MID-TERM REVIEW

Science Inquiry

A Report to Inform the Mid-term Review of the Healthy Waterways Strategy

Healthy Waterways Strategy 2018-2028

Port Phillip & Westernport, Victoria

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Acknowledgment of Traditional Owners

The rivers, wetlands and estuaries of the Port Phillip and Westernport region are part of Country belonging to the Bunurong, Gunaikurnai, Taungurung, Wadawurrung and Wurundjeri Woi-wurrung peoples. These Traditional Owners have lived in and been connected to the land, water, plants and animals of this area for many thousands of years, and we offer our respect to their Elders past and present.

Bunurong Land Council

Gunaikurnai Land and Waters Aboriginal Corporation

Taungurung Land & Waters Council
First people of the rivers and mountains

Wadawurrung

Wurundjeri Woi-wurrung

About the Health Waterways Strategy

Our rivers, creeks, wetlands, floodplains, estuaries and bays are shared places of significance for Victoria's economic prosperity, Traditional Owners, local communities and biodiversity. These places make up our complex and interconnected regional waterway system and collectively are of immense value. This Healthy Waterways Strategy recognises and embraces the complexity of regional waterway systems and waterway management.

Healthy Waterways Strategy 2018-2028

50 YEAR VISION

Healthy and valued waterways are integrated with the broader landscape, and enhance life and liveability. Waterways connect diverse and thriving communities of plants and animals; provide amenity to urban and rural areas, and engage communities with their environment; and are managed sustainably to enhance environmental, economic, social and cultural values.

The Healthy Waterways Strategy was created in 2018, establishing a region-wide plan to protect and improve the health of rivers, wetlands and estuaries across the Port Phillip and Westernport catchment. It reflects the aspirations and expectations of communities and stakeholders and the desire to achieve long-term protection and enhancement of the region's waterways.

The Strategy was co-designed by over 600 people and 220 organisations involved in water management including state agencies and local governments, water corporations, developers and community groups. Together, a 50-year whole-of-region Vision was established, along with Catchment Programs for each of the five catchments in the region – Werribee, Maribyrnong, Yarra, Dandenong and Westernport.

The Catchment Programs include a vision, goals, ten-year performance objectives and long-term targets (10 to 50 years).

This Science Inquiry Report forms part of the Healthy Waterways Strategy mid-term review which assessed Strategy progress and identified areas for improvement. The review provides an opportunity to look at what has changed in the operating environment since 2018 and how these changes may impact the ability to meet 2028 Strategy targets.

Find out more about the Healthy Waterways Strategy 2018-2028 >>

Learn about the mid-term review >>

Foreward

As members of the Mid-Term Evaluation Panel, we are pleased to present this inquiry into the values and threats to Melbourne's waterways as part of the mid-term evaluation of the Healthy Waterways Strategy. The inquiry has been complex and rigorous, drawing on data and modelling from Melbourne Water's various waterways research programs to inform an evaluation focused primarily on environmental values, and to a lesser extent, social values.

We acknowledge that an assessment of cultural values was not undertaken and was not in the scope of this inquiry. We encourage Melbourne Water to support Traditional Owners in their work to assess the health of Country and where Traditional Owners deem it appropriate, to integrate this knowledge into end-of strategy evaluation processes.

The role of the Evaluation Panel was to provide advice to Melbourne Water's evaluation coordinators, Melbourne Water governance groups and the Regional Leadership Group on the evaluation process and findings. We met 15 times between March 2022 and June 2023 and provided advice on the methods, findings and judgements associated with 10 technical reports as well as this overall inquiry report. Our deliberations have been collaborative and constructive drawing on the collective experience and knowledge of the Panel.

Our focus has been on ensuring the evaluation findings are robust and supported by transparent reasoning with the limitations and uncertainties clearly explained. Through a learning process, Melbourne Water and the Panel have refined the evaluation methods, developed evaluation capacity and identified where further work is required for the end-of-strategy evaluation.

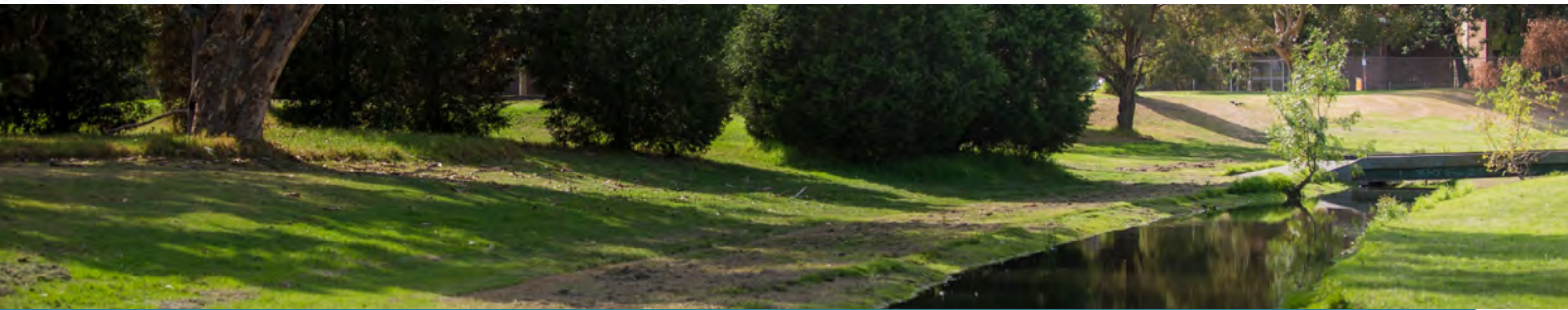
The inquiry has drawn on a long history of research and monitoring of environmental values, and it is evident that Melbourne Water is continuing to apply new technology and expand its knowledge assets. Despite this, some aspects of the evaluation have been limited by changes in methodologies and limited data. Whilst the analysis of social values, estuaries and wetlands is not as advanced as the in-stream environmental values, great strides have been made since the start of the Strategy. We encourage Melbourne Water to continue to progress monitoring, investigations, and research to address the knowledge gaps raised through this evaluation in preparation for Strategy renewal.

This inquiry has found that the challenges faced by our waterways are now greater than when the Strategy was developed. Updated climate projections indicate the impacts to instream values will be greater than anticipated in the≈ Strategy. The need to act to address the reduced availability of water is now clearer, while the threat from too much water associated with unmitigated urban development also continues.

With our support and encouragement, the Melbourne Water team have integrated the findings from various lines of inquiry to identify a set of focus areas. These focus areas not only highlight areas of concern based on the current assessment of values, threats and level of Strategy implementation but also point to the future, identifying areas for consideration based on our updated understanding of the impacts of a drying and warming climate.

Despite the sobering findings from this evaluation, the identification of focus areas provides an opportunity for Melbourne Water to recommit to achieving the Strategy's performance objectives. Further investigation of the likelihood of meeting performance objectives and the role of collaboration will help build a comprehensive picture about the effectiveness of Strategy implementation to date. We urge Melbourne Water and its partners to capitalise on the impressive work undertaken through this inquiry to guide the remaining five years of the Strategy.

Michelle Dickson (Chair)
Tamara Boyd
Leon Metzeling
Ian Rutherfurd



Executive Summary

About the Science Inquiry and Mid-term Review

The Science Inquiry is a critical part of the Healthy Waterways Strategy mid-term review, which is designed to help Melbourne Water, delivery partners and the Region-wide Leadership Group understand how implementation of the Strategy is progressing and what needs attention.

The mid-term review has been divided into three main parts:

- A **Science Inquiry** (this Report)
- An **Implementation Inquiry** to assess implementation progress and co-delivery, and
- A formal '**response**' developed in collaboration with delivery partners to outline next steps for the *Healthy Waterways Strategy.*

The Healthy Waterways Strategy considers the health of waterways using a framework of waterway values and waterway conditions with long term targets (50 years) set for each. Ten-year regional and sub-catchment Performance Objectives were also established to guide on-ground actions, initiatives and collaborations that progress towards the long-term targets. Performance Objectives cover themes such as stormwater, vegetation and pests, water quality, water for the environment, cultural and social values.

The Science Inquiry assessed the trajectory of key values across the region and the state of current threats to waterway conditions. The Implementation Inquiry assessed implementation progress and co-delivery.

Figure 1. Context of the Science Inquiry and Implementation Inquiry.

What the Science Inquiry Examined

The Science Inquiry brought together multiple lines of evidence from Melbourne Water's monitoring and research program to inform Healthy Waterways Strategy decision-makers.

It focused on answering key evaluation questions to understand:

i. How key values and conditions were tracking,

ii. The status and management of threats across the region,

iii. If interventions (for example - revegetation) were effective, and

iv. The key remaining knowledge gaps that need to be addressed.

Importantly, the Science Inquiry also identified focus area sub-catchments where implementation efforts should be brought back on track as a priority.

Science Inquiry Assessment and Limitations

Investment in monitoring and evaluation through the Healthy Waterways Strategy has enabled both environmental (macroinvertebrates, platypus, fish, riparian vegetation, riparian birds, wetland birds, and frogs) and social (community connection, recreation, and amenity) values to be evaluated.

Despite this, there are gaps in the Science Inquiry for some values and conditions. In particular, not all values could be assessed across all sub-catchments and there was limited environmental condition data (e.g. physical form and litter) available for the mid-term evaluation.

Data collection programs have recently been established for estuaries; however, it was not yet possible to assess the status of values or threats for estuaries as part of this mid-term evaluation. It was possible to assess the status of social values (Community Connection, Recreation, and Amenity), but further understandings of threat potential, data availability and confidence, threat impact, trajectory, and assumptions are needed.

The Science Inquiry did not examine the status and trends of cultural values and this is recognised as a limitation of the evaluation. The incorporation of cultural indicators and Traditional Owner systems for assessing health of Country into the end of Strategy evaluation will be an important step forward. Further work is required to enable and support Traditional Owners to lead this process.

What the Science Inquiry Found

Key Values Trajectories

Key value trajectories were mostly assessed at the sub-catchment scale, of which there are 69 across the five major catchments. In-stream environmental values (platypus, fish and macroinvertebrates) were largely on the target trajectory ('on-track') to achieve long-term targets, with stable trajectory ratings in greater than 72% of assessable sub-catchments.

There is evidence that the condition of vegetation is improving along reaches that are being actively managed. Sites which have been revegetated for over 10 years have similar species richness to remnant areas however weeds dominate the understory and the sites lack important structural components such as recruitment.

The evaluation found Riparian birds to be on the target trajectory ('on-track') to meet long-term targets across most of the assessable sub-catchments (37 of 45 or 45% of all 69 sub-catchments). Wetlands birds were found to be on the target trajectory ('on-track') to achieve long-term targets in 18 of the 25 assessable priority wetlands. Social values (Community connection, Recreation, and Amenity) were evaluated at a larger scale (14 management units) than other values and only 2-3 (out of 11 assessable management units) for each value were found to be on the target trajectory to achieve long-term targets - this result is not cause for concern at this stage as most of satisfaction percentages have stabilised or improved since 2018. An interim assessment of threatened frog species trajectory pointed to possible widespread declines across the Melbourne region, including in sub-catchments not associated with rapid urbanization, mirroring similar declines elsewhere (regionally and globally) – further investigation is required to confirm this finding.

Where values were not on the target trajectory to achieve long-term targets, particularly for instream values, this was often associated with the longer-term degradation of waterway condition caused by multiple threats. Importantly, the Healthy Waterways Strategy is aiming to reverse this condition deterioration.

Impact of the Strategy to date

Modelling has provided new insights into the likely effectiveness of selected management activities for environmental conditions and the predicted impacts on some values. The removal of in-stream barriers in several sub-catchments (Dandenong Creek Lower, Yarra River Lower, Darebin Creek and Maribyrnong River) have been associated with improvements in the habitat suitability of migratory fish species, highlighting the immediate benefits of enabling river connectivity. Forest cover is predicted to have increased across the region due to revegetation activities, but the change is considered relatively minor (in age of vegetation and spatial extent) and not enough to achieve detectable effects on habitat suitability yet. There has been limited implementation of stormwater control measures which has been associated with an increase in directly connected imperviousness.

Overall, these changes to environmental conditions, principally driven by unmitigated urbanisation, are associated with a slight deterioration to no discernible improvement in habitat suitability for macroinvertebrates, platypus and native fish species.

Threats

The evaluation identified that a number of threats have increased since 2018. Urbanisation (unmitigated stormwater) decreased water availability, and pest animals (mainly deer) were identified as the top three threats to environmental values that have increased since the start of the Strategy. In particular, the Victorian Government long-term water resources assessments for each catchment indicated significant declines in water availability. Additionally, the inquiry has identified that we have underestimated the potential impact of climate change for the Healthy Waterways Strategy long-term targets (10 to 50 years) and, to a lesser extent, the 10-year performance objectives. Air temperatures will be greater, and flow conditions generally drier, than originally predicted. The impact of these changed climate predictions for our index of macroinvertebrate health are minimal. However, for platypus, and the native fish species assessed (River blackfish and Ornate galaxias), climate change may pose a greater risk than originally modelled, with reductions in the highest quality habitat predicted even with planned interventions that improve riparian vegetation and manage for stormwater.

Although the Urban Growth Boundary (UGB) has not changed since 2018, our ability to mitigate development with adequate stormwater interventions in priority areas has not kept pace with the rate of development.

The loss of wetlands and headwater streams through physical modifications related to urban development has been highlighted through annual reporting on the Healthy Waterways Strategy and remains an area of concern.

Wastewater impacts, instream barriers, and streamside vegetation clearance (low confidence) are the only threats ranked as stable or decreasing in all sub-catchments. Forested sub-catchments (mainly in formally protected areas) have the fewest threats, although climate change is considered a significant threat, particularly in relation to an increased risk in the frequency of high-severity forest fires. Threats from deer were identified as potentially impacting values in many areas, and the potential threat from recreational access has been flagged but low confidence in this assessment means further investigation is required. In many cases threats to environmental values are also threats to social values (i.e. good environmental condition underpins many aspects of social values).

How this information was used

Using this combined information, the Science Inquiry identified focus areas for further investigation in the Implementation Inquiry. Focus areas are sub-catchments identified as having multiple stable values (18/69 sub-catchments), multiple declining values (16/69 sub-catchments), and either being climate change strongholds (14/69 sub-catchments) or climate change vulnerable (18/69 sub-catchments).

Focus areas were further classified on the basis of existing environmental condition into Group A (mostly moderate to very high rating of environmental conditions) or Group B (mostly very low to low rating of environmental conditions) for the purpose of informing strategic planning over the remaining strategy time frame.

It was emphasised that sub-catchments with low and very low condition scores are still important in the Healthy Waterways Strategy and many of these sub-catchments have performance objectives to improve conditions and values over time.

Climate change stronghold and climate change vulnerable sub-catchments were mostly situated in the upper, least- disturbed parts of the region's catchments. These areas support some of the region's greatest ecological values, including threatened species and ecosystems, and the findings indicate that greater effort may be required to support their resilience into the future.

Lessons and Recommendations

A number of key learnings emerged during the Science Inquiry.

First, our ability to mitigate the impacts of urban development has been limited to date. While progress has been made in overcoming in-stream barriers and revegetating riparian zones, there has been minimal implementation of stormwater control measures and the extent (and environmental impact) of imperviousness has increased since the start of the Strategy.

Second, an examination of new climate change predictions has revealed that we have underestimated long-term predicted impacts to environmental conditions and values.

Third, the Science Inquiry has highlighted that declining water availability is a key threat to the Strategy and further work is required to understand the extent of impact and what this means for effective management actions.

Fourth, adequate and appropriate data availability has been vital to ensure the evaluation of conditions and value, but there remain extensive data gaps, particularly for estuaries and wetlands, and improvements to data storage and management will improve future Strategy evaluation.

Finally, attributing the influence of management actions to observed changes in long-term monitoring data trends is challenging and requires learnings from multiple lines of evidence that is guided by an informed understanding of the connections within a system (e.g. via conceptual models underpinned by available scientific evidence).

The Science Inquiry has identified focus area sub-catchment and themes (e.g. increasing climate change threat) through analysis of available evidence. These findings will be considered by the Implementation Inquiry and inform future strategic planning. The knowledge gaps and general learnings highlighted by this Science Inquiry will also inform future applied research activities as well as ongoing monitoring, evaluation and reporting practices.

Recommendations

Draft recommendations were developed through the key values and threats technical papers and research fact sheets which were then reviewed and refined to formulate a consolidated list. Recommendations are grouped in the following themes:

- Knowledge gaps - Monitoring and investigations
- Knowledge gaps - Research, and
- Implementation program improvements (to be considered in the Implementation Inquiry).

Knowledge gaps – Monitoring and investigations

Value/ Condition	Near-term (i.e. for remainder of current HWS and to inform the development of the next strategy)	Long-term (on-going)
Knowledge gaps	**S-1.1** Prioritise Monitoring and Investigations knowledge gaps through the process outlined in the Mid-Term Evaluation Science Inquiry and develop a monitoring and investigation plan to include in the Healthy Waterways Strategy Mid-Term Evaluation Response Report.	

Knowledge gaps – Research

Value/ Condition	Near-term (i.e. for remainder of current HWS and to inform the development of the next strategy)	Long-term (on-going)
Knowledge gaps	**S-2.1** Prioritise Research knowledge gaps through the process outlined in the Mid-Term Evaluation Science Inquiry and develop recommendations to be included in the Response Report.	

Implementation program improvements

Use latest knowledge to continuously improve program delivery. Specifically:

Value/ Condition	Near-term (i.e. for remainder of current HWS and to inform the development of the next strategy)	Long-term (on-going)
Traditional Owners	**S-3.1** Support a self-determined review process by Traditional Owners, aiming for this to be progressed over the next 12 months.	
Focus Areas	**S-4.1** Focus Implementation Inquiry on priority themes and focus sub-catchments emerging from the science synthesis.	**S-4.2** Investigate management options in climate vulnerable sub-catchments to improve resilience for identified species or communities.
Multiple	**S-5.1** Urgently develop strategic management plans for key threatened species such as Growling grass frog, Southern toadlet, Yarra pygmy perch and key macroinvertebrate species, including the consideration of translocation as an option following disturbance events.	**S-5.2** Prioritise the implementation of long-term intervention monitoring programs for key works such as vegetation establishment and maintenance, fishway performance and stormwater interventions to validate and support programs.
Vegetation	**S-6.1** Prioritise locations for deer management using modelling and field data and consider developing targets and metrics for annual reporting.	**S-6.4** Update Melbourne Water's revegetation guidelines to include climate change mitigation actions, new information on chemical use, bird habitat design and amenity outcomes such as shading.
	S-6.2 Identify sites that could be used for direct seeding to build capacity in applying this technique that has the potential to increase the efficiency of revegetation efforts at suitable sites.	
	S-6.3 Improve the success of revegetation outcomes by ensuring adequate mid-storey vegetation and native groundcover is established and maintained in revegetated areas.	
Fish	**S-7.1** Continue to invest in in-stream barrier removal and fishways. Evidence suggests that fishways are an effective management lever to support migratory species when they are well maintained and functioning.	
	S-7.2 Investigate opportunities for a more pro-active approach to fish and platypus habitat restoration and whether new POs in priority locations should be considered for the next strategy.	

Value/ Condition	Near-term (i.e. for remainder of current HWS and to inform the development of the next strategy)	Long-term (on-going)
Platypus	**S-8.1** Investigate opportunities to improve habitat (10-40 km additional) upstream of existing urban areas (i.e. above Princess Freeway) for the existing platypus community in Cardinia Creek and change the riparian vegetation (increase extent) targets if appropriate.	**S-8.3** Consider developing POs for improving connectivity at major storages and managing the threat of litter on platypus in priority locations.
	S-8.2 Investigate the feasibility of re-introducing platypus to Toorourrong Reservoir.	
Frogs	**S-9.1** Review location of POs for Bibron's toadlet and add new priority sub-catchments where data indicates populations are more likely to be present.	
Social Values	**S-10.1** Develop social values POs and targets for priority wetlands. Consider the potential for conflicting impacts between social and environmental values on different wetland typologies.	
	S-10.2 Consider additional funding and incentive mechanisms to improve interpretative signage along waterways to provide information on plants, animals and cultural values.	**S-10.5** Improve outcomes for social values by considering the strategic provision of facilities such as toilets, bins and seating and more community events, including opportunities for communities to be involved in management activities (e.g. clean-up and tree planting days).
	S-10.3 Continue to support citizen science programs such as Waterwatch, Frog Census and Estuary Watch and ensure adequate training on monitoring design and data analysis is undertaken to ensure data collected can be used effectively. Ensure recognition events are conducted regularly to acknowledge the valuable contribution citizen scientists make to waterway management.	
	S-10.4 Utilise data from the implementation of the new litter monitoring method to validate threat rating and identify litter prioritisation hotspot spatial analysis. Ensure high litter areas are reported either through the RPO or consider the addition of sub-catchment POs.	
Water for Environment	**S-11.1** Consider improved ways of assessing and reporting on the delivery of existing environmental entitlements and allocations on the strategy website to allow greater transparency and progress tracking.	
Water Quality	**S-12.1** Develop indicators and rubrics for construction runoff to ensure progress can be more quantitatively assessed for these POs.	
	S-12.2 Continuously improve the management options delivered by Melbourne Water's rural land program by integrating relevant monitoring data and research findings to inform the design and range of potential interventions, including updating the water quality metrics used to assess the likely benefits of particular interventions.	
	S-12.3 Review the location of performance objectives for managing run-off from industrial areas and associated water quality impacts and develop indicators, targets and/or quantitative metrics for assessing progress, including the required actions necessary to achieve sub-catchment and regional targets. Further develop spatial mapping of existing and future hotspot areas for industrial pollution. Consider the development of a 'toolkit' for structural and non-structural management options in industrial estates.	
	S-12.4 Combine the available knowledge and data on contaminants that accumulate in stormwater wetland sediments and consider using in existing maintenance prioritisation tool. Assess how contamination influences wetland performance, desilting frequency, waste disposal and maintenance costs, to help inform management protocols.	
	S-12.5 Advocate for changes in bifenthrin application for termite control in housing estates. Actions could include updating urban construction guidelines, education of construction companies and the pest control industry or chemical substitution.	

Value/ Condition	Near-term (i.e. for remainder of current HWS and to inform the development of the next strategy)	Long-term (on-going)
Stormwater	**S-13.1** Understand the barriers to the implementation of HWS stormwater POs (e.g. lack of policy, guidance, capacity, funding, and/or sector willingness).	
	S-13.2 Update industry guidance for stormwater infiltration design (e.g. update constructed wetland guidelines to support design of effective infiltration).	
	S-13.3 Review guidance and procedures to prevent stormwater wetlands from being constructed within waterways.	
Wetlands, headwaters and floodplains	**S-14.1** Strengthen reporting on the need for protection of natural wetlands from the specific threat of urban development. Consider the addition or alteration of RPOs.	
	S-14.2 Develop and implement updated waterways spatial data for streams that are considered "designated waterways" in accordance with the Water Act 1989.	
	S-14.3 Ensure new regional priority wetlands identified since 2018 (that do not have POs) are managed to maintain existing values for example risk-based predator control. Include these in Annual Reporting.	
	S-14.4 Seek to update state wetland spatial data in the Port Phillip and Westernport region to reflect the best available information and alignment with the Healthy Waterways Strategy and the Regional Catchment Strategy.	
	S-14.5 Investigate options for changing policy instruments to support the protection of natural wetlands.	
	S-14.6 Explore further opportunities for improving wetland protection e.g. using the Catchment and Land Protections Act, 1994 and development referrals, particularly for those natural wetlands of most significance such as seasonal herbaceous wetlands.	
	S-14.7 Develop guidelines for the protection/restoration of natural wetlands and headwater streams in urbanising catchments, including setbacks that protect floodplain function and develop performance measures to track protection efforts.	**S-14.8** Further investigate opportunities to re-connect waterways with floodplains and billabongs, using lessons learnt from recent intervention monitoring projects such as Yellingbo.

Next Steps

The recommendations stemming from the Science Inquiry will be considered alongside those from the Implementation Inquiry Report and will be responded to and prioritised through the formal response.

Glossary of Terms and Abbreviations

AI	Attenuated Imperviousness
AF	Attenuated Forest cover
BAUF	business as usual future (for 2068)
CURR	Current, 2018 baseline
DCI	Directly Connected Imperviousness
ETP	Eastern Treatment Plant
GCM	global climate models
GED	General Environmental Duty
HSM	habitat suitability model
HWS	Healthy Waterways Strategy 2018
HWS priority wetland groups	The 82 wetland groupings (or 123 individual wetlands) identified in the 2018 HWS strategy which include targets and performance objectives
KEQ	Key Evaluation Question
LUMaR	Land Use Macroinvertebrate Response index, a macroinvertebrate index that has been developed for the Melbourne region
Long-term targets	Targets set during HWS development that indicate the aspirations of the community for each value over a 50+ year time frame
MEP	Monitoring and Evaluation Plan
MERI	Monitoring, Evaluation, Reporting and Improvement
PO	Performance Objective
RBI	Riparian Bird Index
RCP	Representative Concentration Pathways: a greenhouse gas concentration (not emissions) trajectory adopted by the Intergovernmental Panel on Climate Change
Regionally significant wetlands	The 249 wetlands identified in the 2020 Wetlands Monitoring and Evaluation Plan (MEP; Melbourne Water 2020b) as being regionally significant. These are identified in the MEP and have monitoring programs suggested
RLG	Region-wide Leadership Group
RPO	Regional Performance Objective
SCPO	Sub-catchment Performance Objective
Strategy	Refers in this instance as the 2018 Healthy Waterways Strategy
SPTs	Sewage treatment plants
UGB	Urban Growth Boundary
Waterways	Refers to either River, Wetland or Estuary
WTD	Works-to-date refers to HSM modelling that incorporates works undertake between 2018 and 2022 for riparian revegetation, stormwater interventions and fishways to understand improvement in habitat suitability across the region
WTP	Western Treatment Plant

Introduction

Context

As part of monitoring the progress of Performance Objectives or actions, all Victorian catchment management authorities (including Melbourne Water) must undertake a mid-term review of the Healthy Waterways Strategy by the adaptive management framework set out in the State Government's Victorian Waterway Management Strategy (2013).

The Monitoring, Evaluation, Reporting and Improvement (MERI) framework for the HWS developed in 2019, and Monitoring and Evaluation Plans (MEPs) for rivers, estuaries, and wetlands are fundamental to supporting the mid- term review. The MEPs describe the monitoring indicators and reporting requirements needed to effectively track the progress towards targets and objectives set in the Healthy Waterways Strategy.

The HWS mid-term review is intended to drive improvements in Strategy implementation, in line with an adaptive management approach, and increase preparedness for end-of-strategy evaluation. Therefore, it is a critical reflection and pivot opportunity toward achieving a shared strategy across Melbourne Water, State and local government, water corporations, Traditional Owner organisations, the community and others who have a role in waterway management.

Scope and Focus of the Mid-term Review

The HWS mid-term review plan was developed which outlined the scope and approach that would be undertaken (HWS Mid-Term Evaluation Plan). It was informed by a participatory evaluation planning process involving key stakeholders and Melbourne Water staff. Through this process stakeholders highlighted that they wanted to know how key values and conditions were tracking and if interventions (e.g. revegetation) were effective. They also wanted to understand what has been achieved so far in terms of collaboration and co-delivery.

The HWS mid-term review has been divided into three main elements, a Science Inquiry (this Report), an Implementation Inquiry (which evaluated where implementation is currently off track, whether the targets are likely to be met by the end of the Strategy and the strengths of the collaborative delivery approach) and a formal response prepared by Melbourne Water with delivery partners and the Region-wide Leadership Group, which decides how findings and recommendations will be actioned from the Implementation and Science Inquiry Reports (Figure 1).

The HWS mid-term evaluation has been divided into 3 main parts (Figure 1).

The Mid-term Review comprises

A **Science Inquiry** to assess changes to the trajectory of key values across the region, the state of current threats to waterway conditions and knowledge gaps.

An **Implementation Inquiry** to assess progress and evaluate factors influencing implementation of the Strategy and the likelihood of meeting 10-year Performance Objective targets.

A formal '**response**' developed in collaboration with delivery partners that outlines adjustments to implementation of the Healthy Waterways Strategy for 2024-2028 and beyond.

Figure 1. Components of the of HWS Mid-term Review.

The Science Inquiry (this Report) presented evidence assessing the trajectory of key values across the region and the state of current threats to waterway conditions. Using this combined information, it identified where additional focus may be required to support key values.

