expected at all locations within the WRPA.

Fish condition scoring was undertaken by considered combining the scores for the different parts of the assessment including:

- The presence of the expected native fish species of (one point per expected species)
- the population demographics of species present at the site and comparison to pre-determined 'good' population demographics comprising an assessment of both recruitment and survivorship (up to three points for both recruitment and survivorship)
- The presence and relative proportion of alien fish (up to two points)
- Scores are averaged across all assessments undertaken for each site (each of the bespoke assessments as well as overall condition, where assessed).

Scoring is then averaged across all the sites in a given reach (see Figure 7-1) to provide a score for each catchment. Condition scores for the catchment scale were the median value of reach scores, as was the overall score for the EMLR WRPA (using the median of catchment scores). As per the environmental outcome (see section 7.2), and Whiterod et al. (2023), a final (median) score of ≥3 was considered to represent moderate or better condition. Fish community condition categories presented in Whiterod et al. (2023) were a score out of 10:

- Poor – <3
- Moderate – 3 to 6
- Good – >6

7.3.3 Recruitment assessment

Fish recruitment was assessed qualitatively by considering the ongoing presence of mountain (and obscure) galaxias and southern pygmy perch for sites in the EMLR WRPA. This assessment considered the previous distribution of these species, current population numbers and current population demographics, as outlined in Whiterod et al. (2023).

7.3.4 Trend assessment

The analysis was undertaken as per section 4.3 using a Bayesian Generalised Linear Mixed Model. Trend assessment used all sites (catchment-reach combination) from the data provided by Whiterod et al. (2023), apart from two sites which had no variation (zero standard deviation) in their condition scores. There were 30 total sites (catchment-reach combination) used, 25 in the EMLR PWRA and 5 in the Marne Saunders PWRA, with most sites having data from 2014 to 2023. Trend assessment was performed and presented for PWRAs, using a Gaussian distribution (identity link). Time step was included as a fixed factor. A random (intercept) factor was used for each site (reach type in each river system), which makes the interpretation the average trend in fish community condition for the 25 and 5 sites sampled in the EMLR and Marne Saunders PWRAs, respectively. The model specification was:

Condition score ~ time step * region + (1|site)

7.3.5 Information reliability

Information reliability was assessed as part of the expert elicitation workshop following the methods outlined in section 4.4.

7.3.6 Limitations and assumptions

Sampling is undertaken in late summer or early autumn when the fish community is at its most stressed. This allows the sampling of what has been able to persist (e.g. obligate species) over the summer months, rather than what might have been present over spring. In this sense, sampling may indicate a fish community is in lower (summer seasonal) condition. This contrasts macroinvertebrate sampling which is performed in both autumn and spring (see section 6.3.2).

The condition model used to assess fish community condition in Whiterod et al. (2023) is better at discriminating between sites in poor or moderate condition than those in good condition (Gannon et al. 2021). This is by design to capture changes in the poorer condition sites due to the nature of the fish communities in the WRPA and the general condition of the rivers of the area. Therefore, the model somewhat lacks sensitivity for sites in good condition.

A limitation with the sampling data from Whiterod et al. (2023; see Table 1 in that report) was that there were two catchment–reach sites for the Saunders Creek, but the Saunders Creek Gorge site had several years of missing values. This means that data informing the environmental outcome and the trend assessment is limited in capturing the condition scores from both upstream and downstream areas of Saunders Creek, and thus, affects the inference made for the Marne Saunders PWRA. Also, Salt, Premimma & Rocky Gully was only represented by one site in the terminal wetlands of Rocky Gully.

7.4 Results

The outcome results presented here are directly from Whiterod et al. (2023). The trend assessment uses the results from 30 sites (reach type for each river system) provided by Whiterod et al. (2023).

7.4.1 Environmental outcome assessment: community condition

The environmental outcome for fish community condition in sampled sites was not achieved, as the latest assessment in 2023 indicated a median condition score of 2 (poor) (Table 7–2). However, the environmental outcome was achieved in the last evaluation in 2019, as fish community were reported with a condition score of 3 (moderate). At some point, all catchments between 2014 and 2019 achieved the environmental outcome. Since 2019, there have been three years with a median condition score of ≥3.4 (Table 7–2), and 77% of catchments have achieved the environmental outcome. Therefore, progression towards the environmental outcome has occurred since Basin Plan adoption (2012) (timeframe: 2025–2048), as 2014 and 2023 were the only two years when the environmental outcome was not achieved.

Table 7–3. Median fish community condition scores for the nine catchments and for the EMLR WRPA as assessed by Whiterod et al. (2023). Cells colours represent catchments classed as either poor (<3), moderate (3–6), or good (>6).