While benefits of actions from the last five years are unlikely to be realised yet, any significant declines in values during the recent past are concerning as our values are lagging indicators of changes occurring in the environment. The Healthy Waterways Strategy made explicit for the first time the effort required to address threats such as urbanisation and climate change and as such long-term targets were sometimes about halting decline.

The mid-term review has been guided by Key Evaluation Questions that were set out in the Monitoring, Evaluation, Reporinting and Imporovement (MERI) framework. The questions were refined when establishing both the science and implementation inquiries (Table 1).

Table 1. Key evaluation questions in the HWS MERI framework and the sub-key evaluationqQuestions developed for the mid-term review for both Science and Implementation Inquiries.

Key Evaluation Questions and sub-Key Evaluation Questions	Where answered
1 – To what extent have the performance objectives of the Strategy been achieved?	Implementation Inquiry
1a. To what extent is strategy delivery on track to achieve the Performance Objective targets by 2028?	
1b. To what extent has collaboration and co-delivery contributed to achieving the Performance Objective targets so far?	
2 – To what extent has progress been made towards the longer-term environmental condition targets for rivers, wetlands and estuaries?	Science Inquiry
2a. What environmental conditions (e.g. Water Quality) and external conditions (e.g. Policy) help explain current key value trends?	
2b. To what extent have projected known and emerging future threats changed from 2018? Have any assumptions about impacts to key values changed?	
3 – What is the state of waterway values?	Science Inquiry
3a. To what extent are key values on the target trajectory?	
3b. What other spatial and temporal trends and patterns for key values are of significance for implementation?	
4 – To what extent have the delivery methods of the Strategy been appropriate, effective, and efficient?	
4a. To what extent are interventions appropriate and effective for achieving outcomes?	Science Inquiry
4b. What are the key remaining knowledge gaps that need to be addressed in the≈next 5 years to improve strategy delivery or prepare for the next HWS?	Science Inquiry
4c. How can collaborative governance enable effective and efficient delivery of the Strategy?	Implementation Inquiry

The mid-term review was coordinated by the Waterways, Biodiversity and Environment team and the Applied Research Team at Melbourne Water and supported by an independent panel including members with a strong background in waterway management, science and evaluation.

While the panel focused largely on the Science Inquiry it also contributed to the Implementation Inquiry. The role of the panel was to guide the evaluation by ensuring the information had sound reasoning, that the evidence used was credible and that any limitations or uncertainties were made explicit. The Group Charter for the panel is available in Appendix 2. The panel reviewed the draft inquiry reports and recommendations. The panel also played a key role in communicating the process and findings to the governance groups including the RLG.

Approach

Long-term investment by Melbourne Water in applied research of waterways together with surveillance and intervention monitoring provided an evidence base to support the evaluation.

Research undertaken through the Melbourne Waterways Research Program informed the evaluation with respect to the effectiveness of many interventions such as revegetation, stormwater management and deer management. There was also new knowledge incorporated from research outcomes about waterway conditions and threats, such as emerging contaminants of concern, physical form and litter.

The Science Inquiry was conducted using multiple lines of evidence (e.g. conceptual models, predictive models, data etc.) through a mixed methods approach. Evaluative judgements were informed by a combination of quantitative and qualitative analysis. Rubrics were developed or refined to guide assessments and ensure transparency in the evaluation findings.

Inquiry Limitations and Constraints

The evaluation process was adaptive, a reflection of learning and capacity building that took place as the inquiries unfolded and it is acknowledged that this is the first time such a complex and rigorous mid-term evaluation of a Melbourne region waterway health strategy has been undertaken. Not all key evaluation questions could be evaluated across all values or all waterways.

In addition, some analyses (e.g. updated climate change predictions and works-to-date habitat suitability models) were not available until mid-way through the process. As such, some key evaluation questions could not be fully evaluated until the analysis was brought together in the synthesis. Further, we were unable to evaluate estuaries due to insufficient data. Specific limitations for important parts of the Science Inquiry are noted where necessary.

The Science Inquiry did not examine the status and trends of cultural values and this is recognised as a limitation of the evaluation. The incorporation of cultural indicators and Traditional Owner systems for assessing health of Country into the end of Strategy evaluation will be an important step forward. Further work is required to enable and support Traditional Owners to lead this process.

Structure of this Report

An outline of the report structure and an overview of each section is provided below:

Part A looks at trajectories of key values where data is available and where possible identifies factors driving either declines or improvements in values.

Part B provides a summary of threats across the region to understand where they are continuing to increase and whether these were expected or based on new information.

Part C uses habitat suitability models to predict the benefits of the works undertaken between 2018 and 2022.

Part D brings together the values trajectory analysis, the effectiveness of 'works to date' as predicted by habitat suitability models and the threats analysis to understand common spatial and temporal patterns across the region and between values.

Part E identifies and reviews on ground interventions being applied across the region to understand the level of application and lessons regarding their effectiveness and appropriateness as management techniques.

Part F summarises key remaining knowledge gaps.

Part G provides insights into the relationship between the HWS and other key strategies and plans and the extent to which the findings of the evaluation are relevant to these related documents.

Part H summarises recommendations.

PART A

Key values evaluation

Introduction

Part A focuses on summarising key value technical documents that addressed key evaluation question 3 and key evaluation question 2, and relevant sub-questions, where possible. The ultimate goal of Part A is to evaluate whether the HWS is on-track to achieve longer term targets for each key value. An additional focus was to unravel the possible reasons for the trajectory, good or bad, of key value targets.

While actions from the last five years are unlikely to be have led to measurable outcomes yet, any substantial declines in the trajectory of values during the recent past are concerning as our values are lagging indicators of changes in the environment. For the first time, the HWS made explicit the effort required to address threats and as such long term targets were sometimes about halting decline.

Where relevant in the text, recommendations and opportunities for improvement were stated. The limitations of each key value evaluation were also summarised.

As stated in the Introduction, this is the first time such a complex and rigorous mid-term evaluation of a Melbourne-region waterway health strategy has been undertaken and, as such, the evaluation process was adaptive, being a reflection of the learning and capacity building that took place as the inquiry unfolded. Some data sets (e.g. updated climate change predictions and the habitat suitability models) were not available until mid-way through the process. As such some key evaluation questions could not be fully evaluated until the analysis was brought together in the synthesis.

Long-term monitoring datasets (that predate the HWS) were available for many key values, particularly for rivers. However, data gaps existed at the time of the evaluation for some waterways and values which limited the ability to conduct a full evaluation. This is reflected in Table 2, which provides an overview of key values that could be evaluated. All values for rivers could be evaluated, some values for wetlands and none for estuaries at the time of this inquiry. Many new monitoring programs have recently been initiated (e.g. eDNA, estuary fish, birds and vegetation) and by the end of strategy review period in 2026 it is envisaged that enough data will have been collected to fill some of the data gaps identified in Table 2.

Table 2. Overview of which key values were evaluated.

Asset type	Key value	KEQ 3a	KEQ 3b	KEQ 2a
Rivers	Platypus	✓	✓	✗
	Fish	✓	✓	✗
	Macroinvertebrates	✓	✗	✓
	Vegetation	✗	✓	✓
	Birds	✓	✓	✗
	Community connection	✓	✓	✓
	Recreation	✓	✓	✓
	Amenity	✓	✓	✓

Asset type	Key value	KEQ 3a	KEQ 3b	KEQ 2a
Wetlands	Birds	✓	✓	✓
	Frogs	✓	✓	✗
	Fish	✗	✗	✗
	Vegetation	✗	✗	✗
	Community connection	✗	✗	✗
	Recreation	✗	✗	✗
	Amenity	✗	✗	✗
Estuaries	Birds	✗	✗	✗
	Fish	✗	✗	✗
	Vegetation	✗	✗	✗
	Community connection	✗	✗	✗
	Recreation	✗	✗	✗
	Amenity	✗	✗	✗

The next section summarises the key evaluation question results for key values: aquatic macroinvertebrates, platypus, riverine fish, riparian vegetation, riparian birds, wetland birds, frogs, community connection, recreation, and amenity.

Macroinvertebrates (Rivers)

Introduction

Macroinvertebrates are a key environmental value in the Healthy Waterways Strategy 2018 and macroinvertebrate assemblages are generally acknowledged to be excellent biological indicators of overall stream health. Macroinvertebrates as indicators of river health are part of the Environmental Reference Standards used to provide guidance on what is expected in various segments of streams and rivers in Victoria (Environment Protection Authority, Victoria 2021).

The Land Use Macroinvertebrate Response (LUMaR) index is a macroinvertebrate index developed for the Melbourne region. The LUMaR index incorporates observed-to-expected ratios and taxon-sensitivity weightings for 59 macroinvertebrate families. Habitat suitability models were developed for the HWS and these were used to illustrate current condition, a business-as-usual future and the long-term target trajectory (Figure 2).

Macroinvertebrates are an important part of the food chain for other key environmental values in the HWS including platypus, fish, frogs and birds so the maintenance and improvement of macroinvertebrates is fundamentally linked to the management of other values. Several species of macroinvertebrate are endemic only to the Melbourne region and are considered vulnerable or threatened (Government of Victoria 1988).

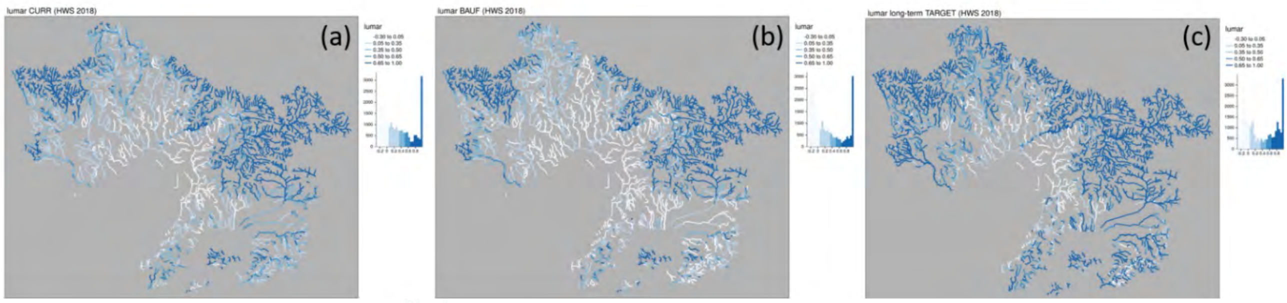


Figure 2. Modelled macroinvertebrate LUMaR values (presented in five categories). Macroinvertebrate LUMaR predictions for the (a) 2018 baseline (CURR), (b) 2068 business-as-usual future trajectory (BAUF), and (c) long-term HWS target for 2068 are displayed. Deeper blues indicate higher predicted LUMaR values.

Evaluation criteria were developed to guide the data analysis and evaluation of the relevant key evaluation questions. These criteria are available in the Macroinvertebrate Technical Report (Macroinvertebrates: A Technical Report to Inform the Healthy Waterways Strategy Mid-term Evaluation) and the HWS Mid-term Values Synthesis findings (HWS Mid-term Values Synthesis Results). Below we summarise the approach and the outcomes of the evaluation.

Photo credit: Eddie Tsyrlin

KEQ 3a. To what extent are key values on the target trajectory?

Approach

An analysis was undertaken at two scales; a) at monitoring site scale based on the long-term macroinvertebrate monitoring data and b) at sub-catchment scale using Habitat Suitability Models (HSMs). The results from the two approaches were combined to answer key evaluation question 3a.

a. Of the 132 long-term monitoring sites in the macroinvertebrate monitoring program, 77 sites had enough data to be analysed for trends over the historical period (1992-2022). Sites that were ‘declining’ or ‘improving’ by >0.15 LUMaR with a high or moderate level of confidence in the trend over the historical period were categorised as having a ‘declining’ or ‘improving’ trajectory.

b. A modelling analysis was undertaken to compare predictions made at the start of the strategy (CURR) with predictions that reflect conditions in 2022 (works-to-date) at the sub-catchment scale. Works-to-date (WTD) modelling integrated all revegetation and stormwater interventions undertaken in priority areas between 2018 and 2022 plus unmitigated urban development in stormwater priority areas - see complete methods in the HSM Management Activities Technical Report (Chee, Walsh, et al. 2022). Briefly, spatially explicit reach-scale changes in habitat suitability were determined for LUMaR – changes were summarised at the sub-catchment scale. The top sub-catchments with a ‘significant’ decline or improvement in habitat suitability (defined as a >0.15 change in LUMaR), were categorised as having a ‘declining’ or ‘improving’ trajectory. An additional modelling analysis was carried out to predict the benefits to macroinvertebrate habitat suitability if all of the 10-year strategy targets are met.

Outcome

Site scale analysis

Macroinvertebrate trends were assessable at the majority (77) of the 132 long-term monitoring sites. A summary of the results by major catchment is provided in Table 3. Thirty-seven of the sites had a ‘stable’ trend, 14 had an ‘improving’ trend, and 20 were classified as having a ‘declining’ trend.

Table 3. The number of sites in each MW river catchment classified as having ‘stable’, ‘increasing’, ‘declining’, ‘variable’, or ‘not yet assessable’ LUMaR index trends over the entire data time span (historical).

Catchment	Stable	Improving	Declining	Variable	Not yet assessable	Catchment total
Dandenong	4	3	0	0	3	10
Maribyrnong	6	0	7	2	12	27
Werribee	3	0	2	2	16	23
Westernport	6	1	4	0	8	19
Yarra	18	10	7	2	16	53
Trend total	**37**	**14**	**20**	**6**	**55**	**132**

A summary of the types of trends observed in each catchment is provided in Table 4.

Table 4. Catchment summary of sites scale trend analysis.

Catchment	Summary
Werribee	The seven sites which could be assessed were classified as 'stable' (two), 'declining' (two) or variable (two). However, most sites in the catchment lacked enough data for a trend assessment.
Maribynong	No sites were classified as 'improving'. All main-stem Maribyrnong River and Deep Creek sites had 'declining' macroinvertebrate trends over the historical time period (full record).
Yarra	75% of assessable sites were 'stable' or 'improving'. But 4 main-stem Yarra River monitoring sites had 'stable' or declining' trends. The only main-stem Yarra River monitoring site that had an 'improving' macroinvertebrate trend was unimpacted by urbanisation upstream.
Dandenong	Macroinvertebrate trends for all sites were either classified as 'stable' or 'improving'.
Westernport	The majority of assessable sites were 'stable', with one site 'improving' and 4 sites 'declining'. Only 1 urban site could be assessed, and it was 'declining'.

Sub-catchment scale analysis

The HSMs predict a net improvement in LUMaR of 933 km (of reaches rated high and very high) if all strategy targets for revegetation and stormwater harvesting and infiltration are met by 2028. However, our works-to-date (WTD) assessment (integrating all revegetation and stormwater works undertaken between 2018 and 2022 and unmitigated urban development in stormwater priority areas) has demonstrated a 20km net decline in LUMaR (of reaches rated high and very high) across the region and 94 km of decline overall (Figure 3).

Stormwater intervention data (to 2022) used to update the models indicates that on ground actions are not managing to keep up with the rate of urban development that is occurring across the region. This estimate of net decline is likely to be lower than actual because the input data used to update the models (WTD) focussed on the stormwater priority areas and did not include urban development that has occurred outside of these areas.

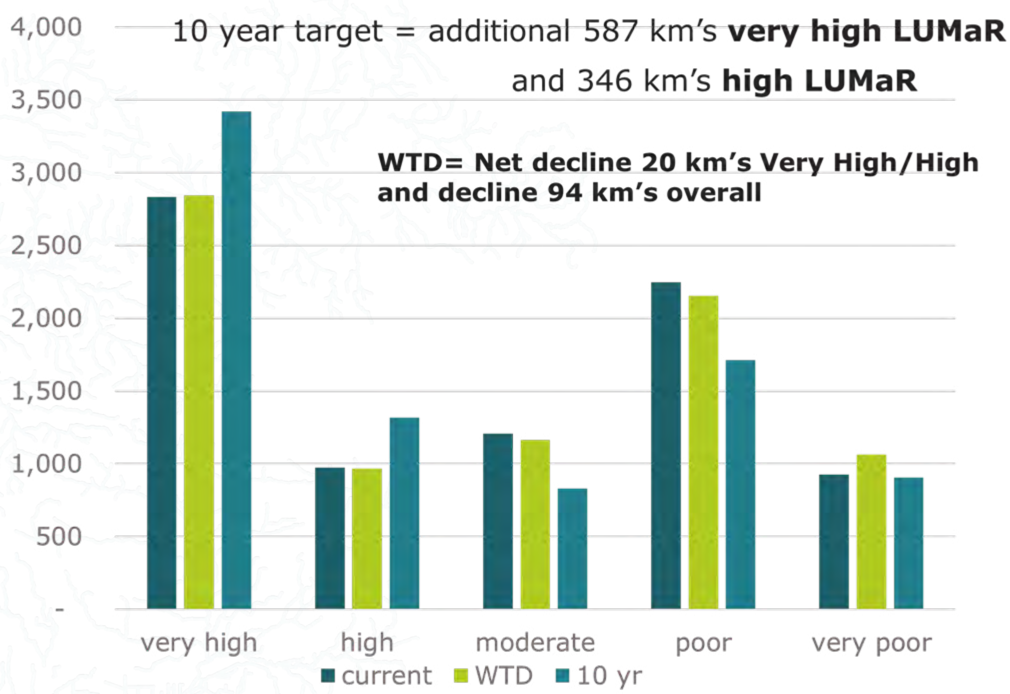


Figure 3. Graph of stream length changes in LUMaR score from updated HSM analysis. Current represents the original 2018 predictions, WTD represented models updated with works and urban development undertaken to 2022 and 10-yr represents the predicted improvement resulting from targets set in the HWS being completed. Whilst significant net improvement in LUMaR is predicted across the region if 10-yr targets are met (total of 933 km improved to High or Very High) the works to date indicates that a net decline of 20 km of stream declined from High and Very High and 94 km of stream has declined overall.

Photo credit: Eddie Tsyrlin

A summary of works-to-date HSM predictions at catchment scale is presented below (Table 5).

Table 5. Summary of HSM modelled predictions of works-to-date (2018-2022).

Catchment	Summary
Werribee	Small reaches of predicted decline in the Upper and Lower Kororoit Creek and Werribee River Lower sub-catchments. Small predicted improvements in Little River Upper. Overall, most sub-catchments did not predict significant change.
Maribyrnong	Declines are predicted in Jacksons, Emu and Upper Deep Creek sub-catchments. Small improvements are predicted in some areas of Emu Creek associated with the Sunbury IWM projects.
Yarra	Significant reaches of decline are predicted in the Darebin Creek sub-catchments to the extent that the trajectory at sub-catchment scale has declined compared with what was assessed as current in 2018. Merri Creek Upper and smaller areas of both improvement and decline are predicted in the Stringybark Creek sub-catchment. Small reaches of improvement are predicted in the Plenty River Upper, Steels and Pauls and Diamond Creek sub-catchments and the Yarra River Upper (Rural) sub-catchment. Overall, most sub-catchments did not record significant change
Dandenong	No declines or improvements are predicted in the Dandenong Creek catchment.
Westernport	Significant reaches of decline are predicted in the King Parrot, Musk Creek sub-catchment to the extent that the trajectory at sub-catchment scale has declined compared with what was assessed as current in 2018. Reaches of decline are predicted also for the Bunyip River lower sub-catchment. Small reaches of decline are predicted in the Tarago sub-catchment. Cardinia, Toomuc, Deep and Ararat Creek sub-catchment has small reaches of both improvement and decline. Small reaches of improvement are predicted for the Mornington Peninsula South Eastern Creeks and for French Island as well as the Bass and Lang Lang River sub-catchments.

Combined site and sub-catchment scale analysis

Site-scale analyses and HSM works-to-date analyses were brought together to produce the resultant map (Figure 4) that indicates there is a high chance that long-term targets will not be met in 19 sub-catchments.

The analysis of these combined results was incorporated into the HWS Mid-term Values Synthesis (HWS Mid-term Values Synthesis Results) and the results of this are presented in Part C - Region-wide assessment of management activities and their effectiveness.

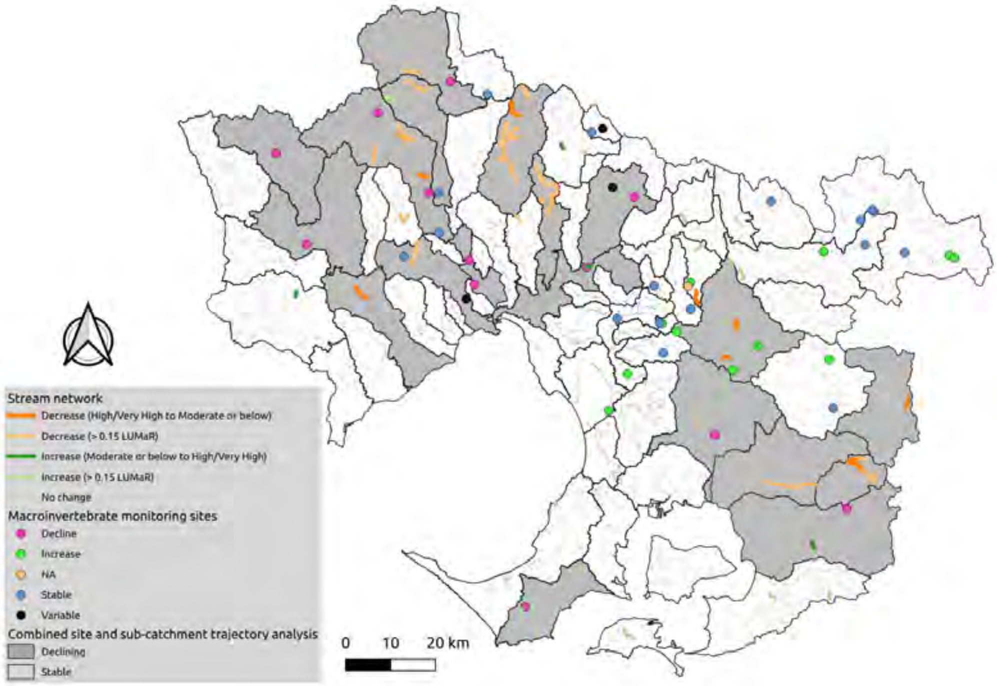


Figure 4. Map of region showing combinations of HSM WTD LUMaR predictions and macroinvertebrate site analysis results. Stream reaches predicted to decline by >0.15 LUMaR are coloured dark orange if the declines are from High or Very High to Moderate or below or pale orange if declines were in other categories. Stream reaches predicted to improve by >0.15 LUMaR are coloured dark green if the improvements are from Moderate to High or Very High or pale green if improvements were to other categories. Sub catchments shown in grey are where the combined site and sub-catchment analyses were brought together resulting in 19 sub-catchments identified as likely to be declining. Site scale classifications are shown as dots and coloured according to trend analysis. 77 monitoring sites could be assessed for trend.

KEQ 2a. What environmental conditions (e.g. water quality) and external conditions (e.g. policy) help explain current key value trends?

Approach

We did not formally evaluate key evaluation question 2a for macroinvertebrates. However, we did focus further investigations on macroinvertebrate sites that we determined to be 'declining' or 'improving' with high or moderate confidence from key evaluation question 3a in order to further investigate the environmental condition changes that may have contributed to the observed trends. Using this criteria, 15 sites were identified for further analysis.

Outcome

For each of the 15 selected sites, we investigated the available datasets relating to environmental conditions. Some data sets were quantitative (e.g. water quality, local flow studies etc.) and some were qualitative (examination of changes in urbanisation and riparian cover over time using aerial imagery) but both were combined in an attempt to identify the most likely environmental condition changes that correlate with macroinvertebrate trend. A summary of the key finding from this analysis is presented in Table 6. For further detail please see the Macroinvertebrate Technical Report (Macroinvertebrates: A Technical Report to Inform the Healthy Waterways Strategy Mid-term Evaluation).

Table 6. Summary of key findings for the 15 sites monitoring site selected for further analysis where trend was assessed to be of moderate or high confidence presented per catchment.

Catchment	Summary
Werribee	Declining trend in **Werribee River** (Werribee River Middle sub-catchment) of moderate confidence. Recent samples lack a number of sensitive families. Causal factors are not clear but are likely associated with a combination of reduced stream flows and urban development. The increasing trend in **Kororoit Creek** (Kororoit Creek Lower sub-catchment) is unusual, given high levels of existing and increasing urbanisation and requires further monitoring.
Maribyrnong	The absence of sensitive families in recent surveys in the forested **Barringo Creek** site (Jacksons Creek sub-catchment) is concerning but requires additional samples to confirm this trend. A small recent declining trend in **Deep Creek** (Deep Creek Upper sub-catchment) is associated with the absence of macroinvertebrate families from a variety of functional feeding groups. Declining stream flow is likely to be contributing to this trend. There is a consistent yet subtle decline over time at two sites on the **Maribyrnong River** (Maribyrnong River sub-catchment). Causal factors are not clear but are likely associated with reduced stream flows and urban development.
Yarra	Trends in LUMaR are increasing at **Lyrebird Gully Creek** (Olinda Creek sub-catchment) and **Cockatoo Creek** (Woori Yallock Creek sub-catchment) and there is some evidence that this may be related to improvements in water regime and water quality relating to changes in agriculture in the catchment. Similarly, there is reasonable evidence to suggest that macroinvertebrate declines in the **Diamond Creek** (Diamond Creek Rural sub-catchment) are related to declining water availability in the catchment. The declining trend in the **Yarra River** main-stem (Yarra River Lower sub-catchment) reflects a gradual loss of a range of macroinvertebrate families. Causal factors are not clear but are likely associated with a combination of reduced stream flows and urban development.
Dandenong	The reduction in variability in LUMaR scores on **Dobson's Creek** (Dandenong Creek Upper) are considered due to significant stormwater intervention in the catchment. Improving trends in two sites on the **Dandenong Creek** (Dandenong Creek Lower and Middle sub-catchments) are driven by an increase in filter feeders and filtering collectors and an increase in sensitive taxa. Improving water quality, possibly linked to large stormwater treatment wetlands, is a potential contributing factor.
Westernport	Declining trends on the **Lang Lang River** (Lang Lang River sub-catchment) are due to a general reduction in macroinvertebrate families, including some sensitive families. It is not certain what environmental factors are causing this trend. Historical erosion impacts could still be contributing to current decline. There is a sustained decline in the presence of sensitive taxa in **Toomuc Creek** (Cardinia, Toomuc, Deep and Ararat Creeks sub-catchment) which is likely related to increasing levels of urbanisation in the catchment since the 90's.

Key themes that appear across many of the 15 sites include:

Improving sites

- Forested sites - changes likely due to improving flow regime (post drought, changes to diversion pressures) (e.g. Cockatoo Creek, Lyrebird Gully Creek).
- Urban sites - some mostly unexplained urban improvements (Dandenong Creek, Kororoit Creek) and one related to significant stormwater interventions (Dobsons Creek).

Declining sites

- Forested sites –need more data to confirm trend (Barringo Creek).
- Rural sites – some unknown and concerning (Lang Lang River), some appear to be related to diversions (Diamond Creek) and/or long-term flow decline (Deep Creek, Diamond Creek).
- Urban – some concerning declines on main-stems (Werribee River, Maribyrnong River and Yarra River) and smaller streams (Toomuc Creek) relating to urbanisation and possibly long- term decline in flows.
- Many changes are not due to a single condition change and are linked to multiple interacting stressors that are simultaneously changing.
- Further information on key changes that have occurred across the region since 2018 is presented in Part B - Status and management of threats across the region.

Overall value summary

Based on the combined site and sub-catchment scale analysis we found that 19 sub-catchments were off-track and there is a high to moderate chance that long-term targets for macroinvertebrates in these areas will not be met.

Whilst there are a range of conditions that help explain the trends in macroinvertebrates that are relevant to each catchment, a combination of reduced stream flows and urban development are likely to underlie declines across multiple sub-catchments, including main-stem river sites (Yarra, Maribyrnong and Werribee). This is supported by information suggesting improving the natural flow regime, either by reducing diversion pressure or by disconnection of urban stormwater has improved macroinvertebrates at particular sites.

There are a number of recommendations stemming from the outcomes of the KEQs for macroinvertebrates. The recommendations are summarised in Part F - Knowledge gaps > Monitoring and Investigations and Part H - Overall summary and recommendations.

Limitations

The macroinvertebrate analysis was the first we conducted as part of the HWS mid-term review process and our understanding of evaluative reasoning and establishing evaluation criteria has grown through the mid-term review process. Were we to conduct this analysis again we are likely to structure it differently. For instance, KEQ 2a could have been evaluated formally and we would have developed criteria around the strength and confidence of the lines of evidence we investigated. This is a key learning for the end-of-Strategy evaluation.