Catchment	Condition score									
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Angas	5.1	3.4	3.9	2.5	3.3	2.9	3.5	3.4	3.5	3.3
Bremer	3.0	3.0	1.0	2.3	3.0	2.0	3.0	3.0	1.0	2.0
Currency	4.0	5.5	2.5	3.5	3.8	3.3	4.8	4.3	1.0	1.5
Finniss	5.0	5.3	5.5	4.8	5.0	3.0	4.4	4.5	4.9	3.5
Reedy	1.0	3.0	9.0	3.0	3.3	4.8	3.5	2.0	7.5	4.3
Salt, Premimma & Rocky Gully	1.0	3.0	3.0	2.0	2.0	3.5	10.0	5.0	4.0	0.5
Tookayerta	2.3	3.0	3.3	2.0	4.5	3.3	5.0	4.0	6.0	2.0
Marne	0.8	1.5	0.0	3.8	2.8	1.0	1.0	2.0	1.0	2.5
Saunders	2.0	5.0	0.0	4.0	0.0	0.0	0.0	1.0	0.0	2.0
Overall	2.3	3.0	3.0	3.0	3.3	3.0	3.5	3.4	3.5	2.0

7.4.2 Environmental outcome assessment: recruitment

Fish recruitment success was assessed qualitatively across the last decade by Whiterod et al. (2023). It was concluded that southern pygmy perch and mountain (and obscure) galaxias were mostly meeting their recruitment targets, considering their ongoing presence in the systems. However, there has been an overall decline in abundance of these species over the last decade.

Key findings related to recruitment success from Whiterod et al. (2023) include:

- Southern pygmy perch and mountain (and obscure) galaxias have declined in abundance.

Southern pygmy perch

- The overall catch of southern pygmy perch decreased between 2014–2023.
- Recruitment for southern pygmy perch was detected at sites sampled in the Finniss River and Tookayerta Creek catchments in 8 of 10 years assessed, compared to 2 of 10 years in the Angas River Catchment where recruitment is now only rarely detected but the species has persisted.
- Sites across the three catchments (Finniss, Tookayerta, Angas) continue to support older individuals, although in typically lower numbers.
- Recruitment of southern pygmy perch is often site-specific, with some sites showing strong recruitment and survivorship (such as sites in the lower Angas River), whilst the species is no longer supported at other sites (such as Deep Creek Rd in the Tookayerta Creek).

Mountain (and obscure) galaxias

- The overall catch of mountain (and obscure) galaxias catch has been highly variable between 2014–2023.
- Recruitment of mountain (and obscure) galaxias has been detected in most years in the Angas (all ten years), Tookayerta Creek (eight out of 10 years) Currency Creek and Reedy Creek (both seven of 10 years) and Marne River (six out of 10 years), but rarely in the Bremer River (three out of 10 years).
- Adult mountain (and obscure) galaxias were observed at sites in all catchments in almost all years with the exception of the Bremer River, Currency Creek and Marne River.

7.4.1 Fish community condition scores

At the WRPA scale, median fish community condition scores from 2014–2023 ranged from 2.0 (poor) to 3.5 (moderate) (Table 7–2). Condition scores increased from 2.3 (poor) in 2014 to 3 (moderate) in 2015. Condition scores were relative stable between 2015 and 2019, where condition was moderate (3) in the last assessment period (2019). Between 2020 and 2022, condition scores increased and had median score of 3.5. In 2023, condition scores reduced to 2 (poor) (

Figure 7-2).

Community condition scores varied within and between catchments over the assessment period (2014–2023) (Table 7–2). However, some catchments were more variable in condition than others. For example, in the Salt, Preamimma and Rocky Gully catchments, condition scores over the assessment period ranged from 0.5 (poor) to 10 (good; maximum score), whereas those in the Finniss catchment were more stable and ranged from 3.0 (moderate) to 5.5 (moderate). In 2023, the catchment with the fish community in the best condition was Reedy (4.3, moderate), while the Salt, Preamimma and Rocky Gully catchment was in the poorest condition (0.5).

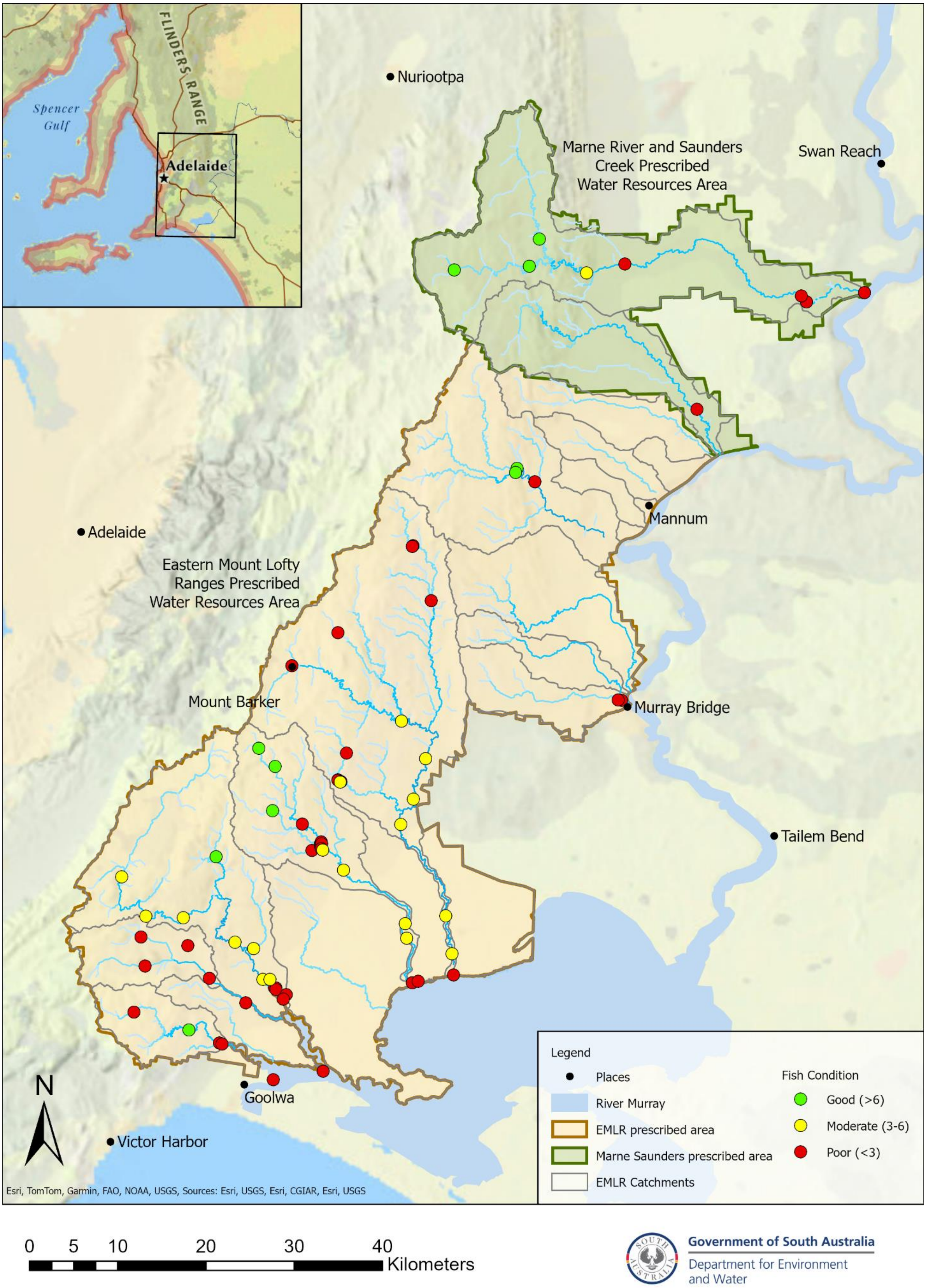

Figure 7-2. Fish community condition for sampled sites in 2023 condition. Sites for the EMLR WRPA are based on the Aquasave fish condition model as reported in Whiterod et al. (2023).

7.4.2 Trend assessment

Trend assessment indicates that fish community condition in sampled catchment-reaches in the EMLR PWRA was likely (74% probability) to have **declined** (median, -0.024) since 2014 (Figure 7-3), although this rate of decline is likely minor. By contrast, condition scores in sampled catchment-reaches in the Marne Saunders was about as likely as not (58% probability) to have declined (median, -0.019), and therefore is considered **stable** (Figure 7-4). The greater uncertainty (based on the credible intervals) for the Marne Saunders PWRA trend is likely due to an improvement in the Marne River sites, but a decline in Saunders Creek sites (noting the limitations with this sample data; see section 7.3.6).

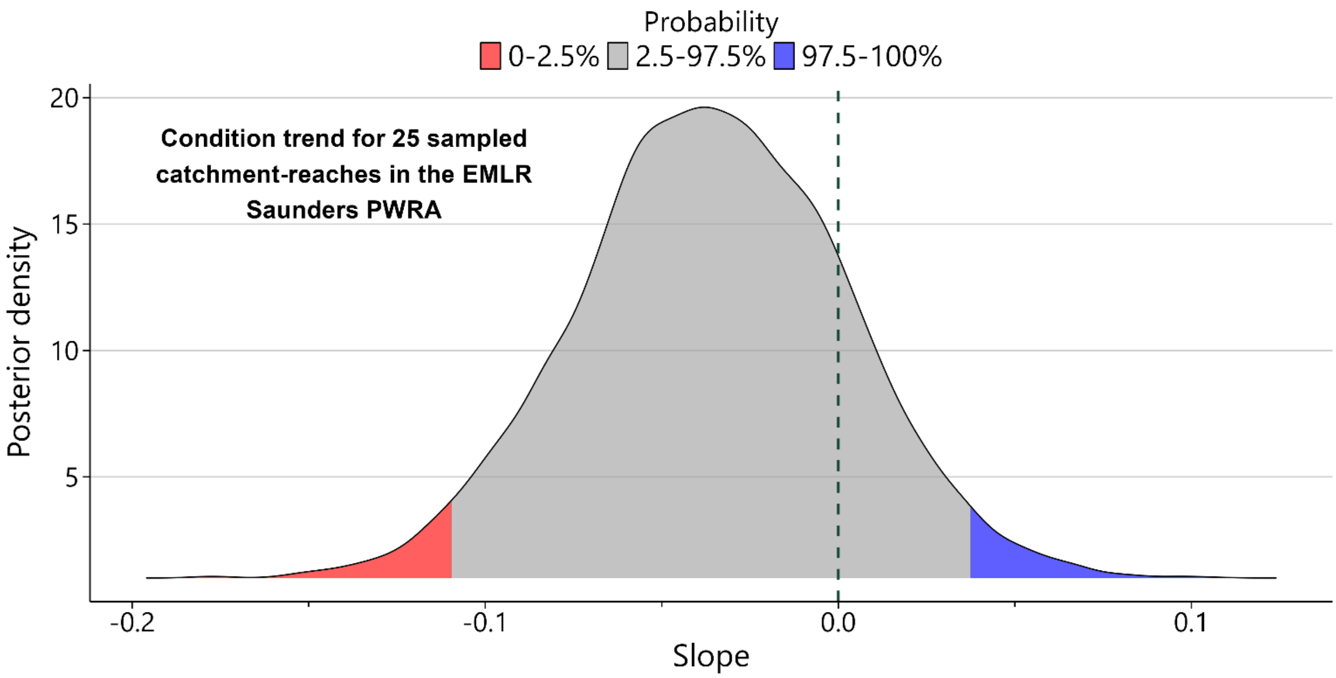

Figure 7-3. Estimated values for the slope generated from Bayesian modelling the fish community condition scores for 25 sampled catchment-reaches in the EMLR PWRA. Posterior slope values >0 infer a positive trend (improved) and values <0 infer a negative trend (declined).