The lack of sufficient macroinvertebrate data in the Werribee catchment in particular limited our ability to understand trends over time in that catchment. Additionally, gaps in the data relating to periods of time when the macroinvertebrate monitoring program was in hiatus, has reduced the confidence in the trend analysis for many sites. Both of the above limitations will be improved over time should the current monitoring program remain in place.

This assessment was somewhat limited in its use of mainly one macroinvertebrate index - LUMaR. Another index, SIGNAL2 was used alongside LUMaR however the analysis of trend and overall understanding of what may be leading to change could have been enhanced by looking at multiple indicators such as EPT, number of families and other indices specified in the Environmental Reference Standards (Environment Protection Authority, Victoria 2021).

Photo credit: Eddie Tsyrlin and John Gooderham

Platypus (Rivers)

Introduction

The platypus has been identified as a key environmental value in the HWS in recognition of the vital role they play in aquatic ecosystems at the top of the food chain and the high level of community interest around this unique native species. Their distribution has substantially contracted since European settlement, and they are now listed as Threatened by the Victorian Government. Without appropriate intervention, the spatial extent of suitable habitat for platypus is predicted to substantially decline by 2068 (Figure 5).

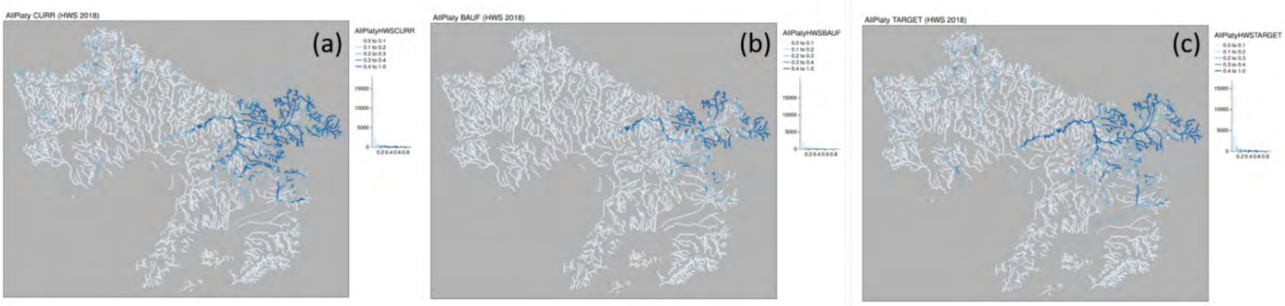


Figure 5. Modelled platypus habitat suitability from the habitat suitability model created in 2018. Habitat suitability predictions for the (a) 2018 baseline (CURR), (b) 2068 business-as-usual trajectory (BAUF), and (c) long-term HWS target for 2068 are displayed.

Evaluation criteria were developed to guide the data analysis and evaluation of the relevant KEQs. These criteria are available in the Platypus Technical Report (Platypus: A Technical Report To Inform The Healthy Waterways Strategy Mid-term Evaluation). Below we summarise the evaluation approach and outcomes.

KEQ 3a. To what extent are key values on the target trajectory?

Approach

This question was partially evaluated at two different spatial scales:

- HWS sub-catchment scale - using Habitat Suitability Model predictions and eDNA survey data, and
- Platypus community scale - 15 platypus communities where we have long-term live-trapping data, using abundance, health, and distribution change information specific to each community.

In Part D – Synthesis, we completed the evaluation using updated climate change information which allowed us to investigate potential longer-term changes to the value trajectory.

Outcome

There is a high chance that long-term targets will not be met for three sub-catchments: Plenty River (Source), Deep Creek Upper, and Emu Creek. Despite 'Moderate' to 'Very High' modelled habitat suitability, platypus were not detected via eDNA in waterways within these sub-catchments. Despite this, more than 88% of sub-catchments (61) were considered to be on the target trajectory (stable or improving trajectory) to meet long-term targets.

Two platypus communities, Cardinia and Lang Lang, were given a performance rating of 'Not assessable / potentially declining'. These ratings were assigned as there is evidence of a decline in abundance within the introduced Cardinia Creek platypus community and we have insufficient data to assess the status and trajectory of the Lang Lang River platypus population. A summary of the platypus trajectory within each HWS catchment is available in Table 7.

Table 7. Platypus value summary for HWS catchments.

Catchment	Summary
Werribee	Little River Lower, Little River Upper, and Toolern Creek sub-catchments were 'potentially off-track'. Known platypus communities in the Werribee River are considered stable.
Maribyrnong	Deep Creek Upper and Emu Creek sub-catchments were not on the target trajectory to meet long-term targets ('off-track'). Platypus are now largely restricted to lower Jacksons Creek, Deep Creek, and the Maribyrnong River.
Yarra	All but one sub-catchment, Plenty River (Source), were on the target trajectory to meet long-term targets ('on-track') and all assessed platypus communities are stable.
Dandenong	All sub-catchments are on the target trajectory to meet long-term targets and the Monbulk Creek platypus community is stable.
Westernport	We were unable to assess the trajectory of platypus communities in two sub-catchments: Cardinia, Toomuc, Deep and Ararat Creeks and Lang Lang River. However, the Bunyip River and Tarago River communities are considered stable.

KEQ 3b. What other spatial and temporal trends and patterns for key values are of significance for implementation?

Approach

This question focused on other trends and patterns not highlighted in key evaluation question 2a and key evaluation question 3a but considered important for platypus. This included changes in distribution at the sub-catchment scale and issues relating to data management and the suitability of the abundance metric used.

Outcome

Platypus were detected (eDNA result = positive) in five sub-catchments we have not previously captured platypus (Steels and Pauls Creek (Rural), Merri Creek Upper, Little River Lower, Little River Upper, and Toolern Creek), but it is likely that their positive detection represents occasional vagrants dispersing and not range expansion as habitat suitability is rated 'Very low' in these sub-catchments. Methodological and data management issues exist and continue to hamper the on-going use of platypus data, particularly the way we calculate and report abundance.

KEQ 2a. What environmental conditions (e.g. water quality) and external conditions (e.g. policy) help explain current key value trends?

Approach

We focused our evaluation of key evaluation question 2a on the sub-catchments and platypus communities that we determined to be 'Significant for implementation' from key evaluation question 3a: there is either a high chance that long-term targets will not be met or their abundance trajectory was rated as 'Not assessable / potentially declining'. For each of these sub-catchments (Plenty River (Source), Deep Creek Upper, and Emu Creek) and platypus communities (Cardinia and Lang Lang), we summarised evidence from the literature (scientific reports and industry communications) and available data on the environmental conditions, external conditions, and threats that underpin the current trajectory of platypus. Finally, we comment on changes to environmental and external conditions in other catchments that may also have impacted platypus.

Outcome

Drought and inappropriate flow regimes underlie many declines in platypus. Climate change, bushfires, fragmentation, works on water supply assets, poor riparian vegetation, as well as negative impacts of urbanization also likely contribute to declines. A summary of the environmental and external conditions that help explain trends in platypus within each HWS catchment is available in Table 8.

Table 8. Summary of the environmental and external conditions that help explain platypus trends in the sub-catchments and platypus communities that we determined to be 'Significant for implementation' from KEQ3a.

Catchment	Summary
Werribee	No sub-catchments or platypus communities were determined to be 'Significant for implementation'.
Maribyrnong	Reduced flows, fragmentation, and poor riparian vegetation have all contribute to the decline in platypus in Deep Creek Upper. Platypus in Emu Creek are thought to only exist in the lower reaches near the confluence with Deep Creek. eDNA has not yet sampled in lower reaches of Emu Creek. Reduced flows and lack of adequate in-stream and riparian habitat contribute to the 'Moderate' habitat suitability rating in Emu Creek.
Yarra	Repeated draining of Toorourrong Reservoir due to capital works, as well as high flows events, bushfire and fragmentation have all contributed to the decline of platypus in Plenty River (Source).
Dandenong	No sub-catchments or platypus communities were determined to be 'Significant for implementation'.
Westernport	The variable/unknown health trajectory of platypus in Cardinia Creek is largely reflective of the low abundance and thus capture rate which is, in turn, likely reflective of multiple pressures (adverse conditions and threats) affecting this population. Many of these pressures existed before the reintroduction program and continue to affect the population. The unknown status of the Lang Lang platypus community and population may be reflective of multiple changed conditions and threats.

Overall value summary

We found that platypus were off-track in three sub-catchments and there is a high chance that long-term targets for platypus in these areas will not be met. A further two sub-catchments are also of concern, with more information required to determine their trajectory with confidence. Whilst there are a range of conditions that help explain the trends in platypus within each HWS catchment, drought and inappropriate flow regime are likely to underlie declines across multiple sub-catchments.

There are a number of recommendations stemming from the outcomes of the key evaluation questions for platypus. The recommendations are summarised in Part F - Knowledge gaps > Monitoring and Investigations and Part H - Overall summary and recommendations.

Limitations

Sufficient data on platypus abundance was not available for some communities to enable trajectory assessment. No live-trapping surveys have been conducted since 2019, exacerbating this issue. Further, the lack of a dedicated database and data management process hindered the assessment of this value. Finally, it must be emphasised that platypus trajectory likely responds greatest to sustained and longer-term changes in environmental conditions and, unlike other in-stream values such as fish and macroinvertebrates, trajectory change due to short-term environmental change may be difficult to detect.

Fish (Rivers)

Introduction

Fish play an important role in Melbourne's waterways; they are usually near the top of the aquatic food chain and also provide food for people and some birds. Their key value recognition is also due to species such as Macquarie perch, Murray cod, River blackfish, Tupong, and Short-finned eel being highly valued for their recreational value by the fishing community and/or cultural importance. Without appropriate intervention, the spatial extent of suitable habitat for native fish is predicted to decline by 2068 (Figure 6).

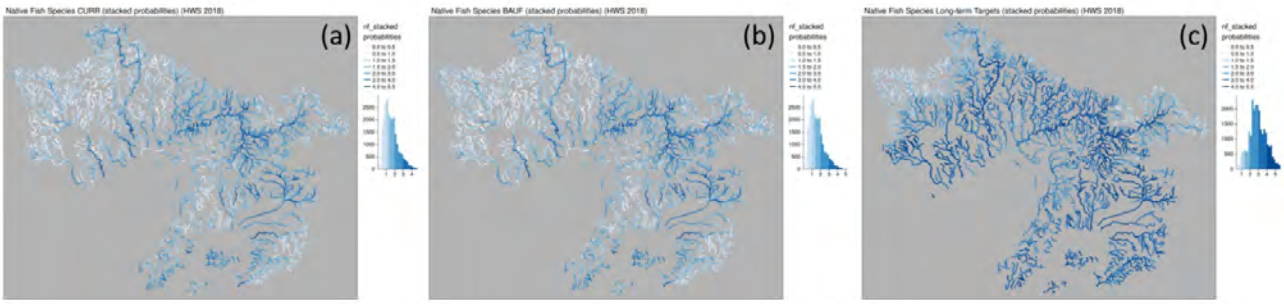


Figure 6. Modelled native fish habitat suitability from the habitat suitability models created in 2018. The native fish metric represents the stacked probabilities from habitat suitability predictions for 13 native fish species. Habitat suitability predictions for the (a) 2018 baseline (CURR), (b) 2068 business as usual trajectory (BAUF), and (c) long-term HWS target for 2068 are displayed. Deeper blues indicate higher stacked probability values.

Evaluation criteria were developed to guide the data analysis and evaluation of the relevant key evaluation questions. These criteria are available in the Technical Report for Fish (Fish: A Technical Report to Inform The Healthy Waterways Strategy Mid-term Evaluation). Below we summarise the evaluation approach and the outcomes of the evaluation.

KEQ 3a. To what extent are key values on the target trajectory?

Approach

An analysis was undertaken to investigate changes in fish habitat suitability between predictions made at the start of the Strategy and available information on works-to-date (2022), including revegetation, stormwater harvest and infiltration, and fishways - see complete methods in the HSM Management Activities Technical Report (Chee, Walsh, et al. 2022). Briefly, spatially explicit reach-scale changes in habitat suitability were determined for 13 native species collectively (i.e. a stacked probability), two non-migratory native species (River blackfish and Ornate galaxias) and one migratory species (Common galaxias) – changes were then summarised at the sub-catchment scale. Native fish species included in the stacked probability are available in the HSM Management Activities Technical Report (Chee, Walsh, et al. 2022). The top six sub-catchments with a 'significant' decline in habitat suitability, for each of the four fish models, were categorised as having a 'declining' fish trajectory. The thresholds for determining significance for model predictions are outlined in the HSM Management Activities Technical Report (Chee, Walsh, et al. 2022).

Outcome

Despite 27 km of improvement in native fish habitat suitability, 73 km of river declined for priority fish species, representing a net decline of 46 km since the start of the Strategy (Figure 8). Approximately 60% of this decline was within the Bunyip River Lower and Woori Yallock Creek sub-catchments (Figure 7). River blackfish habitat suitability has declined in some areas where they have a high probability of occurrence (Woori Yallock Creek and Tarago River sub-catchments) (HWS Mid-term Values Synthesis Results). Declines in Common galaxias were widespread across the Melbourne region, and declines in Ornate galaxias were largely restricted to upland streams and rivers (HWS Mid-term Values Synthesis Results).

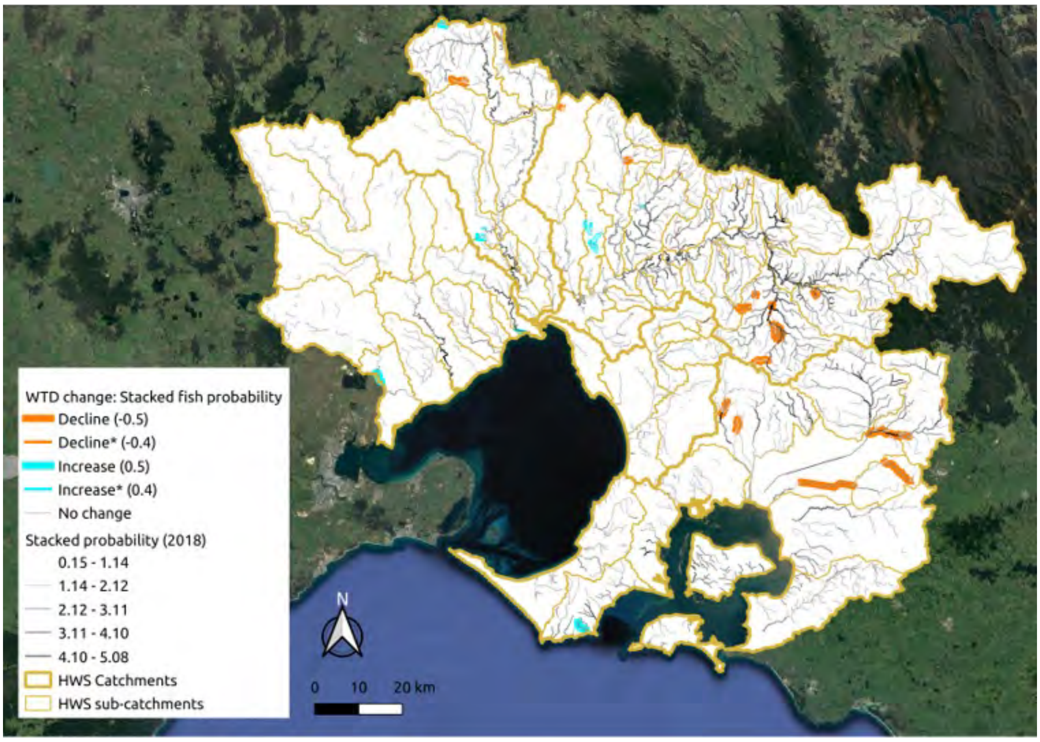


Figure 7. Spatially explicit changes in the stacked native fish habitat suitability indicating where works-to-date (WTD) stacked probabilities differs from that of the CURR scenario used in HWS 2018. On this diverging colour scale, darker orange indicate lower stacked probabilities relative to CURR and blue indicate higher stacked probabilities relative to CURR.

There is a high chance that long-term targets will not be met for 11 sub-catchments, with all found to have declining trajectories for fish (Appendix 4) (HWS Mid-term Values Synthesis Results). Almost half of these sub-catchments (Bunyip River Lower, Cardinia, Toomuc, Deep and Ararat Creeks, King Parrot and Musk Creek, Lang Lang River, and Tarago River) were situated in the Westernport region. Three sub-catchments (Darebin Creek, Stringybark Creek, and Woori Yallock Creek) were categorised as declining and not likely to meet long-term targets in the Yarra catchment. Kororoit Creek Lower was categorised as declining and not likely to meet long-term targets in the Werribee catchment. Deep Creek Upper and Jacksons Creek were categorised as declining and not likely to meet long-term targets in the Maribyrnong catchment. Seven out of the eight sub-catchments in the Dandenong catchment were identified as data gaps for fish trajectory.

KEQ 3b. What other spatial and temporal trends and patterns for key values are of significance for implementation?

Approach

While we used modelling to predict changes in fish habitat suitability for key evaluation question 3a, for key evaluation question 3b we undertook an analysis of historical fish data to investigate:

a. how species richness and nativeness have changed over time at the catchment scale, and
b. whether there is any evidence of range expansions or contractions over time (since 1973) using site-occupancy models (site = sub-catchment) for seven native and two exotic species within the Yarra catchment.

This analysis helped us better understand how management interventions (e.g. fishway installation) and catchment change (e.g. population growth and urbanization) have historically impacted fish and what lessons can be learnt.

A detailed description of the methods used to answer key evaluation question 2a is available in the Fish Technical Report (Fish: A Technical Report to Inform The Healthy Waterways Strategy Mid-term Evaluation).

Outcome

There is no apparent decline in the proportion of native species, at the river basin scale, over the study period within the limitations of the available data. Nativeness scores were the lowest on average in the Dandenong Creek basin and highest in the Westernport area: this likely reflects the intensity of development across these catchments and proximity to Melbourne's main urban centres.

There is evidence of a long-term decline in the range of non-migratory fish species within the Yarra catchment. Being entirely restricted to freshwater environments, non-migratory species have limited capacity to avoid deteriorating environmental conditions. Such patterns are observable in River blackfish, Southern pygmy perch, and Ornate galaxias.

We observed positive increase in occupancy of some migratory fish species (i.e. Common galaxias, Short-finned eel, Tupong) within the Yarra catchment, likely reflecting improvements in river management that have been made over the last five or so decades such as improved fish passage, environmental flow regimes, and habitat restoration. Estimates of Common galaxias site occupancy for the Yarra River catchment is presented in Figure 8.

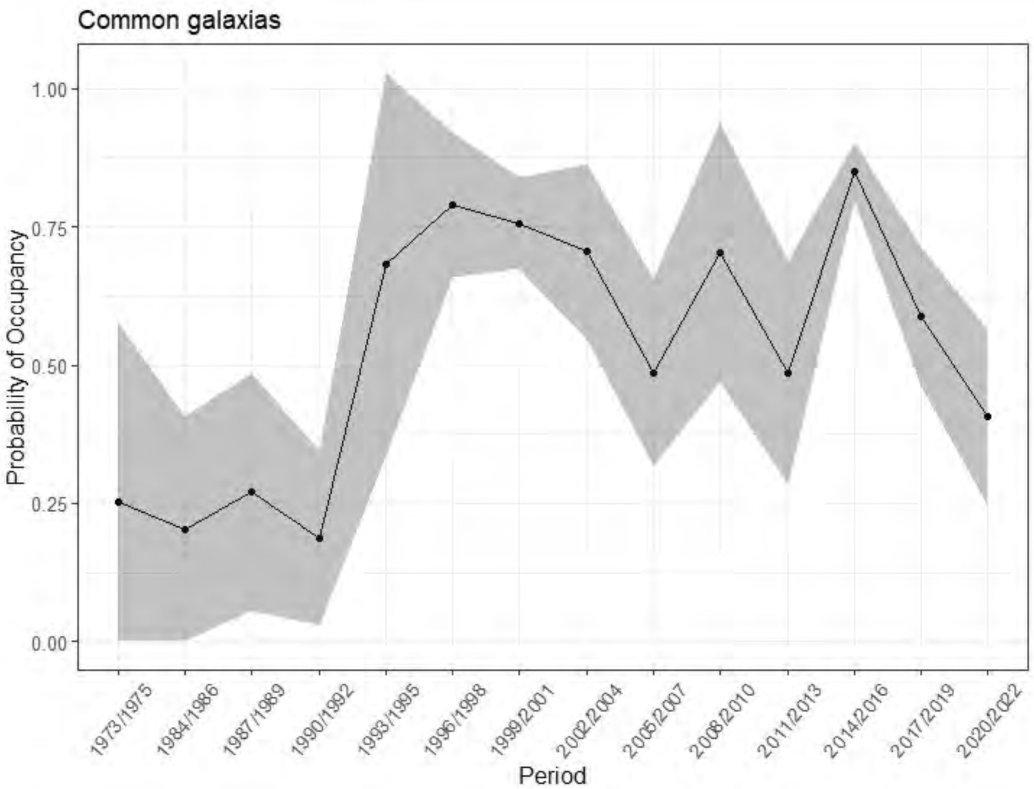


Figure 8. Model-averaged estimates of annual probability of site (sub-catchment) occupancy for common galaxias within the Yarra River catchment.

Overall value summary

While there have been improvements in some areas, habitat suitability of the assessed fish species has declined across the Melbourne region. The largest and most widespread predicted declines were for Common galaxias habitat suitability. Further, River blackfish habitat suitability has declined in some areas where they have a high probability of occurrence.

Despite the overall declines in habitat suitability, there is evidence that improvements in river management such as improved fish passage, environmental flow regimes, and habitat restoration have benefited the site occupancy in the Yarra catchment of some migratory species such as the Common galaxias.

Limitations

Scenario analyses using HSMs identified interesting potential trade-offs associated with the three primary interventions and how they affect different native fish species – see HSM Management Activities Technical Report (Chee, Walsh, et al. 2022). Not all modelled interventions were predicted to be beneficial to all fish species. For example, revegetation was detrimental to predicted habitat suitability of Common galaxias and Australian grayling. Whether this is a modelling artefact, or a real implementation limitation is not yet certain.

The site-occupancy analysis was performed only in the Yarra catchment due to limited data, at the time of analysis, in other catchments. Future work should focus on undertaking similar site-occupancy analyses in other major catchments as well as at smaller spatial scales (i.e. sub-catchments).

Finally, the lack of a dedicated database and data management process hindered the assessment of this value.

Photo credit: Tarmo A. Raadik

Riparian vegetation

Introduction

The Healthy Waterways Strategy (HWS) (Melbourne Water 2018) identifies vegetation as a key value in its own right, as well as supporting the condition of other key values such as birds, macroinvertebrates, fish and social values (e.g. amenity). Improving vegetation coverage (extent) and quality along riparian zones is one of the most important activities that can be done to improve vegetation's support of terrestrial fauna, overall stream health and social values. Management typically includes revegetation, stock exclusion and pest plant and animal control. Flows, water quality and physical form are also important conditions required to support healthy vegetation along waterways.

Despite being such an important component of waterways, a thorough evaluation of changes to vegetation condition across the region has been difficult largely due to the evolution of survey methods over time and the lack of a dedicated vegetation database. Monitoring of vegetation in the past has been ad-hoc and localised and hampered by changing methodologies. In summary, the datasets include:

- the Index of Stream Condition methods – referred to as ISC1, ISC2 and ISC3 – developed to assess streams across the state - methods have changed over time and are limited in extent
- The MW Vegetation Visions methods – developed in 2018 (VV18) and revised in 2021 (VV21) but are not fully comparable
- Lidar aerial assessment analysis used to derive 2016 vegetation extent data used as input to HSMs that have not been replicated to date. This is being resolved with new aerial imagery and AI, and
- Restoration Outcomes Monitoring Protocol (ROMP) – a monitoring method developed in 2021 to assess the effectiveness of management interventions such as revegetation. Due to its recent application, there is insufficient data to assess trends over time yet.

Given the limitations of existing datasets we could not comprehensively evaluate key evaluation question 3a. However, we have drawn lines of evidence for key evaluation question 3a from four works monitoring studies that demonstrate how vegetation condition is changing in some locations. The VV21 dataset was then used to partially address key evaluation question 3b and key evaluation question 2a and compare condition across the region, identifying new areas of high-quality vegetation and assessing contributing factors such as the presence of pest plants and animals. Evaluative criteria are available in the Vegetation Technical Report (Riparian vegetation: A Technical Report to Inform the Healthy Waterways Strategy Mid-term Evaluation) and Jellinek et al. 2022a. Below we summarise the approach and the outcomes of the evaluation.

KEQ 3a. To what extent are key values on the target trajectory?

Approach

As described above due to limitations we have not directly addressed this key evaluation question but provided some lines of evidence of how vegetation condition is changing in some areas as a result of management. The studies include:

- Yarra River 2007 to 2013 (Kershaw, et al. 2013) – compared vegetation quality and weed abundance along 60 km's of the Yarra River Wonga Park to Digit Falls, Abbotsford
- Comparison of revegetation sites against remnant vegetation areas using ROMP (Jellinek, Greet and Chee 2022) – 2021 masters study (Foley-Congdon, et al. 2023) – compared 17 sites which have been revegetated for 10-14 years to nearby remnant sites
- Plant survivorship post-planting – ROMP assessment of plant survivorship at 19 sites planted in 2018 (Jellinek 2022), and
- Works effectiveness monitoring using ISC2 streamside zone sub-index – compared 30 sites over 10 years (2010-2020) (Jellinek, Greet and Chee 2022).

Outcome

The results of this analysis demonstrate that the condition of vegetation is improving where vegetation management works are being carried out. A summary of each of the studies that were assessed is provided below.

The Yarra River study found an overall increase in vegetation quality between the 2007 and 2013 with high quality vegetation increasing by from 36 % to 44 %, medium quality vegetation increasing 49 % to 54 %, and low-quality vegetation decreasing from 15 % to 2 % (Figure 9). This change in vegetation quality was not uniform across all river sections, with the majority of vegetation increase in quality occurring in only some sections. A critical assumption of the Healthy Waterways Strategy is that vegetation quality can be improved through management and can step up from one vegetation quality category to another over time. Based on this study, this assumption is taken to be at least partially correct, though the extent to which positive change may occur is subject to a range of environmental factors and may vary greatly between regions.

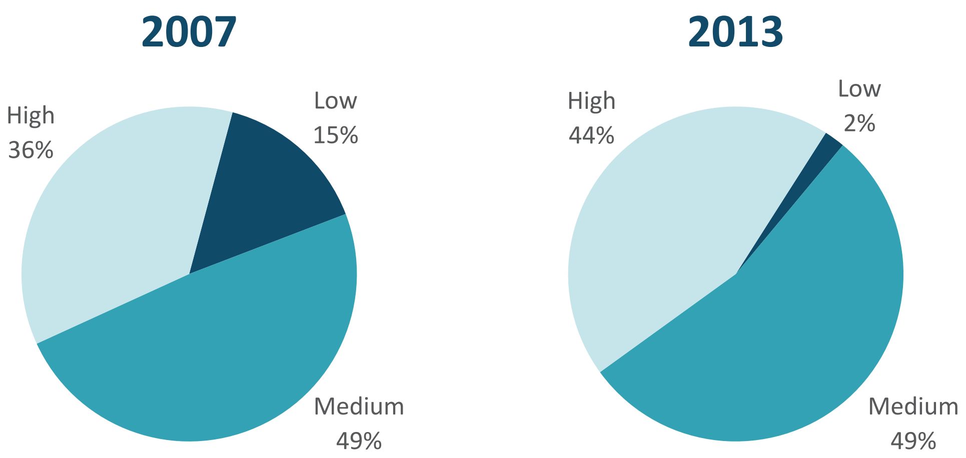


Figure 9. Relative extent of High, Medium and Low vegetation quality between 2007 and 2013 for all sections of the Yarra River. See Kershaw et al. (2013) for further information.

The study which compared revegetated areas with remnant vegetation sites (assessed using ROMP) found that while revegetated areas may have similar species richness and tree cover as remnant areas, weeds are often dominant and important structural components such as shrubs and ferns, and ecological processes such as plant recruitment, are lacking in revegetation (Figure 10).