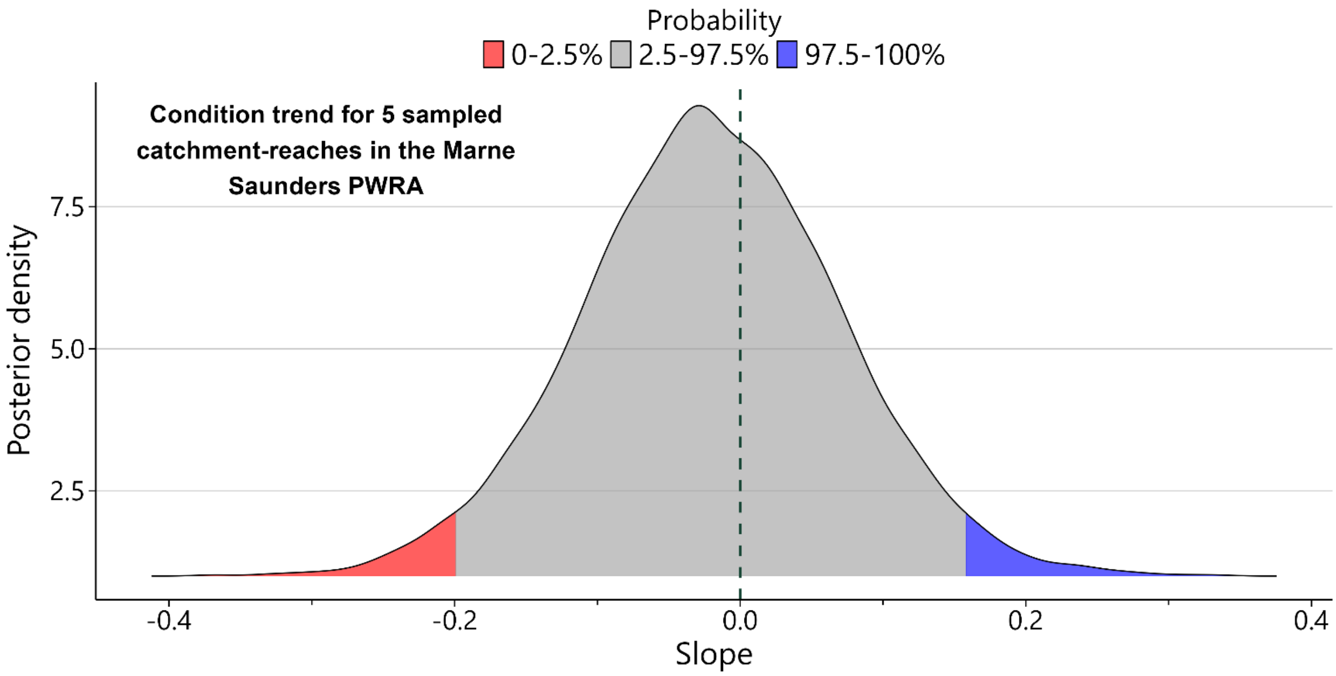

Figure 7-4. Estimated values for the slope generated from Bayesian modelling the fish community condition scores for 5 sampled catchment-reaches in the Marne Saunders PWRA. Posterior slope values >0 infer a positive trend (improved) and values <0 infer a negative trend (declined). Note that trend data for the Marne Saunders PWRA had an overrepresentation of catchment-reaches from the Marne River, and there was only six years of data from a Lowland reach in the Saunders Creek.

7.4.3 Information reliability

The information reliability rating for fish in the EMLR WRPA was **good** (final score of 10). Justification for the scoring is provided in Table 7–4.

Table 7–4. Information reliability used to assess environmental outcomes and trend for fish. The methods used in data collection as well as the representativeness and repetition of data were scored based on the answers to questions regarding each facet of data collection. Answers to questions on the method, representativeness and repetition of data collected were scored 2 points – Yes, 1 point – Partially and 0 points – No.

Methods	Question	Answer and justification	Score
Methods used	Are the methods used appropriate to gather the information required for evaluation?	**Partially.** Methods developed specifically to assess fish community condition in the EMLR and Marne Saunders. Condition scores can be heavily influenced by single species of fish.	**1**
Standard methods	Has the same method been used over the sampling program?	**Yes.** Consistent methods used at each site. Site-specific sampling methods sometimes used but consistent across year and accounted for using catch-per-unit-effort (CPUE) numbers.	**2**
Representativeness			
Space	Has sampling been conducted across the spatial extent of the assets with equal effort?	**Partially.** Comprehensive sampling network covering many catchments and habitats. However, not all reaches in all catchments were sampled.	**1**
Time	Has the duration of sampling been sufficient to represent change over the assessment period?	**Yes.** Data has been collected since early 2000s, assessment based on last decade.	**2**
Repetition			
Space	Has sampling been conducted at the same sites over the assessment period?	**Yes.** Site-specific sampling used and consistent across time.	**2**
Time	Has the frequency of sampling been sufficient to represent change over the assessment period?	**Yes.** Annual sampling over at least 20 years.	**2**
Overall score			**10**
Information reliability			**Good**

7.5 Evaluation

The environmental outcome for fish community condition was not achieved in this assessment, as the latest assessment (summer 2023) indicated a poor (2) condition score at the EMLR WRPA scale (see section 7.4.1). However, there has been some progression towards the outcome (timeframe: 2025–2048) since 2014. Condition scores suggest that three catchments that have achieved a moderate community condition score (Angas, Finniss and Reedy Catchments), and all catchments since 2014 have achieved the outcome at least once. Trend assessment indicated a decline in condition scores for the EMLR PWRA, but a stable trend for the Marne Saunders PWRA (see section 7.4.2), noting that there was limited data from Saunders Creek (impacting the inference of trend for the Marne Saunders PWRA). Since 2019, 77% of catchments have achieved a moderate or better condition score, with six of nine catchments in 2023 rated as poor by Whiterod et al. (2023).

The environmental outcome for fish recruitment was considered achieved in this assessment. While at least seven out of ten years with successful recruitment was not observed at some locations, populations in catchments assessed in the WRPA have generally been sustained. This was despite localised species loss in the northern parts of the WRPA during the 2018 and 2019 dry period, where mountain (and obscure) galaxias were not detected in the Marne River catchment between 2018 and 2022, but returned in 2023 (Whiterod et al. 2023). Therefore, there remains some capacity for mountain (and obscure) galaxias to withstand poor flow conditions and improve when suitable conditions reoccur (Whiterod et al. 2023).

The factors that have impacted fish communities are climate (see section 7.5.1), flow regime (see section 7.5.2), water quality regime (see section 7.5.3), barriers to dispersal (see section 7.5.4) and invasive fish species (see section 7.5.5).

7.5.1 Climate and rainfall

Climate directly impacts the fish community condition, primarily through influencing flow regime, as discussed in section 5.5.1, but also through increased temperature, evapotranspiration, reductions in runoff through drier soils, and higher demand for water resources for consumptive purposes. All of these factors alter the flow regime detrimentally for fish communities.

The condition observed in the Salt Creek, Preamimma and Rocky Gully catchments were quite variable between 2014 and 2023. This area is covered by a single sampling site in the terminal wetland of Rocky Gully, and flow is not monitored, but is thought not to contain mapped baseflow or permanent pools (DEW, Unpublished Data). The system is highly ephemeral, and condition scores are likely highly impacted by rainfall.

7.5.2 Flow regime

Flow regime and intermittency are key factors that influence fish community condition and for sustaining populations of key fish species like southern pygmy perch and mountain (and obscure) galaxias. For example, shorter durations of cease-to-flow periods and more bankfull days over summer have been shown to increase the abundance of mountain galaxias in the EMLR, and flow metrics over a three-year period (compared to per annum conditions) better predict the number of recent recruits (Whiterod et al. 2017). The timing and duration of natural seasonal flows in the Mount Lofty Ranges can affect the water quality in pools during the low-flow season and impact the dispersal and migration capabilities of mountain galaxias, reinforcing the need to restore and maintain the low-flow component during summer (Whiterod et al. 2017). This is also particularly important for diadromous species, as they require hydrological connectivity to migrate between marine and freshwater environments during key stages of their life history. The connectivity between these two environments is critical for ongoing presence of these species in the WRPA catchments.

The poor condition observed in 2023 was contrary to expectations, considering the above-average rainfall for 2023 in the EMLR (see section 5.4.2), and recent years with sufficient flow, at least in the EMLR PWRA (see section 5.4). Lag effects originating from the 2018 and 2019 dry period should have been mitigated by improved flow conditions since 2021, which was reflected in an increase in median condition scores (to moderate) in 2020, 2021 and 2022. Some contributions to lower condition scores in 2023 might be due to gorge-sites in the Bremer River and Reedy Creek catchments being the only reaches with good condition, whereas the status of upper pool-riffles and terminal wetlands deteriorated between 2022 and 2023 (Whiterod et al. 2023). There were significant increases in common carp in 2023, and a lack of a corresponding increase in native fish abundance was highlighted by Whiterod et al. (2023) as contributing to a "continued decline in the fish community over this period".