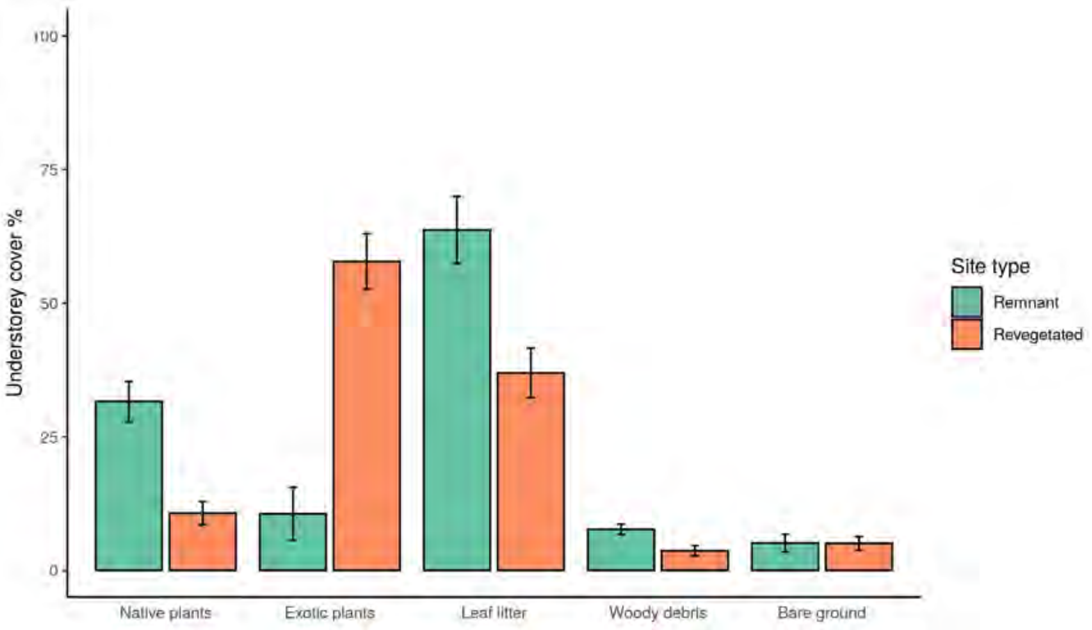


Figure 10. Understorey vegetation and ground layer components at remnant (green, n = 10) and revegetated (orange, n = 17) sites (bar plots indicate raw means ± SE).

Plant survival assessment at 19 sites planted in 2018 (using ROMP) found that plant survival ranged from 72 – 91%, with two catchments (Yarra and Werribee) falling below the expected 80% survival rate. Aridity was likely a major factor driving plant survival, with more arid catchments (Werribee, Maribyrnong and the western Yarra) having lower plant survival (Figure 11).

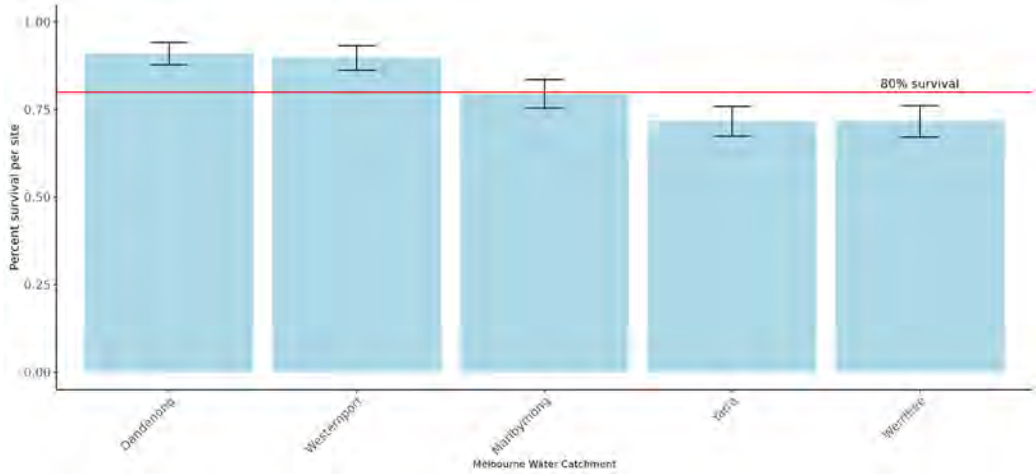


Figure 11. Survival rates of plantings at 2 or more years (at a total of 19 sites) across the five major catchments of the Melbourne Water region. Bars represent standard errors and the red line represents expected 80% survival rate.

An analysis of the MW works monitoring program (using ISC2), found that works sites have a higher streamside zone score than control sites (Figure 12), which was largely driven by understory vegetation, litter, canopy cover, recruitment and connectivity (Jellinek, Greet and Chee 2022). While there are some limitations to the analysis it does indicate that revegetated areas are likely to be increasing in vegetation quality over time.

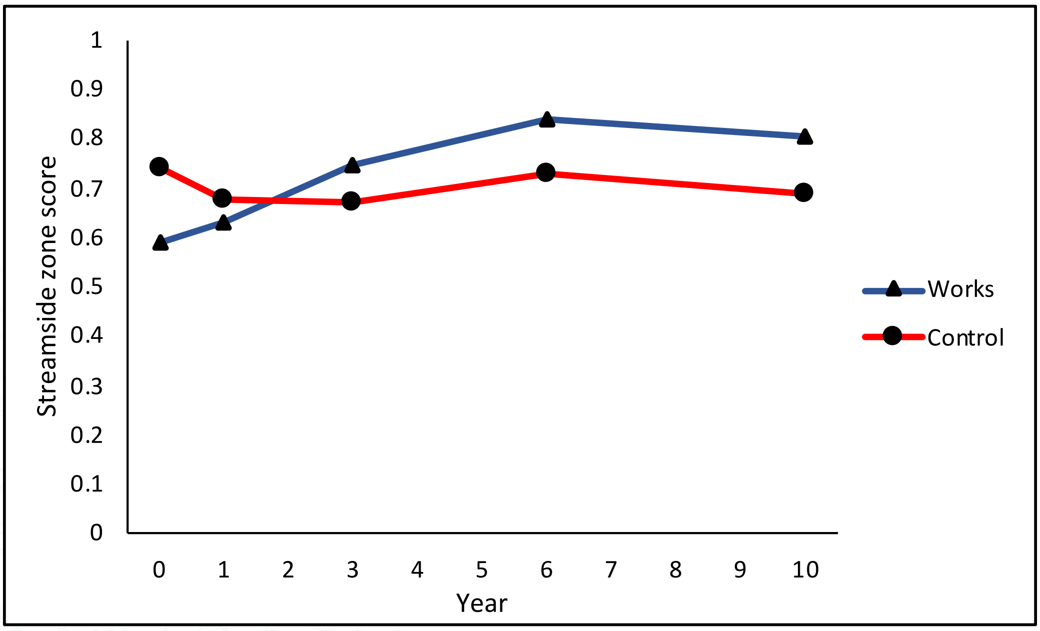


Figure 12. Mean weighted scores of the streamside zone sub-index comprising 9 metrics at works (n = 22–25) and control sites (n = 17-19) over the 5 monitoring periods (labelled as 'Year').

KEQ 3b. What other spatial and temporal trends and patterns for key values are of significance for implementation?

Approach

This key evaluation question was evaluated in two parts. Firstly, we used the new VV21 data (see background in the introduction section) to determine if there were any additional areas of high-quality vegetation in the region that had not been identified by the VV18 data. This is important because the HWS 2018 has Performance Objectives around protecting all high-quality vegetation areas and new areas identified since 2018 are outside of the priority reaches. Secondly, we wanted to flag areas of potential decline by comparing the VV21 and VV18 datasets. While we are confident that management actions are effective at maintaining or improving condition (see results of key evaluation question 3a), we do not have a good understanding of variation in condition in areas which are not being actively managed. There are limitations with comparisons of the VV21 and VV18 data, as outlined in the Vegetation Technical Report (Riparian vegetation: A Technical Report to Inform the Healthy Waterways Strategy Mid-term Evaluation).

Outcome

The evaluation has identified new high quality vegetation areas and has flagged other areas where there is a possible decline.

There were 213 high and very high quality VV21 sites across the region, and 120 (56%) of these did not correspond with previously identified high quality reaches (i.e. from the VV18 data, Figure 13). While this percentage is high, only 12% (25 sites) did not sit within the broader vegetation performance objective priority areas which are focused on establishing vegetation (Figure 14). This suggests that there are areas of high-quality vegetation in the HWS region not currently included in HWS performance objectives and hence may not be being appropriately protected.

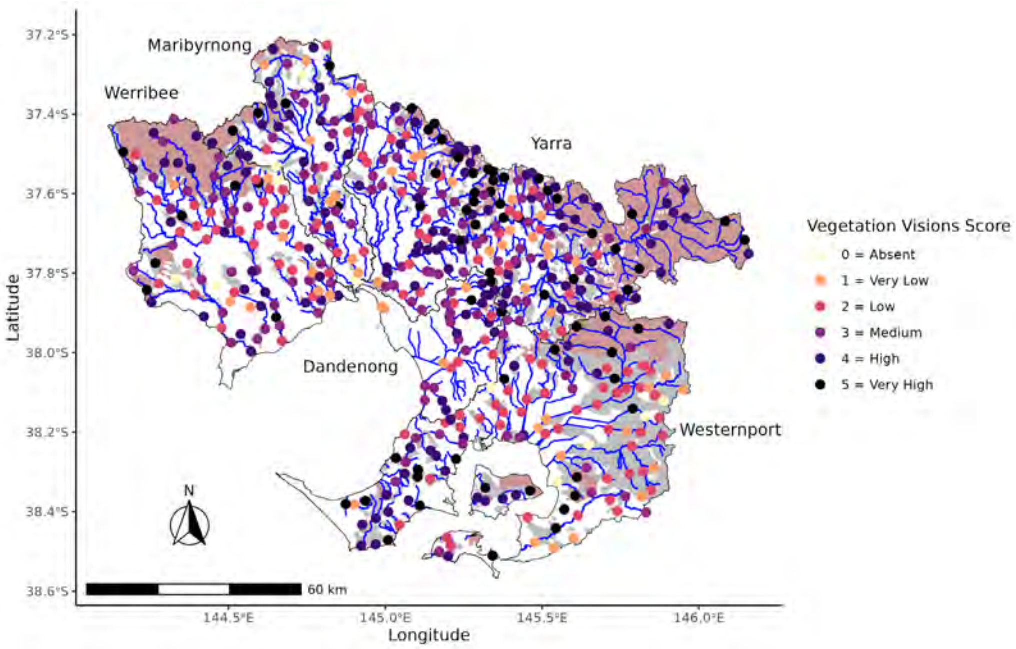


Figure 13. VV21 scores in the Melbourne Water region. The Light red and grey polygons are where vegetation performance objectives exist (light red = protect high quality and light grey = establish and maintain).

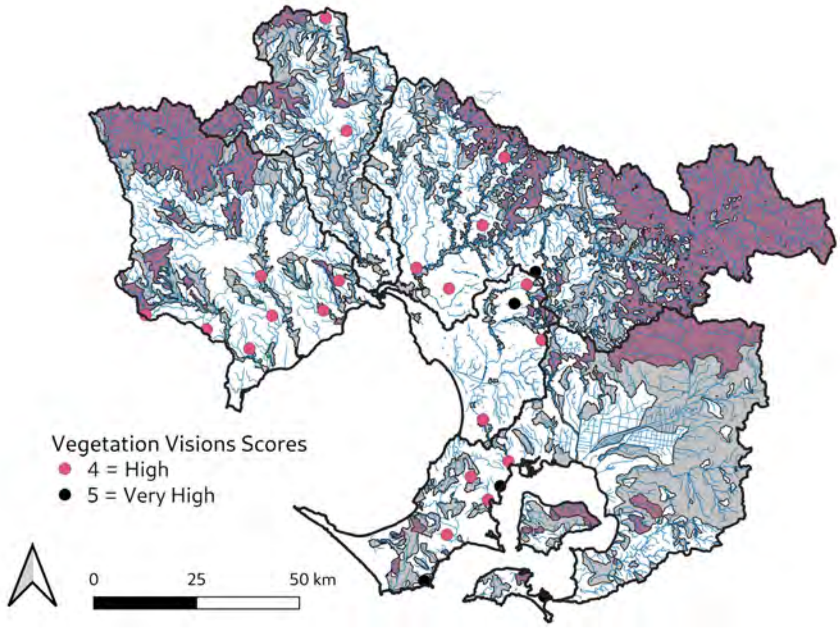


Figure 14. VV21 scores in the Melbourne Water region for high and very high-quality vegetation that are outside where performance objectives exist. The light red and grey polygons are where vegetation performance objectives exist (light red = protect high quality and light grey = establish and maintain). This illustrates where areas of high-quality vegetation may not be adequately managed or protected in the HWS.

Comparison of the VV21 and VV18 data revealed 8 sites of possible decline (i.e. where the VV21 data was 2 or more categories below the VV18 data). All sites are located in the Yarra and Werribee catchments. Given limitations of comparing these two datasets it is suggested that these sites are visited in future years to assess if they are actually declining. A summary of the vegetation condition analysis is presented in Table 9.

Table 9. Summary of vegetation condition analysis.

Catchment	Summary
Werribee	There are seven sites with high quality vegetation currently outside vegetation performance objective priority areas. These are in the following sub-catchments: Werribee River Lower, Cherry Creek, Skeleton Creek, Lollypop Creek and Little River Lower and two sites in Little River Upper. There were two sites in the Lerderderg River sub-catchment where there is a potential decline in condition and one site in the Werribee River Upper sub-catchment. Further monitoring is required to confirm this trend.
Maribyrnong	There are two sites in Deep Creek Upper and Deep Creek Lower with high quality vegetation currently outside vegetation performance objective priority areas.
Yarra	There were four sites with high quality vegetation currently outside vegetation performance objective priority areas. These are in the following sub-catchments: Brushy Creek, Merri Creek Lower, Gardiners Creek and two in Diamond Creek (Rural). There are five sub-catchments where there is a potential decline in condition i.e. Plenty River Upper Woori Yallock Creek, Yarra River Middle and two sites in the Yarra River Upper (Rural) sub-catchment. Further monitoring is required to confirm this trend.
Dandenong	There were four sites with high quality vegetation currently outside vegetation performance objective priority areas. These are in the following sub-catchments: Blind Creek, Eumemmerring Creek, Dandenong Creek Middle and Kananook Creek.
Westernport	There were six sites with high quality vegetation currently outside vegetation performance objective priority areas. These are in the following sub-catchments: Mornington Peninsula North-Eastern Creeks (two sites), Mornington Peninsula South-Eastern Creeks (two sites), French and Phillip Islands, Mornington Peninsula Western Creeks, and Dalmore Outfalls.

KEQ 2a. What environmental conditions (e.g. water quality) and external factors (e.g. policy) help explain current key value trends?

Approach

The sub indicators of the VV21 data were used in this evaluation to assess some key factors that contribute to the condition of vegetation. These sub indicators included regeneration, connectivity, weeds and deer (presence/absence). Attention was focused on sites of high quality.

Outcome

The new field data confirmed our assumption that low quality sites have low natural regeneration rates due to the degree of disturbance and pressures at these sites. However, we were interested to see whether any high-quality vegetation sites also had low regeneration rates, as this may indicate a possible future decline in condition and resilience. The results suggest that only 10 sites in the MW region have a high VV21 score and low (<3) regeneration score. Maribyrnong was the only catchment where there were significant implications for implementation as 13% of these high-quality sites had low regeneration (thee sites).

Connectivity between patches of vegetation is an important factor for vegetation condition. The VV21 methodology is somewhat limited in its ability to assess connectivity as it only assesses connectivity for a site and not between sites. While additional data and analysis for connectivity measures are required, we assessed high quality sites that had low connectivity scores as these sites may be vulnerable. Only two sites had low connectivity but VV21 high quality scores.

Further investigation of sites with potential low regeneration rates and low connectivity is required to improve the conceptual understanding of the link between vegetation connectivity and vegetation quality.

Nearly half the monitoring sites (i.e. 99 sites or 47%) with high to very high VV21 scores had high general weed loads, however, highly invasive weeds were present in only 20% of these sites. The highest weed loads, both for weeds generally and highly invasive weeds, were recorded in the Dandenong catchment. There is a need to investigate the current level of weed management for these sites to inform on-ground works planning.

The presence of deer was assessed using the VV21 data and model predictions (Figure 15.) Model predictions show deer densities are greatest where there is close proximity to large water bodies and at intermediate levels of forest cover. Elevation and rainfall are also important factors highlighting greater densities in the south and east part of the region (Figure 16). The VV21 data showed deer were most prevalent in the Yarra catchment (59% of sites) followed by Westernport (27% of sites). Signs of deer presence was recorded as wallows, browsing and scats/prints for the VV21 data, with the highest presence likely where all of these signs were recorded. On average, deer were more likely to be found at sites that were of high vegetation quality (VV21 score of 4 or 5) and 30% of these sites had high deer densities according to recent modelled predictions. Deer management is needed if vegetation assets are to be protected.

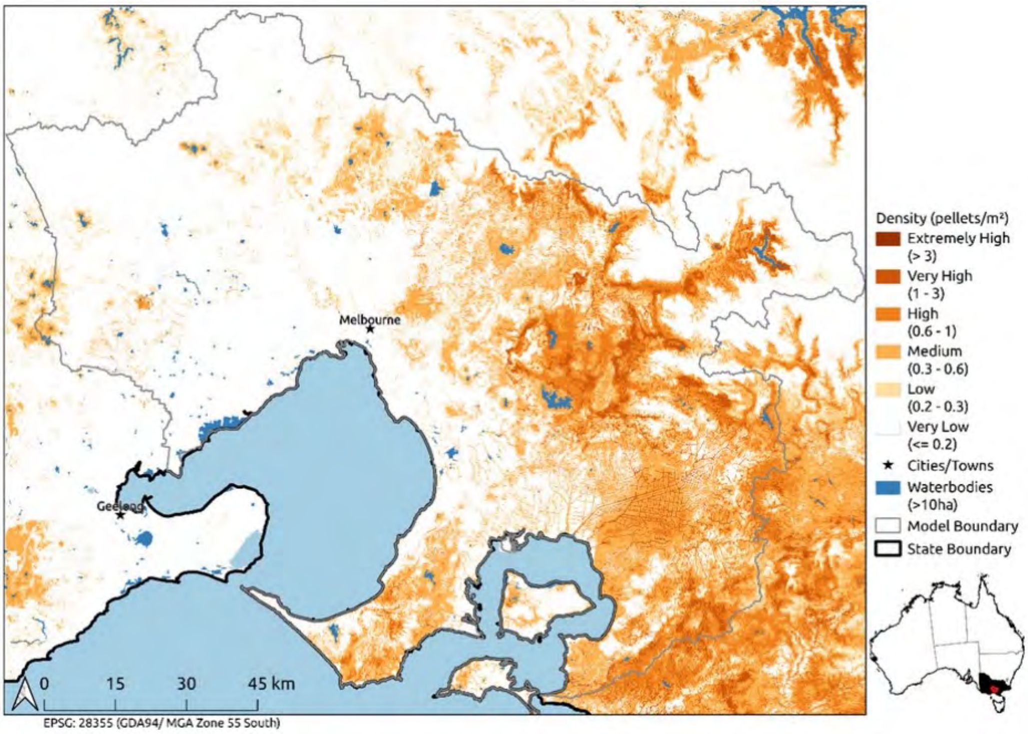


Figure 15. Predicted deer densities across the region.

Overall value summary

Despite inadequate comparable data to assess region-wide temporal changes to vegetation condition and comprehensively address all the key evaluation question, we were able to use multiple lines of evidence to demonstrate the following:

- The condition of vegetation is improving along reaches that are being actively managed.
- Sites which have been revegetated for over 10 years have similar species richness to remnant areas. However, weeds dominate the understory, and the revegetated sites lack important structural components and natural recruitment.
- More broadly, weed loads are high in most sites (remnants and restored areas) as confirmed by the VV21 data. Fortunately, the proportion of highly invasive weeds is low (20%) in reaches where vegetation condition is in good quality.
- Deer are a threat to vegetation and are in high numbers particularly around large water bodies and forested areas in the higher rainfall areas of the catchment.
- New areas of high-quality vegetation have been identified at 120 sites with 25 sites not currently included in HWS 2018 vegetation priority areas.
- There are several sites (five in the Yarra and three in the Werribee) where condition may have declined, however confidence in this result is low and requires further investigation.

Limitations

A key limitation to robustly reporting on vegetation changes has been the lack of systematically documented, integrated, curated, retrievable and easily reusable vegetation data. This suggests that a dedicated database for vegetation data is urgently required. Similarly, a lack of a dedicated region-wide surveillance monitoring program for vegetation condition has limited our ability to evaluate progress towards long-term targets. This monitoring gap is being addressed and a long- term monitoring program has been established to evaluate vegetation condition and the influence of management interventions such as revegetation. However, current business investments have not supported the development of specialist roles, in particular in vegetation management. These roles are required to effectively manage vegetation quality and extent in the future.

As outlined above, previous methods were not similar enough to allow robust comparisons to report on vegetation changes and associated key evaluation question since the implementation of the strategy. It is expected that, in the future, using Vegetation Visions data (i.e. VV21) as well as the Restoration Outcomes Monitoring Protocol (ROMP, to assess management interventions such as revegetation), vegetation measures should be more reliable and robust. Other vegetation assessment methods are also being developed, such as remote sensing of vegetation quality, aerial imagery and artificial intelligence data to track vegetation extent, which will help to answer some of the key evaluation question in the future.

Further, the VV18 and VV21 datasets are not directly comparable as they have different constitutive elements and are scored differently, were undertaken at different scales (waterway reaches for VV18 data and discrete sites for VV21 data) and were assessed differently (expert elicitation for VV18 data and field assessments for VV21 data). So, caution needs to be taken when comparing the two. Future assessments using the VV21 method will provide more accurate data on changes in vegetation condition. Given only one round of data (i.e. 2021 was used in this evaluation), these preliminary results need to be reviewed with caution and reassessed in future years. Finally, the connectivity score for the VV21 data is limited to a visual assessment at the site and does not take into account of broader landscape analysis. A spatial analysis as a component of the VV21 could improve the method.

Riparian birds

Introduction

The HWS bird value is treated as riparian or wetland bird values separately and were identified as key values because of the pleasure birds bring through their colour, calls, flight and other behaviours, and because of the ecosystem functions they provide, such as pollination, seed dispersal and regulation of some insect populations.

The riparian bird value is taken to be native species richness and abundance. This incorporates underlying factors such as the need for persistent populations that are resilient and self-sustaining in the long-term, through drought, storm, flood, fire, epidemics and climate change. Analysis and modelling of Birdlife Australia's extensive bird data set was used to derive a list of expected riparian species for each of the major catchments (AECOM 2012).

Melbourne Water works with Birdlife Australia to ensure streamside and wetland sites in the region are visited by birdwatchers trained to report the results of their bird surveys. Data for this mid-term review include the results of 27,887 daytime surveys between 1998 and 2021, including 488,942 species records and 320 bird taxa recorded.

As part of this regional data collection program, targeted, quantitative bird counts by qualified personnel have been conducted at as many works and control sites as could be arranged. This work focusses on willow removal effects and builds on a 2011-2013 study (AECOM 2012, AECOM 2013). But we acknowledge works evaluation responses by riparian bird communities is a major gap.

A Riparian Bird Index (RBI) was developed prior to the 2013 Healthy Waterways Strategy and despite acknowledged simplicity it is a useful high-level measure of relative riparian bird community 'health' over time. The index has been improved over time with expected species lists for each of the five major river catchments.

The Riparian Bird Index was used to describe the condition of riparian bird communities in 2017, as the baseline for the HWS. Expert elicitation was employed to test the Riparian Bird Index results, and to estimate possible future condition scores for the 2018 HWS. The development of the 2017 version of the Index and how HWS performance objectives were set are described in the Healthy Waterway Strategy Resource Document (Melbourne Water 2020).

KEQ 3a. To what extent are key values on the target trajectory?

Approach

The Riparian Bird Index was calculated for all sub-catchments for which there is at least 40 robust surveys for the five-year period preceding the 2018 HWS (the new 2018 baseline) and the period July 2018 to December 2021 ("current").

Assessing whether riparian birds are on-track was evaluated by comparing the 2022 ("current") score with the target score. 'On-track' is when the current score is the same as the target score, 'slightly off-track' is when the current score is one category below the target score and 'off-track' is when the current score is two categories below the target.

Outcome

Results show that data collection has improved over time and a larger proportion of sub-catchments than before have sufficient data to allow us to derive an index score. The number of sub-catchments scoring 'Very low' has declined from 1 to zero. The number of sub-catchments scoring as 'Moderate' and 'High' have increased since 2013/14-2017/18, as many sub-catchments move up in condition (Figure 16).

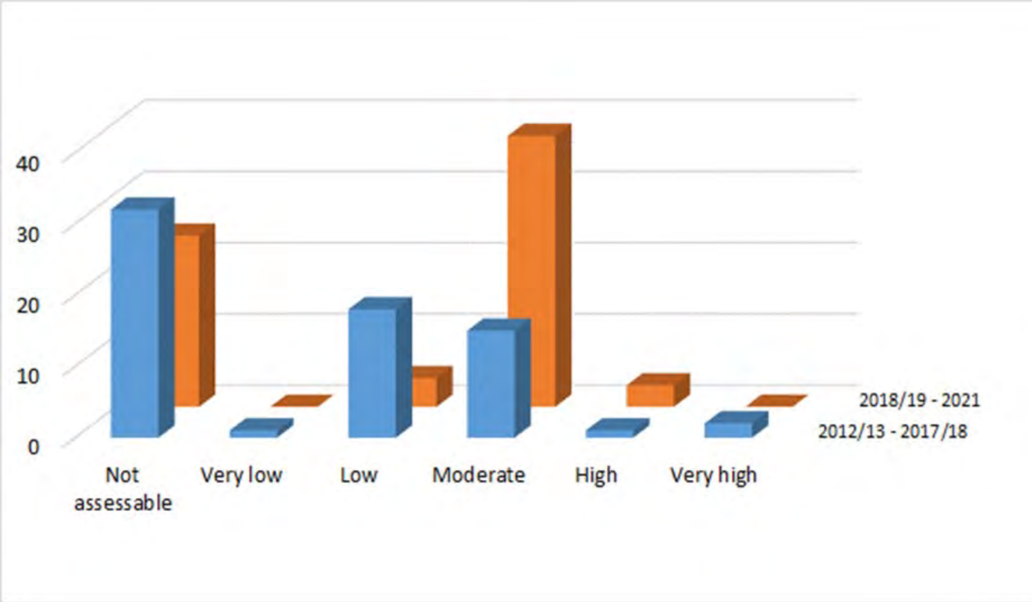


Figure 16. Changes in coarse reporting category for riparian bird communities, comparing the 2013/14-2017/18 and 2018/19-2021 periods.

While 24 of 69 sub-catchments currently have insufficient data to permit an assessment, the majority of sub-catchments assessed (n = 37) are 'on track' according to the agreed rubric. Two sub-catchments are 'off-track' (Watts River Source and Watsons Creek) and six sub-catchments are 'slightly off-track' (Eumemmerring Creek, Gardiners Creek, French and Phillip Islands, Bunyip Middle and Upper, Bayside and Mornington Peninsula SE Creeks).

Table 10. Bird value summary for HWS catchments.

Catchment	Summary
Werribee	10 of the 14 sub-catchments could be assessed, all of which were rated as being on the target trajectory to meet long-term targets ('on-track'). Werribee River Middle is above target, which is surprising given the extent of urban development occurring in this area. Little River Lower has increased in score, which possibly reflects a capital works program initiated in 2014 to improve bird habitat.
Maribyrnong	Unfortunately only four of the 10 sub-catchment could be assessed. Of these all were rated as being on the target trajectory to meet long-term targets ('on-track').
Yarra	17 of the 25 sub-catchments could be assessed. Of these 14 are on the target trajectory to meet long-term targets ('on-track'), 1 is 'slightly off-track', and 2 are 'off-track'. These two sub-catchments (Watsons Creek and Watts River (Source)) were partly burnt in the 2009 'Black Saturday Fires', which may have contributed to the lower score. Gardiners Creek which is 'slightly off-track', is not cause for concern as the rating has improved since the baseline.
Dandenong	All sub-catchments could be assessed and all were on the target trajectory to meet long-term targets ('on-track') except two which were 'slightly off-track'. One of these sub-catchments, Eumemmering Creek, is only just 'slightly off-track'. One sub-catchment Dandenong Creek Upper is currently scoring above the target. As there was insufficient data to establish a baseline, we likely underestimated the riparian bird value in this area. Blind Creek and Dandenong Middle have seen the greatest increase in Index score and further investigation is required to understand what is driving this.
Westernport	Six of the 14 sub-catchments could not be assessed. Of the eight which could be assessed, 3 were on the target trajectory to meet long-term targets ('on-track') and three were 'slightly off-track' (i.e. Mornington Pen. SE Creeks, French and Phillip Islands and Bunyip Middle and Upper). Despite this status these sub-catchments are not cause for concern at this stage as changes to the RBI relative to the baseline are very minor.