Overall, Whiterod et al. (2023) concluded that:

> *"Assessment of the ecological assets in the EMLR showed that conditions were moderate during most years but were found to be poor in 2023. Of concern is a decline in the condition score in Tookayerta Creek (from good to poor), Reedy Creek (from moderate to poor) and Salt, Preamimma & Rocky Gully (from moderate to poor) catchments in 2023. The Tookayerta Creek has generally been considered to be in good condition, due to permanent base flow, so mechanisms behind the observed declines warrant more detailed investigation."*

7.5.3 Water quality regime

Water quality is a key factor in influencing fish community condition in the EMLR WRPA. Like macroinvertebrates, changes in the fish community are influenced by salinity, nutrients and dissolved oxygen levels. Generally, most streams in the EMLR have sufficient dissolved oxygen concentrations. However, monitoring does not cover seasonal variation, and spot monitoring during fish sampling is required to provide insights into fish being absent from some sites. There are several sites where dissolved oxygen has been identified as a concern, such as Rodwell Creek, where intervention strategies are in place to help preserve the river blackfish population. There are several considerations for the risk and impact of low dissolved oxygen concentrations specifically over the cease-to-flow period, as the effects can be compounded if there are large–bodied fish (particularly common carp) in the pools. Sustained nutrient pollution from surrounding land uses, the increased concentration of these nutrients due to lower stream flow, and higher water temperatures may lead to reduced dissolved oxygen levels due eutrophication and algal decomposition (Klose et al. 2012).

The river systems of the EMLR WRPA are naturally high in salt and other dissolved solids due to the weathered nature of the catchments (South Australian Murray–Darling Basin Natural Resource Management Board 2019; South Australian Murray–Darling Basin Natural Resources Management Board 2019). Increased freshwater runoff during the flowing season allows streams and surrounding floodplains be to flushed, reducing salinity leading to improved water quality conditions. However, excessive salinity for the fish community is a concern during low flow periods. The population of river blackfish in the lower Marne River is considered to be at extreme risk of local extinction as the salinities of the pools across this reach are at, or exceeding their upper threshold for salinity tolerance (Gannon et al. 2021).

7.5.4 Barriers to dispersal

System connectivity (apart from the natural intermittent flow regime) and barriers to dispersal are an important factor for fish species in the WRPA. The WRPA would have previously hosted a diverse array and abundance of diadromous species including common and climbing galaxias, shortfin eels, congolli and potentially pouched lamprey (Whiterod & Hammer 2014b), but have been disconnected historically from the rivers and creeks in the WRPA due to regulating structures such as the Lakes barrages, on-stream dams present throughout the WRPA catchments, and barriers across the plains (e.g. Angas Plains) that prevent upstream dispersal. However, improvements to the number and design of fishways on the Lakes barrages (Bice et al. 2017) (and their continued openness since 2019), and enhanced passage to parts of the lower reaches of the southern WRPA rivers contributed through various programs (e.g. Sea to Hume Fishway Program, Barrett & Mallen‐Cooper 2006), have since improved upstream-downstream connectivity between the WRPA, the River Murray and the Lakes. It is noted that while these barriers impact the natural environment, they may have prevented the upstream dispersal of invasive species into the headwaters of rivers in the EMLR, but this benefit relative to the isolation of headwater habitat from diadromous native fish species is unknown.

7.5.5 Invasive fish species

The impact of invasive fish on native fish species is multifaceted. Firstly, many of the invasive species are large-bodied pelagic predators, not normally part of the fish community in these watercourses. As an introduced predator, they can exert a strong top-down pressure on the community that can alter the macroinvertebrate community (see section 6.5.5), with some parts of the community being more heavily influenced than others (e.g., pelagic swimmers). This is particularly notable for reaches with introduced trout and, to a lesser extent, redfin perch (McIntosh et al. 2010; Rowe et al. 2008). Aggressive invasive species like eastern gambusia, the most prevalent fish in the EMLR WRPA, made up nearly a third of all fish caught between 2014 and 2023 (Whiterod et al. 2023). Eastern gambusiais a small–bodied live bearer that is able to recruit quickly and is well adapted to still or low flow conditions with poor water quality (Seebacher & Kazerouni‐Ghanizadeh 2021), and can prey and injure other fish species (Rowe et al. 2008). Common carp impact water quality in streams due to the disturbance of sediment increasing turbidity, which may have impacts on visual hunting macroinvertebrates (Saikia & Das 2009).

Currently, the legal stocking of rivers in the WRPA with Rainbow and Brown Trout is not permitted, and ceased in 2018.

7.6 Conclusion

The environmental outcome for fish community in moderate or better condition was not achieved in the EMLR WRPA, as the overall median score was poor in 2023. However, the environmental outcome was achieved in every year except 2014 and 2023, and there has been a notable increase in fish community condition between 2019 and 2022. Trend since 2014, however, indicates a minor decline in overall condition at sampled sites (Whiterod et al. 2023). Populations of southern pygmy perch and mountain (and obscure) galaxias have likely been sustained over the assessment period, however Whiterod et al. (2023) reports some decline in abundance. Overall, Basin Plan has contributed to environmental outcomes through the Flows for the Future program, restoring low flows in the EMLR WRPA, maintaining pool environments and reducing the duration of cease-to-flow periods, which contribute to environmental outcomes for fish communities.

8 Actions to achieve environmental outcomes

The actions discussed below are considered the key actions to achieve the environmental outcomes identified in the LTWP for the EMLR WRPA; however, they are not the only actions available. These key actions have been identified through current plans or programs in place to undertake actions, or significant evidence to suggest that the action will result in a higher likelihood of achieving environmental outcomes.

8.1 Restoration of low flows

The continued implementation of low flow devices across the EMLR WRPA is seen as a critical part of the restoration of low flows and, in turn, the achievement of environmental outcomes for the WRPA. The achievement of the environmental outcomes for the WRPA are predicated on the assumption that low flows will be released for all dams and watercourse extractions (which comprised all licensed dams and watercourse extractions in the Marne and Saunders catchments and all licensed dams and watercourse extractions plus stock and domestic dams over 5 ML in volume for the EMLR catchments) (VanLaarhoven & van der Wielen 2012). Currently, the implementation of the low flow devices is being undertaken by the Flows for the Future Program, funded by the South Australian and Australian governments as part of the Sustainable Diversion Limit Adjustment Mechanism under the Basin Plan.