KEQ 3b. What other spatial and temporal trends and patterns for key values are of significance for implementation?

Approach

Bird abundance, species richness and functional guilds respond to varying resources within a habitat, some of which are not attributable to management. Since we suspect annual rainfall and other environmental factors may play an important role in determining riparian bird community structure, the long-term trends in Riparian Bird Index were investigated.

Two approaches were tried. Where possible (i.e. when 40 or more robust scores were available for three or more time periods for a sub-catchment) these five-year measures were plotted to track riparian bird community health at a coarse level. In addition, the annual Riparian Bird Index was calculated for those sub-catchments with sufficient data. The annual Index score provides a more detailed view of trends over time.

The five-year time periods used were:

- A - 1 July 1998 to 30 June 2003 (Drought)
- B - 1 July 2003 to 30 June 2008 (Extended drought)
- C - 1 July 2008 to 30 June 2013 (Post-drought recovery)
- D - 1 July 2013 to 30 June 2018 (Variable rainfall)
- E - 1 July 2018 to 31 December 2021 (Generally drier than average)

Outcome

There was no consistent trajectory in trends using the five-year RBI time periods apart from a potential dip in the index in between 2013 – 2018 (i.e. block D) for many of the sub-catchments. This potential dip is more evident using the annual RBI (Figure 17). The annual RBI shows a reassuring 'smoothness' in pattern, with clear trends shown and few extreme variations between consecutive data points. Further testing and validation are required to verify the observed trends and explain the drivers.

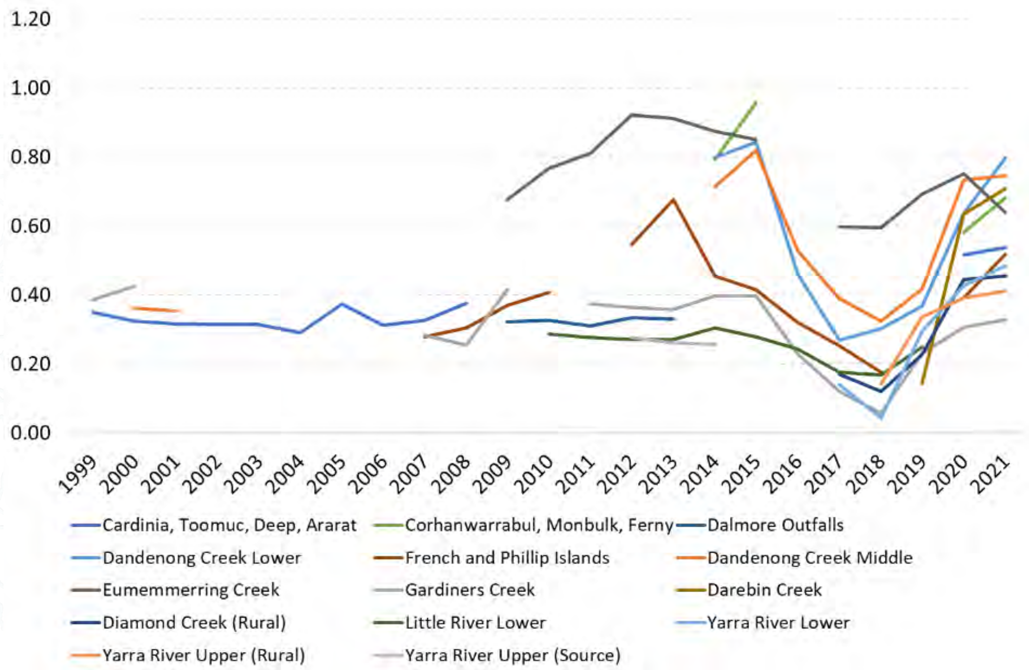


Figure 17. Annual RBI trends over time for 14 sub-catchments.

KEQ 2a. What environmental conditions (e.g. water quality) and external conditions (e.g. policy) help explain current key value trends?

Approach

It is not possible to attribute improvements in riparian bird community scores to on-ground works associated with the Strategy implementation. There is annual variability in Riparian Bird Index scores (Figure 17) which possibly relates to annual rainfall, and other environmental factors, and we cannot determine the extent to which the improved categorical reporting is a result of these. Given that revegetation is known to require some years before providing good quality bird habitat, any observed improvements also might be attributable to on-ground works dating back to before the current HWS.

Outcome

The Riparian Bird Index was designed for five-yearly reporting. We have not yet analysed the Index against the nature and scale of our works in any sub-catchments. This assessment is needed, especially in connection with our vegetation management.

Given the lack of targeted works aimed at improving riparian bird habitat we have limited opportunities to investigate works effectiveness. The long response time between vegetation management and bird responses, and the external factors that influence bird community health mean we cannot confirm any clear relationships in the region.

Overall value summary

Long-term bird surveillance monitoring allowed us to evaluate 45 of the 69 sub-catchments with the majority (37) being 'on track' and many sub-catchments improving in condition. The two sub-catchments that are 'off-track' are Watsons Creek and Watts River (Source) both of which have significant forested areas of which some was burnt in the 2009 'Black Saturday Fires'. These sub-catchments need to be re-evaluated in future years to determine whether the declines are of concern.

Limitations

The Riparian Bird Index is a coarse measure of riparian bird community structure that is based on presence/absence data collected from an uncontrolled range of disparate streamside sites. The Index is intended solely as a high-level reporting tool for comparing scores aggregated across large areas (sub-catchments) over long time scales (years).

Data are vetted by Birdlife Australia and only the most robust surveys of the available community-collected data were selected. But the data collection is still somewhat ad hoc and there is a lack of rigour around standardising the timing or seasonality of surveys. Birdlife Australia are asked to advertise sub-catchments requiring additional survey effort, but sites surveyed are decided by individual birdwatchers.

The Riparian Bird Index has not been tested to ascertain the influence of environmental (non-management) factors, such as annual rainfall, drought years, bushfires, etc. Therefore, we cannot, yet distinguish between changes in score and management interventions/ investment versus environmental factors at the very large spatial scale of sub-catchments.

The Riparian Bird Index cannot be used to explain causes of changes in score. It was never intended for this purpose, but only to indicate changes in riparian community elements over time which might then be investigated.

While we can be confident that management interventions are based on robust science and will ultimately benefit riparian birds, we cannot provide specific information on how much management, using what combination of techniques, is benefiting birds in what way, over what time frame.

Wetlands birds

Introduction

Wetland birds, like birds in riparian areas have been identified as a key value because of their importance to the community. People value birds through the pleasure they bring through their colour, calls, flight and other behaviours, and because of the ecosystem functions they provide, such as pollination, seed dispersal and regulation of some insect populations.

Since 2002/03 Melbourne Water has worked with Birdlife Australia to develop a comprehensive regional, community-based wetland bird monitoring program. This sees teams of volunteers recruited to conduct standardised surveys at many of the region's priority wetlands.

Despite available data, timeframes during HWS development prevented a thorough assessment of bird communities and AVIRA scores were used to estimate wetland bird community condition. Since the HWS the 2018 the baseline for wetlands have been updated using historical and new data and an improved bird index as described in the Wetland Monitoring and Evaluation Plan (Wetlands MEP), (Melbourne Water 2020).

Surveillance monitoring of wetland birds is planned at 120 wetlands across the region where standardised bird surveys are conducted every quarter (or monthly for key wetland with reporting obligations, such as under the Ramsar Convention). There are 82 HWS priority wetland groups, comprising 123 individual priority wetlands, but only 108 of these priority wetlands have wetland birds as a value. For the mid-term evaluation there was enough data for 20 wetlands to be evaluated for key evaluation question 3a and 19 wetlands for key evaluation question 3b.

Evaluation criteria were developed to guide the data analysis and evaluation of the relevant key evaluation questions. These criteria are available in the Wetland MEP (Melbourne Water 2020). Below we have summarised the evaluation approach and the outcomes of the evaluation.

Climatic conditions are one driver of bird community variation, and unlike other waterway values in our region, rainfall variations outside our region (e.g. across the Murray-Darling Basin) are an important consideration when understanding wetland birds in the region.

KEQ 3a. To what extent are key values on the target trajectory?

Approach

To assess whether the Strategy is 'on track' with the HWS target trajectory, the Wetland Bird Index was re-calculated, for all priority wetlands for which we have at least 20 robust surveys for the five-year period preceding the 2018 HWS (our new 2018 baseline) and the period July 2018 to mid-2022 ("current").

The 2022 ("current") scores were then compared with the new 2018 ("baseline") to assess the trajectory. This assessment follows the rubric presented in the Wetlands MEP. While the new baseline may be different, the long-term targets are based on either maintaining or improving when compared against the baseline state.

Outcome

Of 44 wetlands for which we can calculate a new baseline index for 2018, most were higher and three had the same score. Only five wetlands, in the Werribee and Dandenong catchments, scored lower following re-calculation than the 2018 HWS assessment (Table 11). The two benchmarks are, therefore, largely comparable and where the Wetland Bird Index score was re-calculated to be lower than the HWS 2018 assessment we believe the index is the more accurate description. We emphasise that when there was a change in the scores (e.g. from Moderate to Low) at one location, from the 2018 HWS assessment to the 2020 assessment, this represents a more accurate assessment rather than a decline or an improvement.

Disappointingly, we can only calculate 'current' (mid-2022) status for 25 of the 123 HWS priority wetlands. Of these 18 are 'on track', five are 'slightly off-track' and two are 'off-track' (i.e. two or more categories below the 2018 baseline; 'High chance that long-term targets will not be met').

The two wetlands that are 'off-track': Paradise Road Ponds at the Western Treatment Plant (WTP), and Truganina Swamp are cause for concern as they are large wetlands providing important migratory shorebird bird habitat. By having only three summer counts, rather than five, we have had less opportunity to detect occasional vagrant migratory species (many of which are threatened), and which positively affect our Wetland Bird Index.

The five slightly off-track wetlands are Tootgarook Swamp, WTP – Western Lagoon, Edithvale North wetland, Serpentine Lagoon – ETP and Banyan Waterhole – ETP.

The apparent declines are concerning and it is uncertain in some of the wetlands what the cause(s) of decline may be. Recent work by the A3P Melbourne Water research-practice partnership has revealed high levels of contaminants in several WTP habitat ponds and also Edithvale Wetlands and Banyan Waterhole (Long, et al. 2022) and we need to understand far better this risk to waterbirds, especially at the region's Ramsar sites.

Table 11. Summary of results for KEQ3a for wetland birds in the 5 major catchments across the region.

Catchment	Summary
Werribee	Of the 55 HWS priority wetlands a new baseline has been set for 11 wetlands of which eight were higher than the old baseline and three were lower (i.e. Austen Road Pond 1 (Summer Pond 1) - WTP, Q4 Wetland - WTP and RAAF Lake, Point Cook). Only five out of 55 wetlands could be evaluated of which one was on the target trajectory to meet long-term targets ('on-track') (Paisley-Challis Wetland at Jawbone reserve and T-Section Lagoon at WTP), 1 was 'slightly off-track' (Western lagoon at WTP) and two were 'off-track' (Paradise Road Ponds at the WTP, and Truganina Swamp). The two 'off-track' wetlands are cause for concern as they are large wetlands providing important bird habitat including migratory shorebirds.
Maribyrnong	Of the six HWS priority wetlands a new baseline has been set for two wetlands, both of which were higher than the old baseline. None of the wetlands could be evaluated.
Yarra	Of the 21 HWS priority wetlands a new baseline has been set for four wetlands, of which one had a higher new baseline and three were the same. Only two of the 21 wetlands could be evaluated of which both were on the target trajectory to meet long-term targets ('on-track') (Ringwood Lake and Lilydale Lake).
Dandenong	Of the 28 HWS priority wetlands a new baseline has been set for 22 wetlands, of which 17 had a higher new baseline, three were the same and two were lower (i.e. The Doughnut at the ETP and Chelsea Heights Wetland, Wannarkladdin Wetlands. Fifteen of the 28 wetlands could be evaluated of which 12 were on the target trajectory to meet long-term targets ('on-track') and three were 'slightly off-track' (including Edithvale North, Serpentine Lagoon at the ETP, and Banyan Waterhole at the ETP). The Serpentine Lagoon is not managed as bird habitat and the decline in bird value is a valid statement of what has occurred there. The other two are cause for concern as they provide important bird habitat including migratory shorebirds. Banyan Waterhole is downstream of a drain that was found to be heavily polluted with lead from an adjacent shooting club.
Westernport	Of the eight HWS priority wetlands a new baseline has been set for three wetlands, of which two had a higher new baseline and one was the same. Three of the eight wetlands could be evaluated of which two were on the target trajectory to meet long-term targets ('on-track') (57 Western Port coastal wetlands and 59 Coolart Wetlands) and one 'slightly off-track' (Tootgarook Swamp).

KEQ 3b. What other spatial and temporal trends and patterns for key values are of significance for implementation?

Approach

This question was used to explore longer term trends using the same wetland bird index and to include all wetlands listed in the 2020 Wetland MEP[1] (and not only those in the HWS with status and targets described). Birdlife Australia was commissioned to analyse the bird data and describe, where possible, the trajectories of wetland bird communities (Birdlife Australia 2022b). This question allowed some wetlands which could not be assessed in KEQ3a due to data limitations to be evaluated here.

The bird count data collected from 2003/2004 were divided into four time periods:

- BLOCK 1 represents the earlier period for wetlands which have sufficient data – 2003/04 to 2007/08 (coinciding with the latter stages of the Millennium Drought)
- BLOCK 2 represents the pre-Healthy Waterways Strategy – 2008/09 to 2012/13
- BLOCK 3 represents the period of the 2013 Healthy Waterways Strategy – 2013/14 to 2017/18, and
- BLOCK 4 represents the post-2018 Healthy Waterways Strategy – 2018/19 to 2021/22.

Outcome

Table 12 provides an indication of the trajectories of the wetland bird indices at 19 wetlands across at least three time- blocks and an indication of whether the bird communities are stable, improving or declining at each wetland.

In summary, the Wetland Bird Indices indicate that the wetland bird communities are stable at 14 of the 19 wetlands that could be assessed. This included most Ramsar Sites, key biodiversity area (KBA) sites, a 'Migratory Shorebird Site' and one of the two 'Regional Wetlands'. No wetlands had improving trajectories and five were declining.

1. There are tens of thousands of wetlands (including natural, artificial/constructed and modified natural) across the region. An initial regional prioritisation process identified 155 wetlands for environmental and/or social values. This list was reduced to 132 based on a desktop review. These priority wetlands were grouped, purely for mapping purposes, into only 82 "wetlands" (comprising 122 named wetlands) in the HWS. Following the release of the 2018 HWS, the wetland priority list was expanded to 249 wetlands based on a more thorough prioritisation process. These are documented in the Wetlands Monitoring and Evaluation Plan (Melbourne Water 2020). The intent was for this list of designated regional priority wetlands to evolve as data availability and knowledge progressively improved. It was intended to monitor wetland birds at around 120 of the 249 priority wetlands. Of these 82 wetland groups, comprising 123 individual wetlands, are current HWS priority wetlands with long- term bird value targets.

Table 12. Summary of results for KEQ3b for wetland birds in the 5 major catchments across the region.

Catchment	Summary
Werribee	Four wetlands could be assessed of which three were stable and one was declining (i.e. WTP - Habitat Ponds). While these small habitat ponds are showing declines in some elements of the index, this is attributed to vegetation encroachment as we manage some of these former shorebird ponds for the endangered Growling Grass Frog.
Maribyrnong	There was insufficient data to assess wetlands in the Maribyrnong catchment.
Yarra	Westgate Park Lakes was the only wetland that could be assessed and has a declining bird index. The declines are not clear and are being investigated with the Friends of Westgate Park.
Dandenong	Of the 11 wetlands that could be assessed two were declining and nine were stable. The wetland bird communities at three of the four Dandenong Valley s/w Wetlands are stable (Heatherton Road North and South Wetlands and Frog Hollow Wetland). The indices for the fourth s/w treatment wetland, Kilberry Boulevard/ Rivergum Creek Wetlands, indicate a decline in the wetland bird community which is thought to be related to the age of constructed stormwater treatment wetlands and vegetation succession i.e. as vegetation increases in density and height over time bird diversity and abundance reduces. Karkarook wetlands also exhibited a decline in bird values.
Westernport	Of the wetlands that could be assessed two were stable (Westernport and Swan Lake) and one was declining (Devilbend Reservoir). Declines in Indices since Block one which may relate to the refuge capacity of the site during the Millennium Drought, and birds leaving once the drought broke.

KEQ 2a. What environmental conditions (e.g. Water quality) and external conditions (e.g. policy) help explain current key value trends?

Approach

This section focuses on evaluating the five wetlands which had declining trajectories summarized in key evaluation question 3b i.e. WTP habitat ponds (Ramsar wetland), Kilberry Boulevard/ Rivergum Creek Wetlands (Constructed stormwater wetland), Devilbend reservoir (Regionally significant wetland), Karkarook (Social value wetland) and Westgate Park (Social value wetland).

Understanding the trajectories of bird communities is underpinned by numerous studies carried out across the region; see the Wetland Technical Report (Wetlands: A Technical Report to Inform the Healthy Waterways Strategy Mid-term Evaluation).

Outcome

While each wetland is discussed below the key factors which affect wetland bird communities are water quality, hydrology, vegetation management and wetland morphology. Vegetation growth, or lack of management, in some wetlands can be shown to adversely affect the wetland bird community – particularly shorebirds and wading species.

WTP habitat ponds (Ramsar wetland)

While the summed reporting rates are stable, a decline in the Wetland Index from the 'Very High' during Blocks 2 and 3 to the 'Moderate' during Block 4 is associated with a decline in Numbers of Listed Species. A decline in the Average Annual Species Richness also recorded during these blocks, could reflect the lower number of surveys undertaken during Covid restrictions, but there is also concern about a decline in shorebird habitat associated with vegetation encroachment and consistently high-water levels. This has reduced expanses of mudflat for shorebirds. This decline in quality of shorebird habitat could result in a decline in numbers of shorebirds in turn manifested in overall species richness and the Numbers of Listed Species.

Kilberry Boulevard/ Rivergum Creek Wetlands (Constructed stormwater wetland)

Most indices and statistics have declined by more than 10% during at least one block since Block 2. The decline in indices and statistics is thought to be associated with the age of constructed stormwater treatment wetlands. Following construction, initially, there is little emergent or surrounding aquatic vegetation. However, as vegetation expands and increases in density over time, a reduction in bird diversity and abundance occurs. As such the declining trajectory is expected and not seen as a reason for concern.

Devilbend Reservoir (Regionally significant wetland)

Most wetland bird indices (except for Number of Listed Species) and statistics for Blocks 2 and 3 were much lower than those for Block 1. Devilbend Reservoir possibly provided a refuge during the Millennium Drought for waterbirds, which then departed once the Drought broke. As such the declining trend is not reason for concern at this stage.

Karkarook (Social value wetland)

Some indices and statistics displayed an increase from Blocks 2 to 3 (e.g. Average Maximum Annual Abundance, Density, Numbers of Breeding Species and Numbers of Listed Species), while others (Summed Reporting Rate and Average Annual Waterbird Richness) declined from Blocks 2 to 3. However, all indices and statistics have experienced substantial declines from Block 3 to Block 4. This wetland is in an urban setting and it's likely that the declines may relate to human disturbance and the dominance of common and abundant bird species.

Westgate Park (Social value wetland)

While the Summed Reporting Rates and the Average Annual Waterbird Richness were stable, all other indices and statistics have shown substantial decreases from Block 1 (i.e. Millennium Drought) to Block 2 and Block 2 to Block 3. The reasons for these declines are unclear and are currently being investigated with the Friends of Westgate Park.

Overall value summary

A new baseline has been calculated for wetland birds in 44 of the 123 HWS priority wetlands (as outlined in the Wetlands MEP) and current assessments can be compared to this revised benchmark for 25 wetlands. Of these, 18 are 'on track' according to the Wetland MEP rubric. There are five wetlands ranked as 'slightly off-track' (Tootgarook Swamp, WTP – Western Lagoon, Edithvale North wetland, Serpentine Lagoon – ETP and Banyan Waterhole – ETP) and two where there is considered to be a high chance that long-term targets will not be met. These two wetlands, Paradise Road Ponds at the WTP and Truganina Swamp, are cause for concern as they are large wetlands providing important migratory shorebird bird habitat.

The longer-term assessment of wetlands (key evaluation question 3b) (i.e. over the past 20 years) has shown that the bird communities at most wetlands that could be assessed are relatively stable. The five wetlands which had declining trajectories were investigated as part of key evaluation question 2a.

Limitations

Climate variability at different spatial and temporal scales is important and this could not be thoroughly investigated. The trajectories of bird communities are likely influenced by climatic conditions both locally and more broadly. As such a decline in the wetland bird index may or may not be cause for concern. New baseline data is limited to a small proportion of wetlands in the region. There was insufficient data to evaluate the bird community in the Maribyrnong catchment – for both key evaluation questions. The causal factors of bird community trajectories were unclear in some wetlands. Quantitative count data collected by community volunteers will vary with observer skills (in addition to other sources of variation in detectability: weather conditions, time of day, etc.). Therefore, while count data will be useful when explaining results, for regional surveillance we have developed indicators of wetland bird community that are not reliant on accurate count data.

Frogs

Introduction

Frogs are key value in the HWS. The still or slow-flowing waters of wetlands provide shelter, feeding grounds and breeding habitat for frogs. 20 species of frog have been recorded in the region since 1839, including the vulnerable Growling Grass Frog (*Litoria raniformis*) and the endangered Brown (*Pseudophryne bibronii*) and Southern (*P. semimarmorata*) Toadlets.

It was envisaged that frog value monitoring, evaluation and reporting would be completed at scale of wetlands (regional priority wetlands only). However, our ability to evaluate and report at the scale of wetlands was restricted by limited data availability. Specifically, we did not have adequate eDNA data to inform a detailed assessment of changes in frog community for individual wetlands. As such, here we focus on the assessment of frog trajectory at the sub-catchment scale using the data available at the time of assessment. It is expected that this sub-catchment evaluation will only be required for this mid-term evaluation and that future evaluation and reporting will be performed at the wetland scale. Evaluation criteria were developed to guide the data analysis and evaluation of the relevant key evaluation questions for frogs. Below we summarise the evaluation approach and the outcomes of the evaluation.

KEQ 3a. To what extent are key values on the target trajectory?

Approach

For the purpose of the mid-term review, we evaluated frog trajectory by assessing changes in species richness over time across sub-catchments. An observed over expected species approach was followed.

We used all available frog data from the following sources: the Victorian Biodiversity Atlas, a survey by consultants in 2010, and our Frog Census records (39,578 records in total, between January 1960 and June 2022). We determined the 'expected' species in each sub-catchment using data between 1960 and 2017 (i.e. the last year before the HWS). We then looked for changes in species richness (Observed/Expected species richness) within each sub-catchment ove three time periods: <2001, 2001 to 2010 inclusive, and >2010.

A full description of the criteria used to assess frog trajectory using this data is available in Table 3 of the *Healthy Waterways Strategy Mid-term Evaluation Synthesis Methodology* (Melbourne Water 2023) and in the *Wetlands: A Technical Report to Inform the Healthy Waterways Strategy Mid-term Evaluation* (Melbourne Water 2023). Briefly, species richness was only calculated for a time period if there was >100 records. Frog trajectories were then determined as follows:

- Declining = clear evidence of decline over all time periods
- Potentially declining = overall decline in time perizods however there are only two time periods or a variable but downward trend in the trajectory (i.e. very high to moderate to high)
- Increasing or stable = no evidence of decline over the time, or
- Data gap = insufficient data (<100 records) in all time periods to assess trends.

Outcome

Twenty of the 69 sub-catchments could not be assessed because of a lack of records (Figure 18). Six sub-catchments were found to be declining and are likely not on the target trajectory to achieve long-term targets. These sub-catchments were: Plenty River Lower, Darebin Creek, Gardiners Creek, Dalmore Outfalls, Jacksons Creek and Lollypop Creek. Sixteen other sub-catchments showed potential declines over time, or variable changes over the three time periods, but data limitations mean we are not confident there is a real decline.

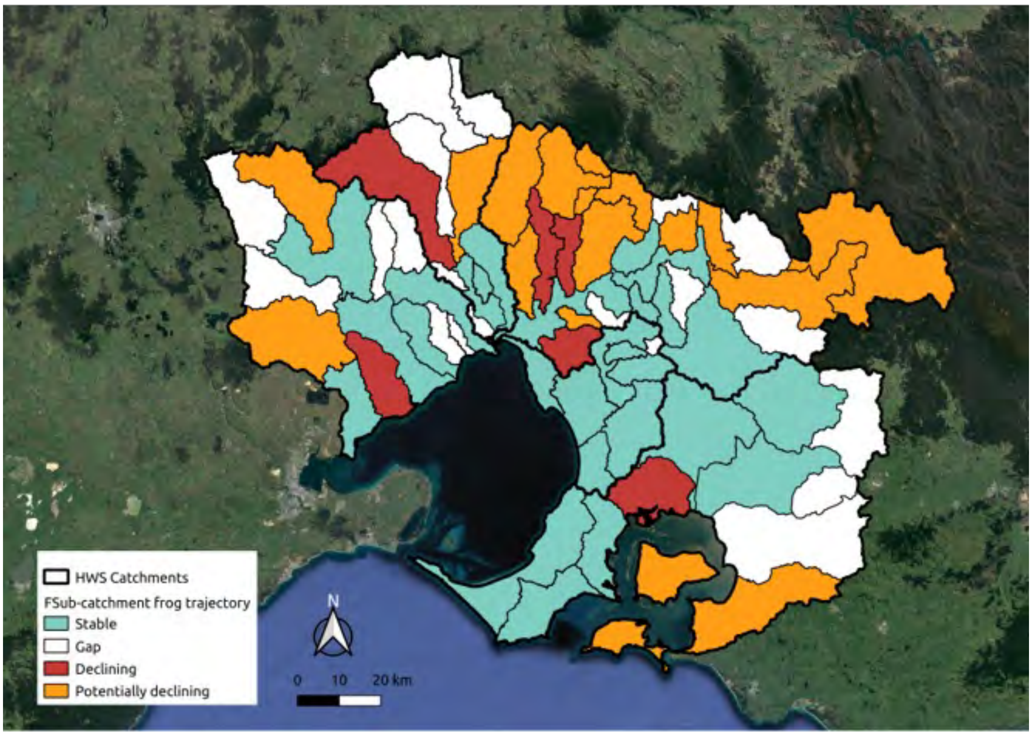


Figure 18. The interim sub-catchment trajectory for frogs.

The likely causes of changes in frog trajectory (i.e. those rated as declining) was not investigated. However, three of the six sub-catchments with a declining frog trajectory are highly urbanized (Plenty River Lower, Darebin Creek and Gardiners Creek). Lollypop Creek has also seen extensive urbanisation. But it is difficult to explain why Dalmore Outfalls and Jacksons Creek should have declining frog health. In particular, Jacksons Creek has seen major revegetation works since the start of the Strategy, and this change has been associated with a detectable response from riparian birds – see the Riparian Birds Technical Report (Melbourne Water 2023).

KEQ 3b. What other spatial and temporal trends and patterns for key values are of significance for implementation?

Approach

This question was used to explore broad-scale spatial and temporal patterns in the recorded presence of the following threatened frog species in each sub-catchment:

- Growling Grass Frog (*Litoria raniformis*) – Vulnerable (EPBC Act, FFG Act)
- Brown Toadlet (*Pseudophryne bibroni*) – Endangered (FFG Act), and
- Southern Toadlet (*Pseudophryne semimarmorata*) – Endangered (FFG Act).

For the purpose of the mid-term review, we combined records for the Brown Toadlet and the Southern Toadlet as '*Pseudrophryne spp.*' as these two species are thought to be indistinguishable via audio analysis and difficult to identify.

Using all available frog record data, we investigated broad-scale contractions in range at the scale of HWS sub-catchments. We did this by noting where (sub-catchment scale) Growling Grass Frogs and *Pseudophryne* spp. has historically (all data) been recorded but have not been recorded since 2010.

Outcome

The Growling Grass Frog was recorded in 34 sub-catchments since 2010 (Figure 19). Historically, the Growling Grass Frog has been recorded in 61 sub-catchments. *Pseudrophryne* spp. were recorded in 38 sub-catchments since 2010 (Figure 20). Historically, *Pseudrophryne* spp. were recorded in 54 sub-catchments.