The Flows for the Future program continues to be delivered but full implementation of low-flow bypasses has not yet been achieved with currently over 440 of the targeted 720 sites passing low flows across the WRPA. While localised benefits are being provided, significant improvements to the flow regime require either increased connectivity between sites passing low flow and/or more sites passing low flows.

The review of the WAP for the EMLR identified an opportunity to re-evaluate the requirements for implementation of low flow devices to support achieving environmental outcomes (Hills and Fleurieu Landscape Board 2024).

It is important to note that full implementation of low flows will benefit the WDEs by improving water quality by more regular flushing with pulses of flow that are currently captured. There is a risk that the low flows may, at certain times of the year, lead to a temporary rise in salinity owing to the theorized impacts of the 'first flush'. However, it is generally considered that the benefits in terms of the majority of other aspects of water quality (e.g. dissolved oxygen, nutrient levels, water temperature) would be worth the temporary increase in salinity.

8.2 Managing high demand

Across the EMLR WRPA there are several management zones that are allocated above the sustainable extraction limit (a form of PEW) set in the WAPs. This is due to allocations being granted based on area of land use and enterprise water requirements rather than the sustainable extraction limits in the WAP. The impact of these high demand areas is currently unclear as there is a known discrepancy between allocation and use, the latter generally being lower, i.e. while allocation are higher than sustainable extraction limits, current use remains within the extraction limits. The Sustainable Diversion Limits under the Basin Plan set for the region are an aggregate figure, and the allocation or use above the sustainable extraction limit for individual zones may be offset by underuse in another zone; thus, take here remains within Basin Plan limits.

The allocation of water above the sustainable use limit represents a risk to WDEs if the full allocation is taken. There is an opportunity to address this risk with the upcoming amendment of the WAPs for the EMLR PWRA.

8.3 Watercourse rehabilitation

Rehabilitation of watercourses is recognised as being beneficial to the condition of macroinvertebrate and fish communities (Castellano et al. 2022; Collins et al. 2013; Osborne & Kovacic 1993). The key activities associated with this are fencing off the riparian corridor to exclude stock and revegetating watercourses to improve water quality and habitat quality. This coupled with improving land management practices to reduce the amount of nutrient running off the surrounding landscape and limiting the amount of erosion and fine sediment deposition occurring has been shown to help manage the risk of further degradation of WDEs (Castellano et al. 2022; Osborne & Kovacic 1993).

These actions fall outside the scope of the WAPs for the water resources of the EMLR WRPA. These restoration activities have occurred in isolated locations across the WRPA, but broader restoration would enhance the achievement of environmental outcomes in the future.

8.4 Barriers to dispersal

Improving dispersal ability of fish across the WRPA to allow fish to move between catchments and between the marine and freshwater environment would allow for further achievement of fish environmental outcomes in the WRPA. These include the ability for fish species to recolonise in the event of localised species loss and the ability for diadromous species of fish to utilise the upper catchments of the WRPA. In order to improve dispersal, the identification and subsequent modification to dispersal barriers across the lowland sections of the larger river systems in the EMLR WRPA are required.

Improvements to fish passage (e.g. fishways) as part of various programs (e.g. Sea to Hume Fishway Program, Barrett & Mallen‐Cooper 2006; Bice et al. 2017) along the River Murray and Lakes has allowed for the return of diadromous species of fish to the lower reaches of many of the EMLR WRPA rivers. However, many barriers moving upstream still exist across the lowland reaches of the major rivers of the EMLR (e.g., offtake structures and flow diversion weirs) and prevent many of the small-bodied diadromous species (e.g., common and climbing galaxias) from reaching the headwater habitats.

9 Appendices

Appendix A

Appendix A: Macroinvertebrate community condition scores (range: 1 – 6) calculated from the CMCM. Colours indicate the range and condition category for continuous scores (see key legend in Figure 6-2).

Catchment	Site	2016	2017	2018	2019	2020	2021	2022
Angas	Childrens Reserve			1.81				
Angas	Cosgrove Rd Site 2					1.97		
Angas	Cosgrove Road			1.76	2.1	2.79	2.45	
Angas	Dawson Ck Trib		2.94			2.36	2.58	2.88
Angas	Doctors Creek Lower				2.5	1.94	1.77	
Angas	Paris Creek LFB	2.59	2.2	2.36	2.34	2.41	2.67	1.89
Angas	Paris Creek Road	2.34	2.33	1.83	2.64	2.6	3.15	2.38
Angas	Quarry Road	3.05	2.88	3.18	3.43	2.95	3.25	2.93
Angas	Red Gum Rd		2.55	2.05	2.76	2.53	2.5	2.48
Angas	Rushmore Reserve	2.51	3.07	2.42	3.09	2.66	2.49	
Angas	Schmitt Road		2.55	2.32	2.22	2.41	2.53	2.64
Angas	Strathalbyn	2.58	3.26	2.87	2.63	2.67	2.36	2.19
Angas	Sunnydale Road	2.53	2.82	2.61	2.5	2.58	2.41	2.43
Angas	Whites Rd		2.98	2.94	2.5	2.61	2.6	2.39
Bremer	Bremer River between MOU and ROD							2.12
Bremer	Bremer River, near Callington							2.63
Bremer	Church Hill Rd		2.98	2.46	2.3	2.65		
Bremer	Frames Fire Track		2.5	1.7				1.57
Bremer	Lower Dawesley Creek, McAvaney property							2.06
Bremer	Mid Mount Barker Creek, Swinbourne property DCMB							2.45
Bremer	Mid-Rodwell Creek, Blackfish site							2.07
Bremer	Mount Barker Springs Alpaca DCMB							2.53