Declines in positive records of Growling Grass Frog and *Pseudrophryne* spp. are generally widespread and include sub-catchments not generally associated with rapid urbanization. A summary of the change in positive records for Growling Grass Frog and *Pseudrophryne* spp. within each HWS catchment is available in Table 13.

We highlight that this investigation was preliminary and of a broad-scale nature – focused investigations are required to confirm these potential widespread declines. Importantly, targeted surveys of Pseudrophryne spp. within Melbourne indicate that the Brown Toadlet is probably extinct (Cleeland 2023) – this indicates that we may have underrepresented declines in *Pseudrophryne* spp. and potentially other taxa.

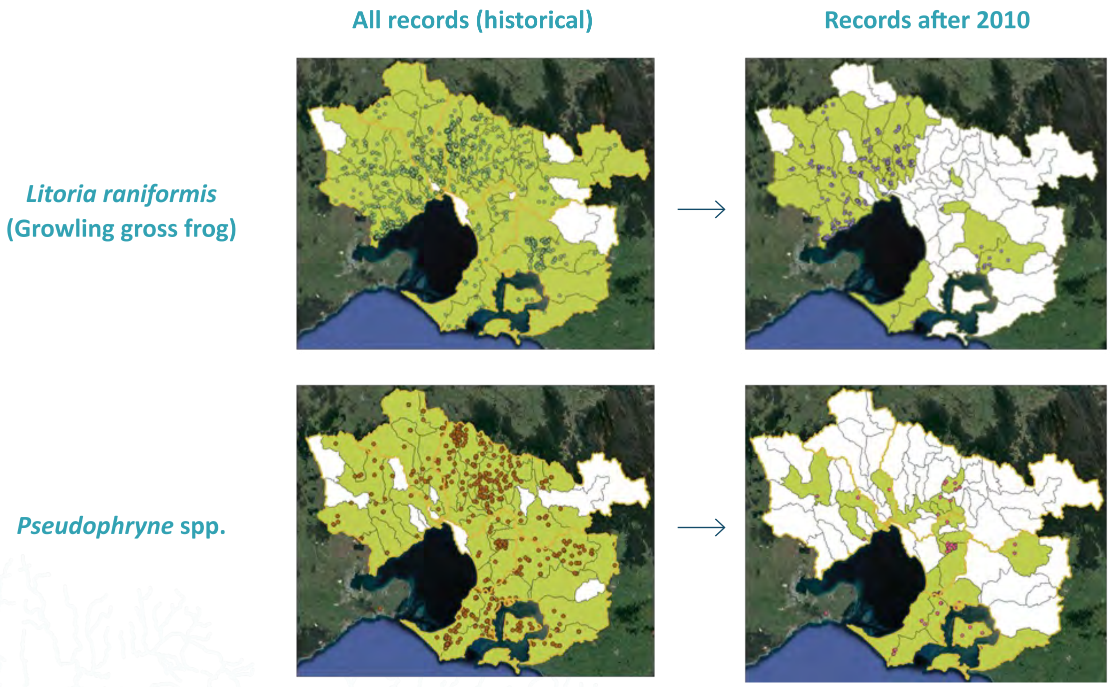


Figure 19. Sub-catchments where the Growling grass frog and Pseudophryne spp. have (a) historically been recorded and (b) recorded since 2010. Individual positive records are also displayed.

Table 13. Summary of the changes in Growling grass frog and Pseudrophryne spp. positive records (historical versus 2010 onward) for each HWS Catchment.

Catchment	Summary
Werribee	Three (historically 13) sub-catchments (Kororoit Creek Upper, Cherry Creek, Laverton Creek) no longer have positive records for Growling Grass Frogs. Six (historically nine) sub-catchments (Lollypop Creek, Little River Lower, Werribee River Lower, Toolern Creek, Lerderderg River, Little River Upper) no longer have positive records for *Pseudrophryne* spp.
Maribyrnong	Two (historically nine) sub-catchments (Deep Creek Upper, Boyd Creek) no longer have positive records for Growling Grass Frogs. Seven (historically eight) sub-catchments (Taylors Creek, Maribyrnong River, Emu Creek, Deep Creek Lower, Deep Creek Upper, Jacksons Creek, Boyd Creek) no longer have positive records for *Pseudrophryne* spp..
Yarra	Only ~20% of sub-catchments that have historically had positive detections of Growling Grass Frogs and *Pseudrophryne* spp. still had positive detections post 2010.

Catchment	Summary
Dandenong	Five (historically six) sub-catchments (Blind Creek, Dandenong Creek Middle, Dandenong Creek Lower, Kananook Creek, Eumemmerring Creek) no longer have positive records for Growling Grass Frogs. Three (historically seven) sub-catchments (Blind Creek, Dandenong Creek Upper, Dandenong Creek Lower) no longer have positive records for Pseudrophryne spp.
Westernport	Six (historically 10) sub-catchments (Lang Lang River, Bass River, Dalmore Outfalls, King Parrot and Musk Creek, French and Phillip Islands) no longer have positive records for Growling Grass Frogs. Four (historically 11) sub-catchments (Tarago River, Lang Lang River, Bunyip Lower, and Cardinia, Toomuc, Deep and Ararat Creek) no longer have positive records for *Pseudrophryne* spp.

Overall value summary

The ability to assess frog trajectory was hindered by limited data availability and appropriate analysis methods. Importantly, we were unable to assess frog trajectory at the wetland scale. Instead, an interim assessment was completed at the sub-catchment scale. Of the 69 sub-catchments assessed, 45% were rated as declining or likely declining. Declines were generally widespread – that is, not confined to one part of Melbourne. This general decline mirrors the trajectory of frogs elsewhere (regionally and globally), including for threatened species in the HWS region (see key evaluation question 3b above), and it is plausible that we have underestimated the decline in frogs across the HWS region.

Limitations

Field data on frogs is still limited and largely 'presence only' records from opportunistic, volunteer recordings of frogs calling. Further, at the time of this mid-term evaluation, we did not have adequate eDNA data for frogs. The intent, at the beginning of the Strategy, and as stated in the 2020 Wetlands MEP, was to use eDNA data to underscore the assessment of presence/absence of frog species, particularly at the scale of individual wetlands. In the absence of widespread and reliable eDNA data at the time of the evaluation, we use the frog records here only as an interim assessment, looking for indications of possible changes in condition of the frog communities. Finally, we highlight that the scale of assessment (sub-catchment scale) is different than the scale of management (wetlands) and, as such, caution should be exercised when interpreting the results.

Photo credit: Peter Robertson

Community connection

Introduction

Liveable places are places that have a sense of community, with communities valuing waterways because they provide settings where people can join together for social interactions, learn from the environment, engage with art and culture and significant places (i.e. to connect with people and nature). They also provide settings for Aboriginal people to connect with Country and their elders past and present.

Evaluation criteria were developed to guide the data analysis and evaluation of the relevant key evaluation questions. These criteria are available in the *Social Values: A Technical Report to Inform the 2018 HWS Mid-term Review* report. Below we summarise the evaluation approach and the outcomes of the evaluation.

KEQ 3a. To what extent are key values on the target trajectory?

Approach

A metric for defining waterway recreation value was developed for the Healthy Waterways Strategy which uses data from Melbourne Water's Community Perceptions Survey. The survey typically has a sample size greater than 2,000, with around 1,500 of those having visited waterways in the last 12 months. The survey ensures coverage across the region and across age and gender.

The values are assessed by associating survey respondents' primary reason for visiting waterways with one of the three social values and then taking the average satisfaction score given in response to the survey question "*How satisfied are you with Melbourne's waterways being suitable for how you use them?*". This gives an assessment of satisfaction with waterways in relation to each recreation values. Table 14 indicates the "reason for visiting waterway" that were associated with waterway community connection values.

Table 14. Association between amenity and reason for visiting waterway.

Corresponding social value	Associated primary reasons for visiting waterway
Community connection	• Social meetings / Family outings • Picnics / BBQs / lunch • Cafes/Restaurants • Community and environmental volunteering i.e. planting trees, • litter clean-up, monitoring water quality or wildlife • To attend events/festivals • Cultural activities

This question was evaluated at 14 management unit spatial scales (Table 15), where management unit satisfaction ratings are the average of sub-catchment scores. The evaluative criteria used to assess performance is outlined in the social values tech paper. Of note, since 2018 no data has been captured in three of the management units - French & Phillip Island, Lower Bunyip, Lang Lang & Bass and Upper Bunyip & Tarago.

Satisfaction scores at the sub-catchment scale are used to help explain and inform trends and patterns across the catchments.

Table 15. Spatial scale of survey data collection. There are 14 management units across the region. This spatial scale was used in the previous HWS. The 69 sub-catchments used in the current strategy are nested within the 14 management units.

Catchment	Management Units
Werribee River	1. Cherry, Kororoit, Laverton, Skeleton Creeks
	2. Werribee and Little River Lowlands
	3. Werribee and Little River Uplands
Maribyrnong River	4. Maribyrnong River Lower
	5. Maribyrnong River Upper
Yarra River	6. Yarra River Lower
	7. Yarra River Middle
	8. Yarra River Upper
Dandenong Creek	9. Dandenong Creek
Westernport and Peninsula	10. Cardinia Creek
	11. French and Phillip Island
	12. Lower Bunyip, Lang Lang and Bass
	13. Mornington Peninsula
	14. Upper Bunyip & Tarago

Outcome

Community connection results across the management units are shown in Table 16. For the 11 management units where data exists, all performance ratings for community connection were 'moderate' in 2022, with scores only varying from 62% (Werribee & Litter River Middle & Upper) to 68% (Yarra River Upper).

Cherry, Kororoit, Laverton & Skeleton Creeks and Yarra River Upper were the only management units rated as on-track because no reductions occurred in 2022 from the 2016 baseline. These management units both had a baseline score of moderate and returned moderate scores in 2022, rather than most other management units where the baseline community connection score was high. All other management units were slightly off-track, where scores reduced by a single category between the baseline and 2022 (e.g. high to moderate). No management units were rated off-track.

The 2022 average community connection satisfaction score was 65%, slightly down from 66% in 2020 and 72% in 2016. There is a statistical significance for the declining trajectories recorded at Werribee & Little River Lowlands in 2020, however community connection satisfaction had improved here by 2022 and are slightly-off track rather than significantly off track.

Table 16. Community Connection Performance Ratings.

Catchment	Management Units	Baseline (2016) Score	2022 Score	Performance Rating
Dandenong	Dandenong Creek	High	Moderate	⚠ slightly off-track
Maribyrnong	Maribyrnong River Lower	High	Moderate	⚠ slightly off-track
	Maribyrnong River Upper	High	Moderate	⚠ slightly off-track
Werribee	Cherry, Kororoit, Laverton, Skeleton	Moderate	Moderate	✔ on-track
	Werribee and Little River Lowlands	High	Moderate	⚠ slightly off-track
	Werribee and Little River Middle and Upper	High	Moderate	⚠ slightly off-track
Westernport	Cardinia Creek	High	Moderate	⚠ slightly off-track
	French and Phillip Islands	N/A	N/A	N/A
	Lower Bunyip, Lang Lang and Bass	High	N/A	N/A
	Mornington Peninsula	High	Moderate	⚠ slightly off-track
	Upper Bunyip and Tarago	Moderate	N/A	N/A
Yarra	Yarra River Lower	High	Moderate	⚠ slightly off-track
	Yarra River Middle	High	Moderate	⚠ slightly off-track
	Yarra River Upper	Moderate	Moderate	✔ on-track

At a sub-catchment scale, the following results were of interest:

Catchment	Summary
Werribee	Three management units could be assessed in 2022, from four sub-catchments of data (Werribee River Lower, Werribee River Upper, Kororoit Creek and Skeleton Creek), including two new sub-catchments in 2022. The Cherry, Kororoit, Laverton and Skeleton Creeks is one of two management units rated as on-track across the region, the other two Werribee River management units were rated slightly off-track. All four sub-catchments scored moderate in 2022, scores ranging between 66% and 62% satisfaction. Only Kororoit Creek sub-catchment recorded increases in community connection satisfaction, improving from 58% (low) in 2020 to 66% (moderate) in 2022.
Maribyrnong	Two management units could be assessed in 2022 (Maribyrnong River Lower and Maribyrnong River Upper), from four sub-catchments of data (Maribrynong River, Moonee Ponds Creek, Jacksons Creek and Stony Creek), including two new sub-catchments in 2021 plus one more sub-catchment in 2022. Both management units rated as ‘slightly off-track’. Three sub-catchments scored moderate in 2022 ranging from 67% satisfaction (Jacksons Creek), to 66% (Maribyrnong River - main) to 65% satisfaction (Stony Creek). One sub-catchment (Moonee Ponds Creek) scored low with 58% satisfaction, down from 62% (moderate) in 2021.
Yarra	Three management units could be assessed in 2022 from 11 sub-catchments of data, including two new sub-catchments in 2022. Yarra River Upper rated as on -track, Yarra River Middle and Lower were slightly off-track. The Yarra River Upper is one of only two management units rated on-track across the region, all 11 sub-catchments scored moderate in 2022 however Yarra River Upper’s baseline had a moderate rating as opposed to other catchments where scores have reduced from a baseline of high to moderate in 2022. The only statistically significant change in community connection within the Yarra River Catchment was received for the Diamond Creek (Yarra River Middle) which scored 73% satisfaction (high) in 2020, which then declined to moderate in 2021 and 2022. The Yarra River (main stem) is the only other sub-catchment sample to score higher than 70% (high), which occurred in 2020 with a satisfaction score of 72%.
Dandenong	Dandenong Creek is represented by one management unit but consists of five sub-catchments of data, including 2 new sub-catchments in 2022. Dandenong Creek rated as slightly off-track for community connection. The maximum community connection satisfaction score for all catchments across the region and years was 76% recorded within the Eumemmerring Creek in 2021 and the equal lowest was 58% recorded at Kananook Creek sub-catchment in 2021 and 2022, Kororoit Creek in 2021, Moonee Ponds Creek in 2022 and Blind Creek in 2022.
Westernport	Two management units could be assessed in 2022 (Cardinia Creek and Mornington Peninsula), from two sub-catchments of data which were reported from 2021. Both management units rated as ‘slightly off-track’. In 2022, both Cardinia Creek and Mornington Peninsula management units scored moderate community connection satisfaction. More data samples are required to better understand the community connection performance in this catchment.

KEQ 3b. What other spatial and temporal trends and patterns for key values are of significance for implementation?

Approach

In the Community Perceptions Surveys from 2020 to 2022, questions were included to further explore ‘organised connections’ as part a key aspect of the community connection social value. In particular satisfaction with engaging in cultural events (satisfaction with facilities), art around waterways (connection to people experiences) and culturally significant places (connection to place experiences) was explored.

Outcome

Across the region, community connection conditions averaged ‘moderate’ scores with 66% satisfaction for engaging with cultural events, 62% satisfaction for engaging with culturally significant places, but only a low score of 59% for engaging with art in 2022.

Cultural event: For facilities that support community and cultural events condition (Figure 20) around waterways, catchments mostly remained with a score of 'moderate' between 2016 and 2022. Exceptions were Cardinia Creek, Yarra River Middle and Dandenong Creek catchments which began with scores of 'high' but declined to 'moderate' by 2022. All other catchments remained within the bounds of a 'moderate' score over the years of recording.

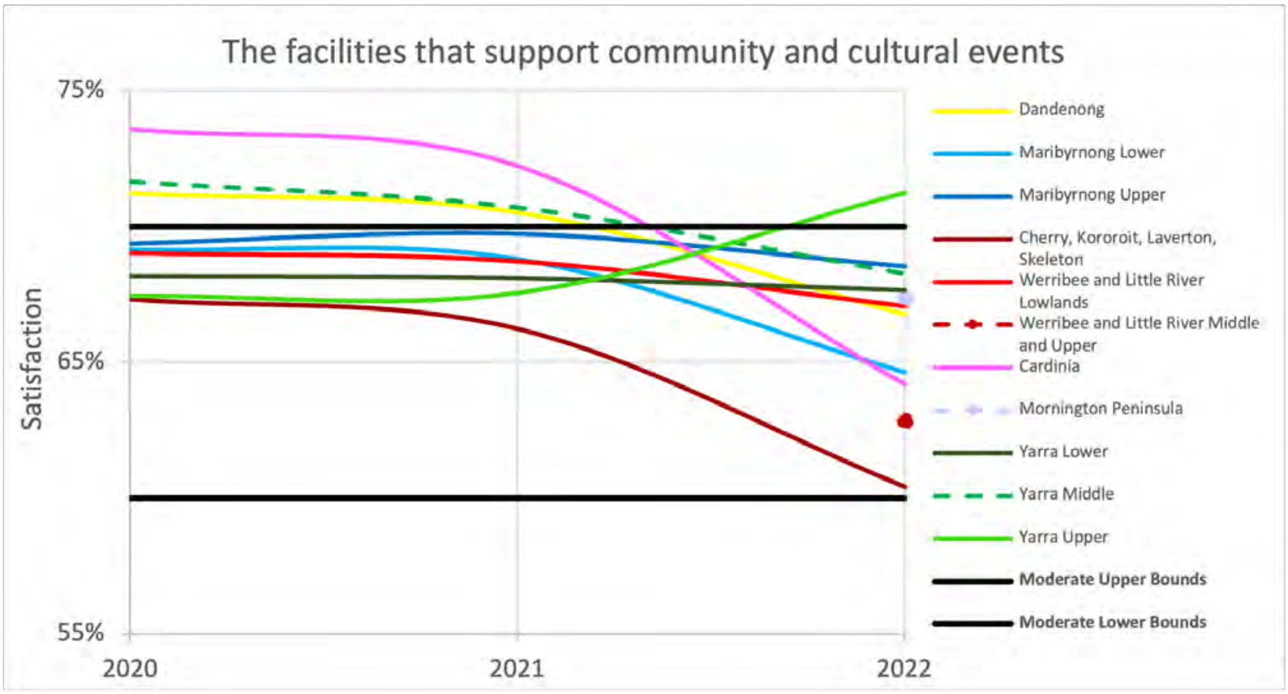


Figure 20. Satisfaction with facilities that support community & cultural events.

Culturally significant places: For engaging with culturally significant places around waterways condition (Figure 21) around waterways, there was consistency with most catchments beginning and ending the evaluation period with a score category of moderate. The exceptions are Cardinia Creek which declined from a high to moderate in 2022 and Yarra River Lower declining from moderate to low rating over the years recorded.

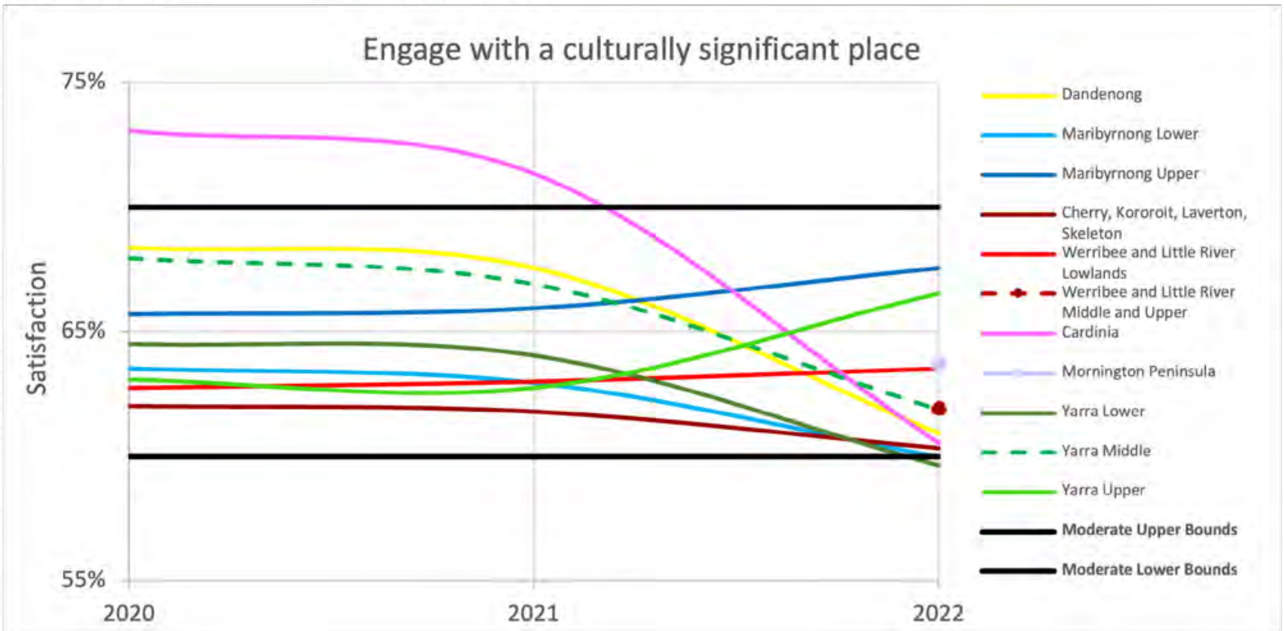


Figure 21. Satisfaction for engaging with culturally significant places around waterways.

Art around waterways: For satisfaction with engaging with art condition around waterways (Figure 22), many sub-catchments begun within the bounds for a score of 'moderate' but had declined to a 'low' category score by 2022. Of note this occurred for all three Yarra River catchments, and also the Dandenong Creek and Cherry, Kororoit, Laverton, Skeleton Creeks catchments.

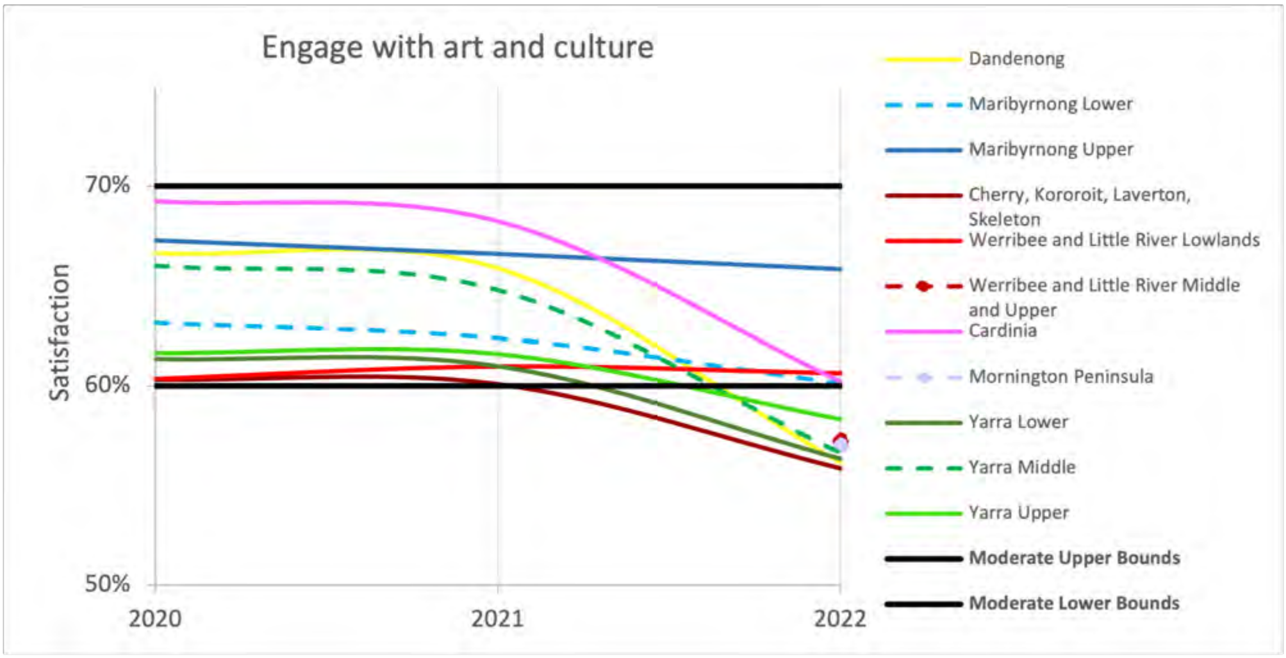


Figure 22. Satisfaction for engaging with art and culture of local waterways.

KEQ 2a. What environmental conditions (e.g. Water quality) and external conditions (e.g. policy) help explain current key value trends

Approach

Several environmental conditions were explored. Here we summarise participation rates of people engaged with waterways along with the potential impacts that COVID19 has had on visitation along waterways.

Outcome

The HWS has targets for participation measured by the number of people engaged in citizen science, recipients of grants for on-ground works, attendance at events and involvement in social media. These measures have different weightings which are outlined in the Rivers MEP. We are currently on-track in all five catchments to meet the 10-year targets Table 17.

Table 17. Progress towards participation performance objectives.

HWS catchment	Target (21/22)	Results (People)	Status - Achieved to Date	Performance Rating
Werribee River	2,771	3,183	115%	on-track
Maribyrnong River	2,477	2,919	118%	on-track
Yarra River	7,190	9,343	130%	on-track
Dandenong Creek	3,412	4,599	135%	on-track
Westernport	1,973	2,948	149%	on-track

To better understand the impact of Covid19 restrictions on participation rates, a research project - E5 Blue Spaces -analysed *Community Perceptions Survey* (2020) data against digital data (human movement data based on mobile phone geolocations) and conducted a further online survey to understand the communities' behaviours interacting with blue-green spaces (i.e. waterways) during the coronavirus COVID19 lockdowns.

According to the Community Perceptions Survey only 12% of respondents visited their local waterway more during COVID19 restrictions. However, based on a separate survey conducted as part of the E5 Blue Spaces research, the majority (80%) of survey respondents said they spent more time in blue and green spaces as a result of the COVID-19 restrictions. Visits to blue and green spaces were frequent, with "daily" or "several times a week" the most commonly selected categories. This was supported by Google's COVID-19 Community Mobility digital geolocation data showing a 112% increase in engagement with local natural spaces (e.g. waterways) between February 2020 and May 2021.

Regarding understanding how we better measure the social values of waterways, the project demonstrates the value of tapping into other data sources such as digital human movement data as well as building in targeted surveys that dive-deeper into specific social values topics. The findings, particularly the digital data and human movement data, highlights the value of blue green spaces as more people were visiting waterways during the COVID19 lockdowns as communities were restricted to five-kilometre limits to their households and also provides a more nuanced insight into variations in visitation across waterway sub-catchments.

Overall summary

For waterway community connection values, there was a general decline in satisfaction scores, with no catchments scoring a 'high' or above for community connection. The exception to this decline was Cherry, Kororoit, Laverton, Skeleton Creeks and Yarra River Upper management units which maintained baseline performance ratings, however noting that Cherry, Kororoit, Laverton, Skeleton Creeks declined to a 'low' rating in 2021 before returning to a moderate score in 2022.

When considering the conditions underpinning community connection values, the Dandenong Creek Catchment was notable for producing a variability of performance ratings, the Dandenong Creek Middle and Eumemmerring Creek sub-catchments produced the highest scores, but the catchment was countered by Kananook Creek sub-catchment which had low scores. The Yarra and Cardinia Catchments also experienced declining scores in consideration of culturalconditions.

Limitations

- **Survey data**: The data source used to calculate waterway community connection (Community Perceptions Survey) is subjective, being based on personal satisfaction perceptions. This method is still producing valuable data and has allowed large data sample sizes to be collected, particularly considering the intrinsic and abstract nature of waterway community connection concepts. However, it is difficult to validate that a respondent has indeed visited a stated waterway or can recall their satisfaction with this waterway, particularly if this their visit was not recent before undertaking the survey. Comparisons with other surveys conducted onsite have produced varying results.
- **Geographical distribution and catchment sample sizes**: The breadth of sub-catchments with statistically significant data (only 36% of sub-catchments in 2022) is viewed as a significant limitation, particularly when reporting on performance ratings at a river catchment scale (for instance only two of twelve sub-catchments in the Mornington and Westernport region are represented).

Recreation

Introduction

Waterways provide settings and opportunities for people to pursue active and/or passive activities within their leisure time, separate to activities that are necessary for their survival, such as work. Waterways can provide a good place for activities such as paddling, fishing, jogging and bike riding.

Evaluation criteria were developed to guide the data analysis and evaluation of the relevant key evaluation questions. These criteria are available in the Technical Resource Document for waterway Social Values. Below we summarise the evaluation approach and the outcomes of the evaluation.

KEQ 3a. To what extent are key values on the target trajectory?