Catchment	Site	2016	2017	2018	2019	2020	2021	2022
Bremer	Upper Bremer River, Harrogate bridge							2.94
Bremer	Upper Dawesley Creek, Goodman property							2.73
Bremer	Upper irne Creek, Ironstone DCMB							2.41
Bremer	Upper Rodwell Creek		3.28	3.66	2.76	2.36	3.15	3.32
Bremer	Western Flat Creek Hack Street							2.89
Finniss	Braeside Road	2.83	3.07	2.69	3.08	3.17	2.55	2.43
Finniss	Bull Ck Trib		2.91	1.67	2.07	2.23	2.79	3.62
Finniss	Bull Creek	2.98	3.2	2.68	2.8	2.76	2.57	
Finniss	Meadows	1.98	2.42	2.59	2.79	2.98	2.4	1.79
Marne	Cranford Road		2.77	2.78	3.15	2.17	2.86	
Marne	Graetz Town Bridge		1.78			1.72	1.74	
Marne	Jutland Water Reserve		2.42	3.04	2.17	2.65	2.02	
Marne	Lartunga			2.26		2.29	2.99	
Marne	Netherford		2.65	3.23	2.62	1.85	1.8	
Marne	North Rhyne		2.27					
Marne	Springton Creek		3.17	2.57	2.9	1.91		
Marne	Vigars Road		2.24	2.73	2.25	1.93	2.21	
Saunders	Myrtle Grove		2.04	1.95	1.78	1.92		
Saunders	One Tree Hill Creek, near Springton		2.31				3.17	
Saunders	Upper Saunders Creek		2.1	1.95	1.39	2.16	1.66	3.07

10 Abbreviations and Glossary

10.1 Abbreviations

CMCM	Contemporary macroinvertebrate condition model
DEW	Department for Environment and Water (South Australia)
EMLR	Eastern Mount Lofty Ranges
EPA	South Australian Environment Protection Authority
EWRs	Environmental water requirements
HEW	Held environmental water
LTWP	Long-term Watering Plan
MDB	Murray–Darling Basin
MDBA	Murray–Darling Basin Authority
NDVI	Normalized Difference Vegetation Index
PEW	Planned environmental water
PWRA	Prescribed Water Resource Areas
WAP	Water Allocation Plan
WDE	Water-dependent ecosystems
WRPA	Water Resource Plan Area

10.2 Glossary

Amphipod	A small crustacean, similar in appearance to a shrimp, but without a shell.
Chironomids	A family of nonbiting midges.
Basin Plan	Adopted in 2012, the Basin Plan is a widespread, across governments, agreement to manage and protect water in the Murray–Darling basin.
Biomass	The total mass of sampled organisms, measured as wet or dry and for a particular sampled area such as m^{-2}.
Diadromous fish	Fish that migrate between salt water and freshwater.
Dissolved oxygen	The amount of oxygen that is dissolved, or carried, in water.
Eutrophication	The increase in the supply of organic matter to an ecosystem. Eutrophic systems are typically characterised by excessive plant and algal growth due to the increased availability of one or more limiting plant growth factors needed for photosynthesis including light, carbon dioxide, and nutrients.
Evapoconcentration	Concentration of a solution, e.g., salinity, due to evaporation of water.
Macroinvertebrates	An invertebrate that is large enough to be seen without a microscope.

Millennium Drought	From late 1996 to mid 2010, much of southern Australia (except parts of central Western Australia) experienced a prolonged period of dry conditions, known as the Millennium Drought. The drought conditions were particularly severe in the more densely populated southeast and southwest and severely affected the Murray–Darling Basin and virtually all of the southern cropping zones. The period from 2007–2010 was particularly extreme with extended periods of no flow through the barrages to the Coorong.
Murray–Darling Basin	An area of about 1 million km^2 in the south-east of Australia, it is almost 1,400 km long and about 800 km wide.
Pelagic	Inhabiting the water column.
Phragmites	Large perennial reed grasses found in wetlands.
Riparian vegetation	Vegetation that grows along the interface between land and a water body such as a river.
Salinity	Measure of the concentration of salt in the water. Commonly reported as PPT (parts per thousand) equivalent to $g\ L^{-1}$.
Turbidity	The measure of cloudiness of water.
Typha	A species of plant that can grow in water up to a depth of 0.8m, it is a noxious weed in Australia.
Water for the environment	Environmental water is 'held' or 'planned' environmental water, defined in the Water Act 2007. Held environmental water is available under a water access right for the purposes of achieving environmental outcomes; planned environmental water is committed to environmental outcomes and cannot be used for any other purpose unless required in emergency circumstances.

11References

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