Approach

A metric for defining waterway recreation value was developed for the Healthy Waterways Strategy which uses data from Melbourne Water's Community Perceptions Survey. The survey typically has a sample size greater than 2,000, with around 1,500 of those having visited waterways in the last 12 months. The survey ensures coverage across the region and across age and gender.

The values are assessed by correlating survey respondents' primary reason for visiting waterways with one of the three social values and then taking the average satisfaction score given in response to the survey question "*How satisfied are you with Melbourne's waterways being suitable for how you use them?*". This gives an assessment of satisfaction with waterways in relation to each social value. Table 18 indicates the "reason for visiting waterway" that were correlated to waterway recreation values.

Table 18. Correlation between amenity and reason for visiting waterway.

Corresponding social value	Correlated primary reasons for visiting waterway
Recreation	• Bird watching • Canoeing / kayaking / boating / rowing • Commuting: walking / cycling • Dog walking • Exercising: cycling/walking/jogging/running • Fishing • Swimming/wading

This question was evaluated at 14 management unit spatial scales (Table 19), where management unit satisfaction ratings are the average of sub-catchment scores. The evaluative criteria used to assess performance is outlined in the social values Technical Resource Document. Of note, since 2018 no data has been captured in three of the management units - French and Phillip Island, Lower Bunyip, Lang Lang and Bass and Upper Bunyip and Tarago.

Satisfaction scores at the sub-catchment scale are used to help explain and inform trends and patterns across the catchments.

Table 19. Spatial scale of survey data collection. There are 14 management units across the region. This spatial scale was used in the previous HWS. The 69 sub-catchments used in the current strategy are nested within the 14 management units.

Catchment	Management Units
Werribee River	1. Cherry, Kororoit, Laverton, Skeleton Creeks
	2. Werribee and Little River Lowlands
	3. Werribee and Little River Uplands
Maribyrnong River	4. Maribyrnong River Lower
	5. Maribyrnong River Upper
Yarra River	6. Yarra River Lower
	7. Yarra River Middle
	8. Yarra River Upper
Dandenong Creek	9. Dandenong Creek
Westernport and Peninsula	10. Cardinia Creek
	11. French and Phillip Island
	12. Lower Bunyip, Lang Lang and Bass
	13. Mornington Peninsula
	14. Upper Bunyip & Tarago

Outcome

Recreation results across the management units are shown in Table 20. For the 11 management units where data exists, no catchment management units are "Off-track" with three "On-track" whereby they are performing better than in the baseline year (2016). On track management units were Werribee and Little River Middle and Upper, Yarra River Lower and Yarra River Upper.

Recreation scores ranged from 62% satisfaction (Cherry, Kororoit, Laverton and Skeleton Creeks catchments in 2021) to76% satisfaction (Maribyrnong River Lower in 2016). In 2022 the average recreation satisfaction score was 68%, slightly down from 69% in 2021 and 71% in 2020.

In performance rating terms for recreation satisfaction, only one catchment scored 'high' - Yarra River Lower in 2022. However, at a sub-catchment scale eight sub-catchment samples scored 'high' (one in Maribyrnong Catchment, five in Yarra Catchment and one in Werribee Catchment), and one sub-catchment sample (Dandenong Creek Middle at Tarralla Creek) scored 'very high'.

Table 20. Recreation Performance Ratings.

Catchments (Management Units)	Baseline (2016) Score	2022 Score	Performance Rating
Dandenong Creek	High	Moderate	⚠ slightly off-track
Maribyrnong River Lower	High	Moderate	⚠ slightly off-track
Maribyrnong River Upper	High	Moderate	⚠ slightly off-track
Cherry, Kororoit, Laverton, Skeleton	High	Moderate	⚠ slightly off-track
Werribee and Little River Lowlands	High	Moderate	⚠ slightly off-track
Werribee and Little River Middle and Upper	Moderate	Moderate	✔ on-track
Cardinia Creek	High	Moderate	⚠ slightly off-track
French and Phillip Islands	N/A	N/A	N/A
Lower Bunyip, Lang Lang and Bass	Moderate	N/A	N/A
Mornington Peninsula	High	Moderate	⚠ slightly off-track
Upper Bunyip and Tarago	Moderate	N/A	N/A
Yarra River Lower	High	High	✔ on-track
Yarra River Middle	High	Moderate	⚠ slightly off-track
Yarra River Upper	Moderate	Moderate	✔ on-track

The maximum recreation satisfaction score was 81% recorded within the Dandenong Creek Middle sub-catchment (Tarralla Creek) and the minimum was 60% recorded at Kananook Creek sub-catchment, both are within the Dandenong Creek catchment. This range of recreation satisfaction scores is representative of all other years sampled, representing the minimum and maximums for the data set across all years. Kananook Creek sub-catchment also recorded a significant decline in recreation satisfaction in 2022 from previous years.

At a sub-catchment scale, the following results were of interest:

Catchment	Summary
Werribee	Three management units could be assessed in 2022, from four sub-catchments of data (Werribee River Lower, Werribee River Upper Kororoit Creek and Skeleton Creek), including two new sub-catchments in 2022. The Werribee and Little River Middle and Upper is one of three management units rated on-track across the region, the other two Werribee River management units were rated slightly off-track. The Skeleton Creek, which is one of two sampled sub-catchments for the Cherry, Kororoit, Laverton, Skeleton management unit, is the only sub-catchment within the Werribee River catchment area with a high score in 2022 with all other sub-catchments scoring moderate in 2022.
Maribyrnong	Two management units could be assessed in 2022, from four sub-catchments of data (Maribrynong River, Moonee Ponds Creek, Jacksons Creek and Stony Creek), including two new sub-catchments in 2021 plus one more sub-catchment in 2022. Both management units rated as slightly off-track. One sub-catchment Maribyrnong River sub-catchment scored high (72% satisfaction) in 2022, all three other sub-catchments scored moderate in 2022 ranging from 69% satisfaction (Jacksons Creek) to 62% satisfaction (Moonee Ponds Creek).

Catchment	Summary
Yarra	Three management units could be assessed in 2022 from 11 sub-catchments of data, including two new sub-catchments in 2022. The Yarra River Lower and Yarra River Upper both rated ‘On-track’ with scores in the same category from the baseline (high and moderate respectively). Five sub-catchments scored high recreation satisfaction in 2022 (Plenty River, Gardiners Creek, Olinda Creek, Brushy Creek and Diamond Creek) and the other six sub-catchments in the Yarra River scored a moderate rating.
Dandenong	Dandenong Creek represents one management unit but consists of five sub-catchments of data, including two new sub- catchments in 2022. Dandenong Creek rated as ‘Slightly Off-track’ for recreation. In 2022, Dandenong Creek Middle sub-catchment rated as very high with a score of 81% satisfaction, which is significant and the maximum recreation score for all catchments across the region and years. All other sub-catchment only rated as moderate for recreation satisfaction. Eumemmerring Creek sub-catchment score of 78% (rating of high) satisfaction in 2021 was of significance, this score had declined in 2022 to 65% (rating of moderate). Kananook Creek sub-catchment score of 60% satisfaction in 2022 was the lowest of any recreation satisfaction scores for all catchments across the region and years. Kananook Creek recreation satisfaction results have continued on a downward trend for each year since 2020.
Westernport	Two management units could be assessed in 2022, from two sub-catchments of data which were reported from 2021. Both management units rated as slightly off-track. In 2022, both Mornington Peninsula and Cardinia Creek management units scored moderate for recreation satisfaction. More data samples are required to better understand the community connection performance in this catchment.

KEQ 3b. What other spatial and temporal trends and patterns for key values are of significance for implementation?

Approach

In the Community Perceptions Surveys from 2020 to 2022, questions were included to further explore waterway recreation satisfaction conditions as related to the conceptual models (Technical Resource Document for waterway Social Values). The recreation conditions included in the satisfaction survey included both the related experiences, such as active recreation through physical exercise and the use of the waterway for commuting. The survey also assessed recreation conditions, notably satisfaction with pathways and facilities for sporting activities.

Outcome

Recreation experiences: Across the region, recreation experiences averaged 72% satisfaction for engaging in physical exercise in 2022 but only 61% satisfaction for using the waterway corridors for commuting (Figure 23). This translates to a categorical score of ‘high’ for physical exercise and only a ‘moderate’ for commuting. For physical exercise experiences around waterways, most management units remained within the bounds for a score of ‘high’ across the three years measured, except for Cardinia Creek catchment which had a significant decline from ‘high’ in 2020 and 2021 to ‘low’ by 2022. For use of waterway corridors for commuting, most management units remained within the bounds for a score of ‘moderate, except for Maribyrnong River Lower, Yarra River Lower and the Werribee River Lower catchments, which declined to ‘low’ in 2022.

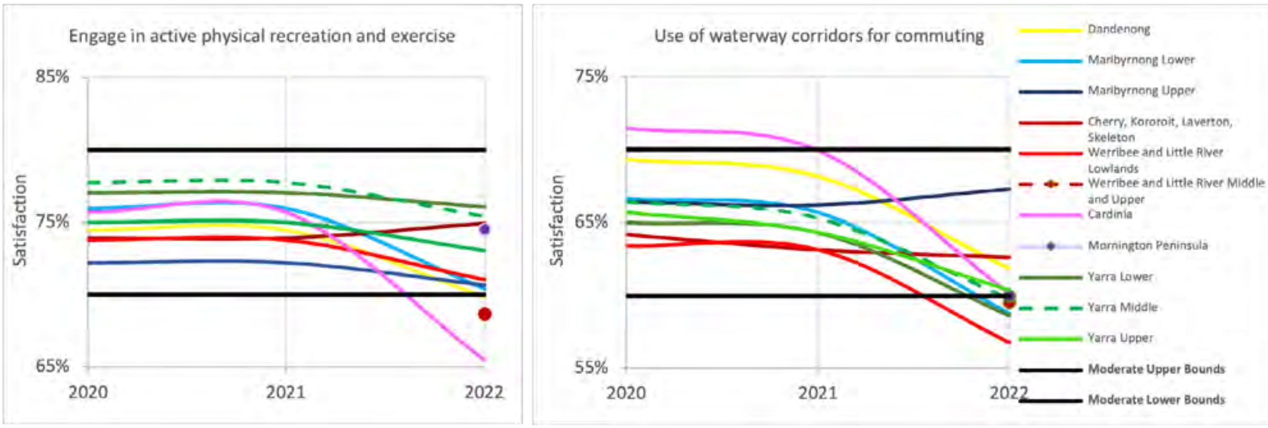


Figure 23. Satisfaction with engaging with waterways for physical recreation & using waterway corridor for commuting (e.g. cycling).

Recreation conditions – pathways: For satisfaction with conditions related to paths along waterways (Figure 24), most sub-catchments remained within the bounds for a score of 'high' across the three years measured with an average score across all catchments of 71%. Except for Cardinia Creek which declined from high score of 77% in 2020 to moderate score of 64% by 2022, also the lowest scoring catchment by 2022.

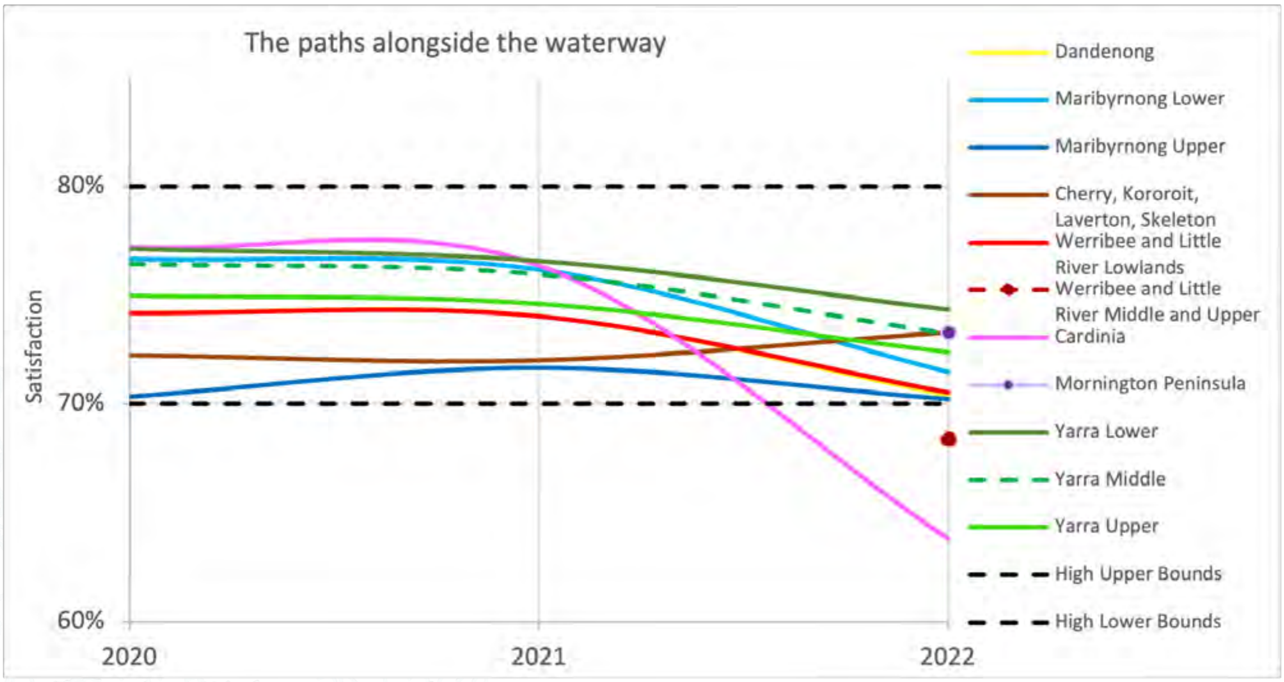


Figure 24. Satisfaction with pathway condition along waterways.

Recreation conditions – sporting facilities: For conditions scores related to satisfaction with condition of sporting facilities around waterways (Figure 25), most sub-catchments remained within the bounds for a score of 'moderate' across the years measured, with an average score in 2022 across all management units of 66%. Only Yarra River Upper rated high in 2022 but just with a score of 70%.

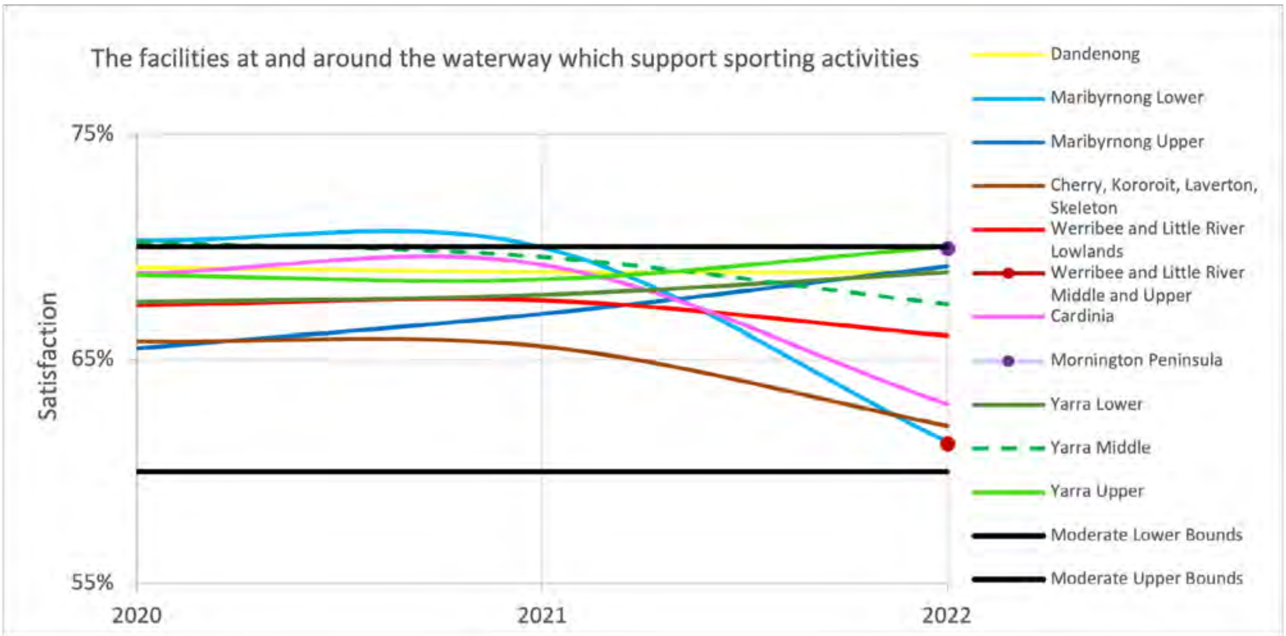


Figure 25. Satisfaction with facilities around waterways for sporting activities (e.g. ovals).

KEQ 2a. What environmental conditions (e.g. Water quality) and external conditions (e.g. policy) help explain current key value trends

Approach

Several environmental conditions were explored, regarding waterway recreation values, recreational water quality results were considered.

Outcomes

Data from the HWS annual reporting process for 2021/22 financial year was used to evaluate progress towards the performance objective access target. The Yarra River, Werribee River, Dandenong Creek and Westernport catchments are well above the targets for 21/22 and are on-track, Maribyrnong catchment is significantly off-track (Table 21).

Table 21. Progress towards access performance objectives.

Catchment	Results (km)	Target* (21/22)	Target 2028	Status - Achieved to Date	Performance Rating
Werribee	25.9	> 9 km	34	76%	on-track
Maribyrnong	7.2	> 14 km	57	13%	significantly off-track
Yarra	25.7	> 11 km	43	60%	on-track
Dandenong	14.8	> 7 km	26	57%	on-track
Westernport	11.3	> 11 km	42	27%	on-track

For recreational activities involving contact with water, water quality, specifically microbial water quality is the critical condition that determines recreational suitability. Many reaches of the Yarra consistently report ‘Poor’ recreational water quality and over the years and this has attracted significant public interest.

The use of faecal indictor bacteria, such as *E.coli,* to assess water quality for recreation is a widely accepted scientific method. However, it applies a standardised estimate of illness risk based on several key epidemiological studies. In many cases these epidemiological studies were undertaken in Europe, and there is some uncertainty about their applicability to Australian conditions and the correlation of faecal indicator species such as *E. coli* and enterococci with actual pathogens.

To better understand the problem Melbourne Water teamed up with the EPA and Monash University to undertake a research project. It used a Quantitative Microbial Risk Assessment or QMRA which estimates human health risks through examination of the actual pathogens present, their number and infectivity, the potential exposure dose and the sensitivity of the person being exposed.

The project is summarised in more detail in the mid-term review research fact sheets, however the key finding is that faecal indicators or organisms (FIB and FIB respectively e.g. *E.coli*) over estimates the potential health risk for recreators in the rural and peri-urban reaches of the Yarra River.

As a next step, Melbourne Water are working with EPA Victoria and Monash University to further embed research findings into practice. A project is being scoped up to run in parallel to the Yarra Watch summer season to streamline the methodology for broader application and to test its viability on a waterway with much less available data.

Overall summary

For waterway recreation values satisfaction scores have generally slightly declined since the 2016 baseline, with only Werribee and Little River Middle and Upper and Yarra River Lower and Upper maintaining baseline levels and therefore ‘On Track’. Only the Yarra River Lower scored a satisfaction rating of ‘High’ in 2022.

When considering the sub-catchment scale community connection values, the Dandenong Creek Catchment was notable for producing a variability of performance ratings, the Dandenong Creek Middle and Eumemmerring Creek sub-catchments producing the high scores, but the catchment was countered by Kananook Creek sub-catchment which had low scores. The Cardinia Creek Catchment produced low condition scores related to recreational experiences declining scores in consideration of cultural conditions, while the Yarra River Upper had high scores.

Limitations

- **Survey data**: The data source used to calculate waterway recreation (Community Perceptions Survey) is subjective as based on personal satisfaction perceptions. This method is still producing valuable data and has allowed large data samples sizes to be collected, particularly considering the intrinsic and abstract nature of waterway recreation concepts. However, it is difficult to validate that a respondent has indeed visited a stated waterway or can recall their satisfaction with this waterway, particularly if this was not recent. Comparisons with other surveys conducted onsite have produced varying results, often more positive.
- **Geographical distribution and catchment sample sizes**: The breadth of sub-catchments with statistically significant data (only 36% of sub-catchments in 2022) is viewed as a significant limitation, particularly when reporting on performance ratings at a river catchment scale (for instance only two of twelve sub-catchments in the Mornington and Westernport region are represented).

Amenity

Introduction

Waterway amenity provides restorative places where people can go to relax, escape normal life, appreciate nature, and feel better through a variety of multi-sensory experiences. Amenity also includes the influence of the micro-climate on people's sensory experiences of waterways, for example by reducing the impact of the urban built environment by riparian vegetation providing shade and temperature moderation.

Evaluation criteria were developed to guide the data analysis and evaluation of the relevant KEQs. These criteria are available in the Technical Resource Document for waterway Social Values. Below we summarise the evaluation approach and the outcomes of the evaluation.

KEQ 3a. To what extent are key values on the target trajectory?

Approach

A metric for defining waterway amenity was developed for the Healthy Waterways Strategy which uses data from Melbourne Water's Community Perceptions Survey.

The survey typically has a sample size greater than 2,000, with around 1,500 of those having visited waterways in the last 12 months. The survey ensures coverage across the region and across age and gender.

The values are assessed by correlating survey respondents' primary reason for visiting waterways with one of the three social values and then taking the average satisfaction score given in response to the survey question: "*How satisfied are you with Melbourne's waterways being suitable for how you use them?*" This gives an assessment of satisfaction with waterways in relation to each social value. Table 22 indicates the "reason for visiting waterway" that were correlated to waterway amenity values.

Table 22. Correlation between amenity and reason for visiting waterway.

Corresponding social value	Correlated primary reasons for visiting waterway
Amenity	• Feeding the ducks / other waterbirds • General relaxation • Nature appreciation • Well-being • To escape to a quiet and relaxing place

This question was evaluated at 14 management unit spatial scales (Table 23), where management unit satisfaction ratings are the average of sub-catchment scores. The evaluative criteria used to assess performance is outlined in the social values Technical Resource Document. Of note, since 2018 no data has been captured in three of the management units - French and Phillip Island, Lower Bunyip, Lang Lang and Bass and Upper Bunyip and Tarago.

Satisfaction scores at the sub-catchment scale are used to help explain and inform trends and patterns across the catchments.

Table 23. Spatial scale of survey data collection. There are 14 management units across the region. This spatial scale was used in the previous HWS. The 69 sub-catchments used in the current strategy are nested within the 14 management units.

Catchment	Management Units
Werribee River	1. Cherry, Kororoit, Laverton, Skeleton Creeks
	2. Werribee and Little River Lowlands
	3. Werribee and Little River Uplands
Maribyrnong River	4. Maribyrnong River Lower
	5. Maribyrnong River Upper
Yarra River	6. Yarra River Lower
	7. Yarra River Middle
	8. Yarra River Upper
Dandenong Creek	9. Dandenong Creek
Westernport and Peninsula	10. Cardinia Creek
	11. French and Phillip Island
	12. Lower Bunyip, Lang Lang and Bass
	13. Mornington Peninsula
	14. Upper Bunyip & Tarago

Outcome

Amenity results across the management units are shown in Table 24. For the 11 management units where data exists, none are off-track with four on-track - Werribee and Little River Middle and Upper, Werribee and Little River Middle and Upper, Mornington Peninsula and Yarra River Upper. All except Yarra River Upper had exceeded their baseline year rating.

Waterway amenity satisfaction scores do not significantly differ across all years of data. In 2022 the average amenity satisfaction score across all regions catchments was 68%, slightly down from 69% in 2021, 72% in 2020 and 74% in 2016.

Table 24. Amenity Performance Ratings.

Catchment	Management Units	Baseline (2016) Score	2022 Score	Performance Rating
Dandenong	Dandenong Creek	High	Moderate	slightly off-track
Maribyrnong	Maribyrnong River Lower	High	Moderate	slightly off-track
	Maribyrnong River Upper	Moderate	High	on-track
Werribee	Cherry, Kororoit, Laverton, Skeleton	High	Moderate	slightly off-track
	Werribee and Little River Lowlands	High	Moderate	slightly off-track
	Werribee and Little River Middle and Upper	Low	Moderate	on-track

Catchment	Management Units	Baseline (2016) Score	2022 Score	Performance Rating
Westernport	Cardinia Creek	High	Moderate	slightly off-track
	French and Phillip Islands	N/A	N/A	N/A
	Lower Bunyip, Lang Lang and Bass	High	N/A	N/A
	Mornington Peninsula	High	High	on-track
	Upper Bunyip and Tarago	Moderate	N/A	N/A
Yarra	Yarra River Lower	High	Moderate	slightly off-track
	Yarra River Middle	Very High	High	slightly off-track
	Yarra River Upper	High	High	on-track

In performance rating terms for amenity satisfaction, eight sub-catchment samples scored 'high', 19 sub-catchment samples scored 'moderate' and one sub-catchment sample (Dandenong Creek Middle at Tarralla Creek) scored 'very high'. The maximum amenity satisfaction score was 80% recorded within the Dandenong Creek Middle (Tarralla Creek) and the minimum was 61% recorded at Kananook Creek sub-catchment, both these catchments are located within the Dandenong Creek catchment.

At a sub-catchment scale, the following results were of interest:

Catchment	Summary
Werribee	Three management units could be assessed in 2022, from four sub-catchments of data (Werribee River Lower, Werribee River Upper Kororoit Creek and Skeleton Creek), including 2twonew sub-catchments in 2022. The Werribee and Little River Middle and Upper management unit rated as 'on track' and both Werribee and Little River Middle and Lower and Cherry, Kororoit, Laverton, Skeleton Creeks management units rated slightly off-track. All 4 sub-catchments units scored moderate amenity satisfaction in 2022, scores ranged between 67% and 63% satisfaction. Kororoit Creek sub-catchment recorded declines in amenity satisfaction, from 71% (high) in 2020 to 66% (moderate) in 2022.
Maribyrnong	Two management units could be assessed in 2022, from four sub-catchments of data (Maribrynong River, Moonee Ponds Creek, Jacksons Creek and Stony Creek), including two new sub-catchments in 2021 plus one more sub-catchment in 2022. One sub-catchment, Jacksons Creek scored high in 2022, the other three all score moderate ranging from 69% satisfaction (Maribyrnong River sub-catchment) to 62% satisfaction (Moonee Ponds Creek Creek). Maribyrnong River Upper management unit rated as on-track and Maribyrnong River Lower management unit rated as slightly off-track.
Yarra	Three management units could be assessed in 2022 from 11 sub-catchments of data, including two new sub-catchments in 2022. Yarra River Upper rated as on -track, Yarra River Middle and Lower were slightly off-track. The Yarra River Upper is on-track with scores in the same category from the baseline (high) Five sub-catchments scored high in 2022 for amenity satisfaction: Yarra River Middle sub-catchment, Yarra River Upper sub-catchment, Mullum Mullum Creek, Plenty River and Olinda Creek. Olinda Creek sub-catchment score of 79% satisfaction in 2020 was significantly the highest of any catchment across the region in 2020.

Catchment	Summary
Dandenong	Dandenong Creek represents one management unit but consists of five sub-catchments of data, including two new sub- catchments in 2022. Dandenong Creek rated as slightly off-track for amenity. In 2022, two sub-catchments rated high (Dandenong Creek Middle and Blind Creek). All other sub-catchments rated as moderate. Dandenong Creek Middle sub-catchment score of 80% satisfaction in 2022 was of significance as the maximum amenity satisfaction scores across all catchments and years. Although not reflective in the ratings, amenity scores across all catchments were on a downward trend between 2020 and 2022 (except Dandenong Creek Middle and Blind Creek which were only introduced in 2022). The equal minimum amenity satisfaction score for all catchments across the region and years was 61% recorded at Kananook Creek sub-catchments in 2022.
Westernport	Two management units could be assessed in 2022, from two sub-catchments of data which were reported from 2021. In 2022, Mornington Peninsula rated as on-track recording a high amenity score with 72% satisfaction. Cardinia Creek rated as slightly off track, scoring a moderate amenity score in 2022 with 66% satisfaction. More data samples are required to better understand the community connection performance in this catchment.

KEQ 3b. What other spatial and temporal trends and patterns for key values are of significance for implementation?

Approach

In the Community Perceptions Surveys from 2020 to 2022, questions were included to further explore waterway amenity satisfaction conditions as related to the conceptual models (HWS Technical Resource Document). The waterway amenity conditions included in the satisfaction survey included both the related experiences (escape from urban environment, naturalness and safety) as well as conditions such as physical form (channel form, topography/landscape views, corridor widths/open space), vegetation (extent, maintenance, sightlines), biodiversity (habitat), facilities (pathways) and water regime (flow). Water quality (odour/litter/dumping) although a condition related to all three social values has been assessed under the social value waterway amenity for this review (and not recreation and community connection) to avoid duplication.

Outcome

Litter: satisfaction with litter around waterways (Figure 26) generally only had minor variations across the catchments between 2020 and 2022, most sub-catchments remained within the bounds for a score of 'moderate' across the years measured. However, of note was the minor increased satisfaction in litter for the Dandenong Creek and Yarra River Middle catchments. Conversely, substantial litter satisfaction reductions occurred in Cardinia Creek and Cherry Kororoit Laverton and Skeleton Creek catchments. In 2022, the whole Werribee River catchment as an average (combined by three management units) had a low score of only 53% as opposed to an average litter satisfaction score of 63% of all other catchments.

The review notes that the Community Perceptions Survey has not been designed to causally relate satisfaction with values and conditions that support each value. Noting this, we've undertaken a regression analysis test for correlations between values. The review considered the assumption that satisfaction with litter (absence) will lead to a higher satisfaction with waterway amenity. Analysis showed that there is a positive correlation (R^2 = 0.49) between waterway amenity and litter satisfaction score. Given the subjective and intrinsic nature of satisfaction data, we consider the correlation between amenity and litter satisfaction to be moderate/strong. The continued collection of litter and amenity satisfaction data and the proposed expansion of the litter monitoring program for the life of the strategy will provide a better understanding about this relationship.

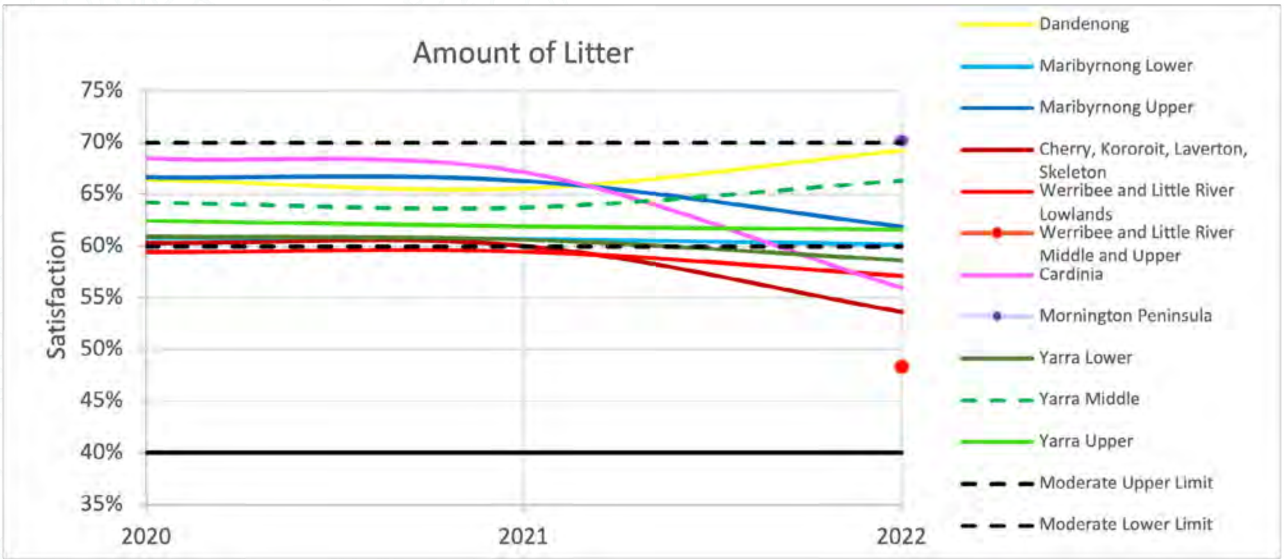


Figure 26. Satisfaction with condition of litter around waterways.

Water colour and clarity: Satisfaction with colour and clarity of water generally only had minor variations across the catchments between 2020 and 2022, most sub-catchments remained within the bounds for a score of 'moderate' across the years measured. However, of note was the increased satisfaction in water colour and clarity for the Yarra River Upper Catchment and slight improved trajectory for Yarra River Middle catchment. Conversely, substantial colour and clarity satisfaction reductions occurred in Werribee and Little River Lowlands, Yarra River Lower and Cherry Kororoit Laverton and Skeleton Creek catchments, which declined from moderate to low ratings. See figure 27.

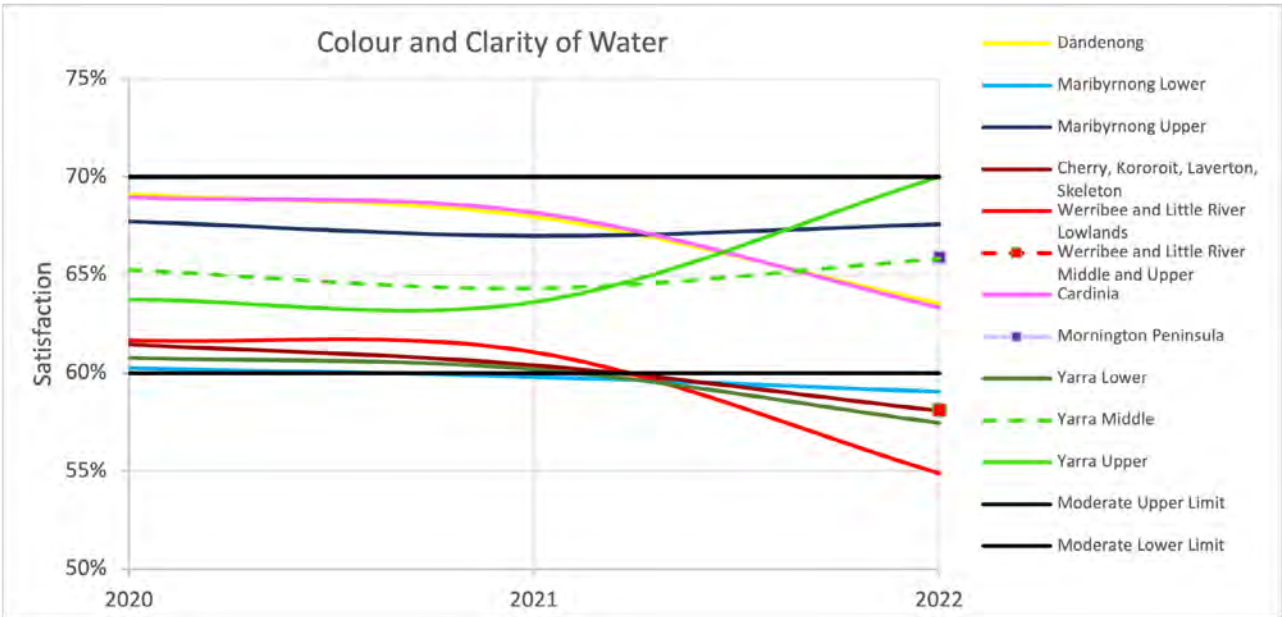


Figure 27. Satisfaction with water colour & clarity in waterways.

Odour: Satisfaction with smells and odours coming from the water (Figure 28) generally only had minor variations across the catchments between 2020 and 2022, most sub-catchments remained within the bounds for a score of 'moderate' across the years measured. There was slight increased satisfaction trajectory for the Maribyrnong River Upper and Lower. Conversely, substantial smells and odours satisfaction reductions occurred in Cardinia Creek, Werribee and Little River Lowlands and Cherry, Cardinia Creek and Cherry Kororoit, Laverton and Skeleton Creek catchments, which in 2021 was significantly below the satisfaction scores as compared to all other catchments.

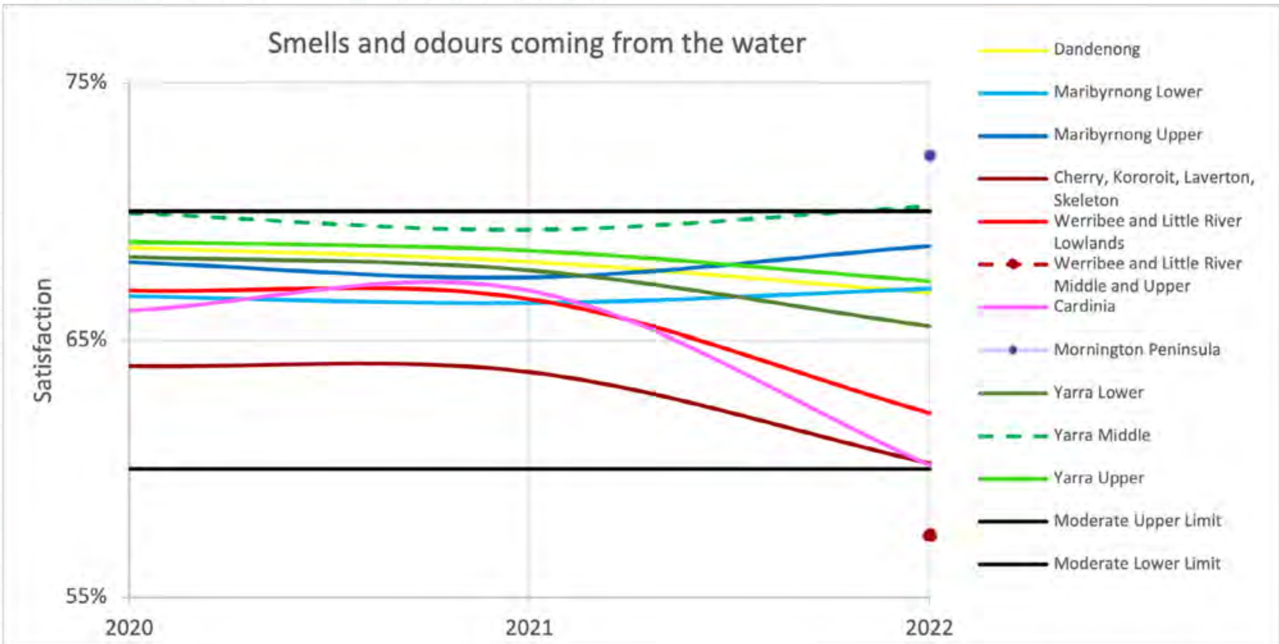


Figure 28. Satisfaction with the smells & odour coming from water in waterways.

Open Space: All social values, inadvertently consider open space under differing conditions, such as corridor width (amenity) and enjoyment facilities for all three values (e.g. sports fields). For satisfaction with open space condition around waterways (Figure 29), all catchments (except Werribee and Little River Middle and Upper catchment in 2022) remained with a score of 'high' between 2020 and 2022. Slight downward trends were found for all except the Cherry Kororoit Laverton Skeleton Creek catchment, however, ratings remain within the 'high' category. This is a condition to monitor in the future and is not yet considered to be significantly declining off-track.

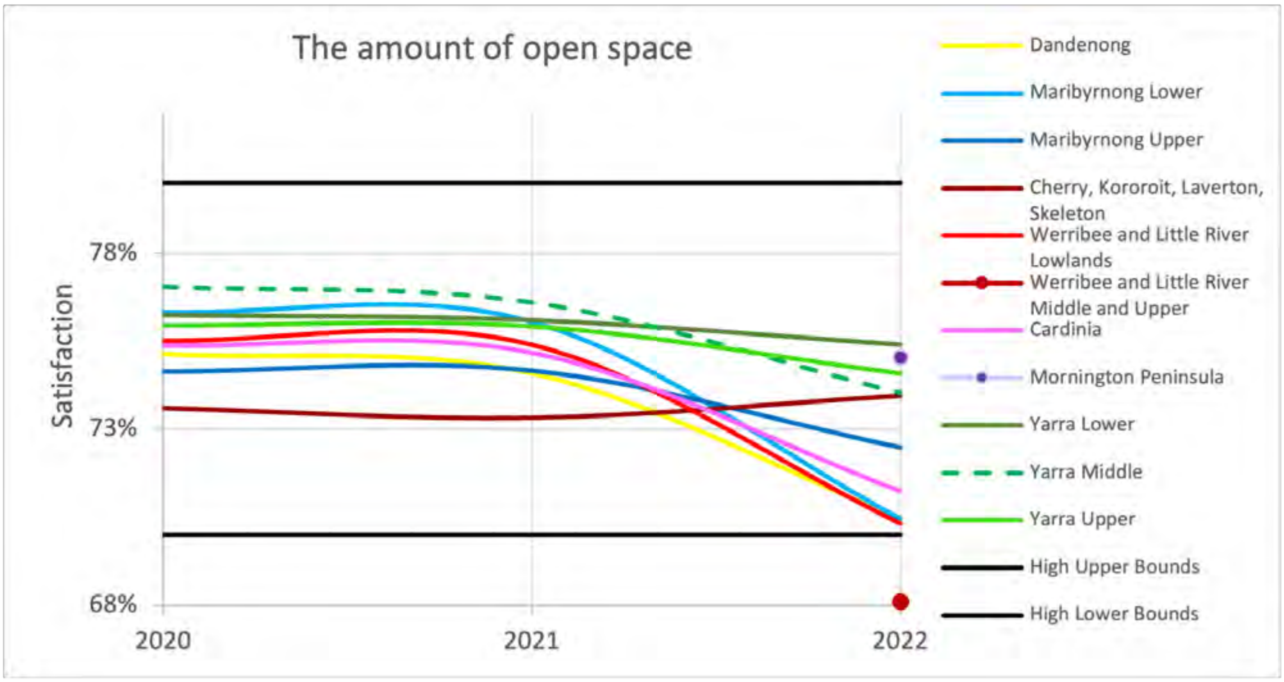


Figure 29. Satisfaction with open space along waterways.

KEQ 2a. What environmental conditions (e.g. Water quality) and external conditions (e.g. policy) help explain current key value trends

Approach

Regarding waterway amenity values conditions considered were:

- Developing litter monitoring methods and case study testing, and
- Water colour and clarity satisfaction scores as a consequence of rainfall.

Outcome

While some litter data along waterways was collected prior to the development of the Healthy Waterways Strategy 2018 (e.g. volumes of litter cleaned out during routine litter trap maintenance), this was not able to support the development of region-wide litter condition ratings and management targets. It also provided little guidance on litter hotspots or the major sources of litter to help prioritise management efforts. As such, a standardized lotter monitoring framework has been developed through the Aquatic Pollution Prevention Partnership (A3P).

A case study was initiated trialling a broad-scale type monitoring program for understanding *the principal types, sources and quantities of litter entering waterways* at 26 sites from six MW sub-catchments. Sites have been surveyed on three occasions since initiation. Results are being used to assess differences in litter type and quantity occurring at sites within each sub-catchment and between sub catchments. Preliminary results from quantitative surveys show that Dandenong Creek and Moonee Ponds Creek have consistently higher litter loads, while Werribee River has the lowest. Data has been used to develop litter catchment ratings which are shown in (Table 25).

Table 25. Data used to develop litter catchment ratings.

	Catchment					
	Dandenong Creek	**Yarra River**	**Stony Creek**	**Moonee Ponds Creek**	**Werribee River**	**Cherry Creek**
Catchment score	6	5.4	6.8	7	5.4	6.8
Catchment Rating	**moderate**	**high**	**moderate**	**moderate**	**high**	**moderate**

Water colour and clarity satisfaction scores as a consequence of rainfall: Water 'colour and clarity' is the on average the second lowest rating condition after litter, reducing amenity satisfaction scores. Water colour and clarity could possibly be inferred as turbidity, and so caused by increased rainfall and runoff (amongst other possible factors). When comparing catchment water colour and clarity against annual rainfall totals (local rainfall stations), there is a similar trend across all catchments (Figure 30), noting Westernport and Peninsula has limited data. This would indicate that there is a good relationship between community perceptions of water colour/clarity and rainfall (and therefore runoff). However, because satisfaction surveys are sampled annually (i.e. once a year) compared to rainfall data sampled at diel intervals (total annual rainfall considered), a strong relationship or consequence cannot be made.

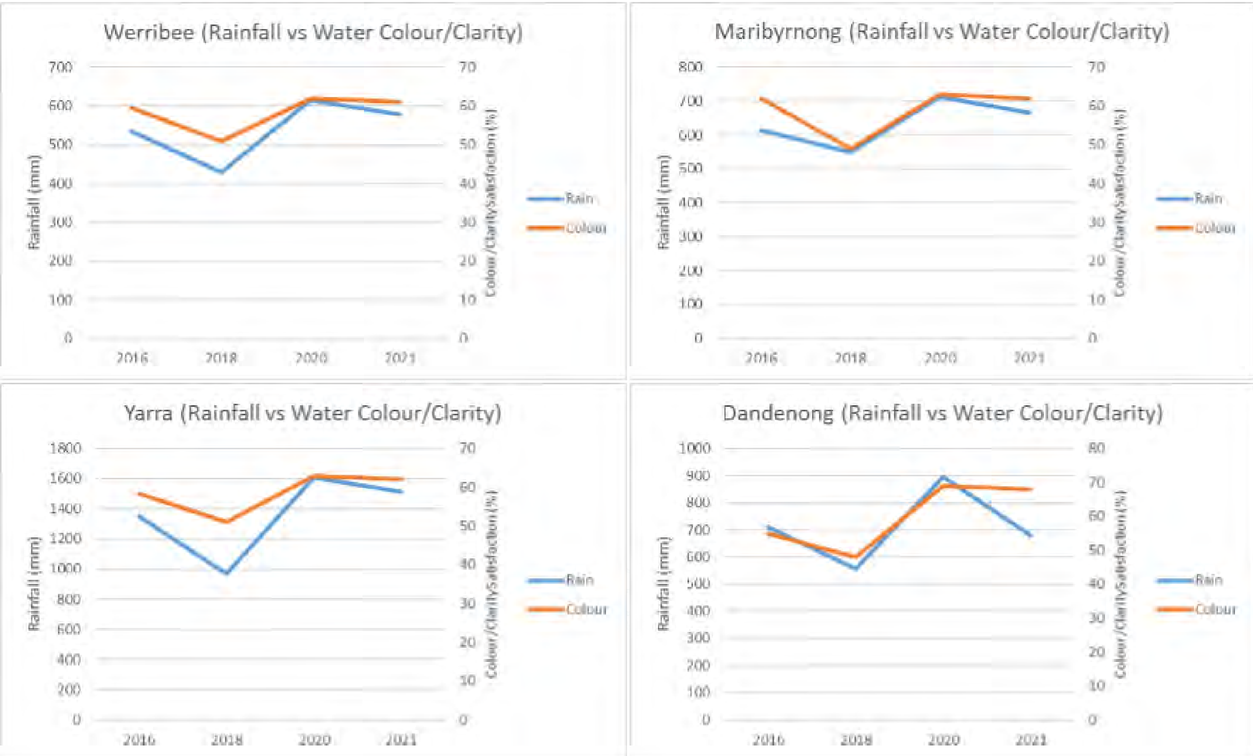


Figure 30. Trends in the relationship between rainfall and water colour/clarity for Werribee, Maribyrnong, Yarra, and Dandenong catchments.

Overall summary

Waterway amenity values are on-track at four catchments including Maribyrnong Upper, Werribee and Litter River Middle and Upper, Mornington Peninsula and Yarra River Upper. Amenity also scored high for the Yarra River Middle, however, is considered slightly off-track because amenity had reduced from very-high levels in 2016.

At a sub-catchment scale, there are ten sub-catchments that recorded either high or very high scores in 2022, these were regionally distributed across all except the Werribee Catchment. In consideration of amenity related conditions (litter, odour and water colour/clarity), Cardinia Creek consistently had declining scores as did the three Werribee River catchments collectively.

Litter results are a condition of interest requiring further focused investigation particularly when relying on the accuracy of satisfaction surveys, for example Dandenong Creek and Yarra River Middle however these weren't reflective in litter research that assessed volumes.

Limitations

- **Survey data**: The data source used to calculate waterway amenity (Community Perceptions Survey) is subjective as based on personal satisfaction perceptions. This method is still producing valuable data and has allowed large data samples sizes to be collected, particularly considering the intrinsic and abstract nature of waterway amenity concepts. However, it is difficult to validate that a respondent has indeed visited a stated waterway or can recall their satisfaction with this waterway, particularly if this was not recent. Comparisons with other surveys conducted onsite have produced varying results, often more positive.
- **Geographical distribution and catchment sample sizes**: The breadth of sub-catchments with statistically significan data (only 36% of sub-catchments in 2022) is viewed as a significant limitation, particularly when reporting on performance ratings at a river catchment scale (for instance only two of twelve sub-catchments in the Mornington and Westernport region are represented).
- **Litter monitoring method**: litter satisfaction ratings are generally low and consistent of this across catchments and years. There are also differences when comparing litter satisfaction to a select number of sub-catchments that have been measuring litter volume and loads (research from Aquatic Pollution Prevention Partnership). For instance, litter satisfaction results were 'low' for the Werribee River Lower and in 2022 the lowest satisfaction of any performing catchment, which are the opposite of the actual litter loads recorded 'high' rating based on litter load study).

PART B

Status and management of threats across the region

Introduction

Threats are negative factors that can impact on waterway condition and values. For example, urban development leads to increased stormwater runoff which conveys pollutants, alters flow regimes and degrades habitat. In developing the HWS, stormwater and climate change were considered the two biggest threats to waterway health.

In developing the HWS, management strategies were compared against a base case (business-as-usual future) to understand the benefits of different strategies for key values. Business-as-usual future involved continued urbanisation and warming and drying from continued climate change. The business-as-usual future trajectory highlighted the effort that would be needed to prevent decline in many values from increasing threats. As a result, the long-term targets for many values and sub-catchments focused on halting further decline rather than improving existing status or condition. For example, the stormwater performance objectives focus on mitigating the impacts of new development – that is, not introducing additional stormwater impacts – with only a few areas prioritised for reducing existing stormwater impacts. Barriers to fish migration, on the other hand, are a relatively stable threat and the performance objectives aim to reduce the threat during the life of the HWS. Mitigating the impacts of stormwater and climate change within the next 10 years, and also in the long term, was an ambitious aspiration and Strategy assumption. This section provides evidence and insights that challenges this assumption.

The HWS conceptual models outline threats to the environmental and social values. In many cases threats to environmental values (e.g. weeds) are also threats to social values as good environmental condition underpins many aspects of social values. There are however instances where the threats are different (e.g. the threat of poor lighting on safety) and in some cases in conflict with each other. For example, large woody debris is good in-stream habitat for fish and macroinvertebrates but can be problematic for recreational activities (kayaking or swimming). In this way, improvements to one value (improving recreation by removing woody debris) could potentially be a threat to another (reducing in-stream habitat for fish).

Photo credit: Chris Lunardi

Approach

An important part of the mid-term review focused on an assessment of threats (i.e. key evaluation question 2b. To what extent have projected known and emerging future threats and conditions changed from 2018? Have any assumptions about impacts to key values changed?).

Threats were grouped into:

- *Urban related threats* such as stormwater, wastewater, physical modifications and litter
- *Rural related threats* such as water availability and agriculture
- *Vegetation and habitat related threats* which include pest plants, pest animals, instream barriers, recreational access and vegetation clearing, and
- *Climate change* which was considered a threat in its own right as well as an amplifier of other threats.

Time and data limitations prevented an equivalent evaluation of threats specific to social values (i.e. where they don't align with environmental threats). These include threats such as unsightly or unsafe vegetation; damaged paths caused by flooding and erosion; incomplete trails or trails located in inappropriate areas and safety concerns such as inappropriate or poor lighting, poor signage or low visitation.

An assessment of threat trajectory (i.e. stable, increasing or decreasing) was made at the sub-catchment scale. Confidence ratings were assigned to each threat class. For example, low confidence was typically assigned to threats where there was very limited, or no data and expert elicitation was used.

If a threat is increasing, it implies that intervention is not mitigating the *increasing* threat (e.g. impacts of new urban development are not being addressed and as such the threat is increasing across the region). This is different to reducing an existing threat - for example, removing fish barriers reduces the threat as no new barriers are being constructed and hence there is a net reduction in the threat. An example of a stable threat is sewage treatment plant discharges where they are not increasing their pollutant load discharges. Another example is a fully developed urban area.

Climate change was assessed as a separate threat category and focused on air temperature and flow changes predicted using the latest climate change projections. Impacts on fish, macroinvertebrates and platypus were assessed using habitat suitability models. Given the importance of climate change it is presented first below.

In order to provide insights into the extent of management of these threats, an assessment of progress towards performance objectives at the sub-catchment scale was undertaken. In addition, significant changes to the operating environment as they relate to specific threats has been documented. This information is also used in the Implementation Inquiry.

Outcomes

Climate change

Climate change represents a large threat to the conditions and values of the region. It leads to temperature increases for both water and air, reduction in average rainfall and annual flow volumes, increased storm intensity and floods, increased bushfire extent and severity, increased frequency of storms (e.g. wind storms), increased urban heat island and sea level rise.

Predictions on how two aspects of climate change – warming and drying – may affect some values was modelled in the HWS using habitat suitability models. Despite using simplistic climate scenarios for the region, predicted impacts were substantial over a 50-year timeframe. Performance objectives and long-term targets took into account this simplistic climate change information. Of significance is the assumption built into the long-term platypus targets that flows can be managed to counter drying.

Climate change can also amplify other threats. For instance, more intense rain events may make 'flashy' urban flow regimes even flashier under climate change. Threats from erosion may increase due to increased storm intensities and storm surges. Changed flow regimes may impact the performance on fishways and certain weeds and pest animals may proliferate.

Many knowledge gaps remain with respect to climate change impacts and there are a number of research projects in the Port Phillip and Westernport region underway aimed at improving understanding of the risks of climate change and adaptation pathways.

Below we summarise the broader (national and state) and more local (Melbourne region) climate change information, focusing on air temperature and flow changes predicted using the latest climate change projections. Using these latest climate change projections, we then assess the impacts of climate change on several instream values including fish, macroinvertebrates and platypus using habitat suitability models.

While there are several limitations to the modelling (see Limitations), these results are important considerations in how we respond to climate change as a threat.

Broader climatic threat

Australia's climate is changing, with temperatures increasing over land and sea, precipitation patterns shifting, and sea levels rising as described in the State of the Climate 2020 (CSIRO and Bureau of Meteorology 2020) and State of the Climate 2022 (CSIRO and Bureau of Meteorology 2022). On average, Australia has warmed by 1.47 ± 0.24 °C since national records began in 1910 (CSIRO and Bureau of Meteorology 2022) and streamflow has changed across the country, broadly increasing in the north and decreasing in the south (see Chee, Coleman, et al. 2022). In the south- east of Australia, precipitation started to decline around 1990, and the average April to October precipitation from 2000 to 2021 is ~10% less than that of the 1900-1999 period (CSIRO and Bureau of Meteorology 2022). Along with this observed decline in precipitation, streamflow has declined substantially in both the south-west and south-east, where changes in streamflow are typically disproportionally larger than changes in precipitation (Wasko, et al. 2021). The climate of Victoria has also been getting warmer, with the mean annual temperature rising by just over 1°C between 1910 and 2018 (Clarke, et al. 2019). Beyond the next couple of decades, the projected change intemperature depends strongly on the greenhouse gas emissions pathway that the world follows.

Melbourne's climate trajectory

Here, we summarise the latest information on warming and drying trajectories for the Melbourne region using the latest downscaled climate information. Updated projections for temperature became available from CSIRO in 2019 and, in 2022, updated projections of runoff became available from the Bureau of Meteorology. A full and thorough description of the method and results is available in the Habitat Suitability Model-Climate Change Technical Report (Chee, Coleman, et al. 2022). Mean annual temperature and runoff are key parameters in our habitat suitability models, and we investigated how changes in these parameters, associated with the new climate information, affects predictions in HWS 2018 (Chee, Coleman, et al. 2022).

We made use of application-ready projections from CSIRO, also known as Victorian Climate Projections 2019 or VCP19 projections. These projections included six global climate models (GCMs) that were downscaled to five km resolution over Victoria. We compare climate predictions made at the time of the HWS development with these six GCMs at two emission intensity pathways (RCP4.5 and RCP8.5) that represent the medium and high emission pathways.

For the purpose of the Science Inquiry, 2,070 is used as the time point of interest for climate change assessment as that roughly coincides with the 50-year horizon of HWS 2018.

Air temperature

Air temperature for all six VCP19 models, and for both emission pathways, were predicted to be greater than the two mean temperature variables used in HWS development (Figure 31). This means that we likely underestimated the impact that climate-related increases in air temperature may have on the trajectory of in-stream values. In fact, for the high emission pathway, median projected warming is between 0.84 °C and 1.96 °C above the 2018 predicted mean annual temperatures (Figure 32). The most pronounced warming in Melbourne is expected to occur around the areas with greatest urban development. See Appendix 3.

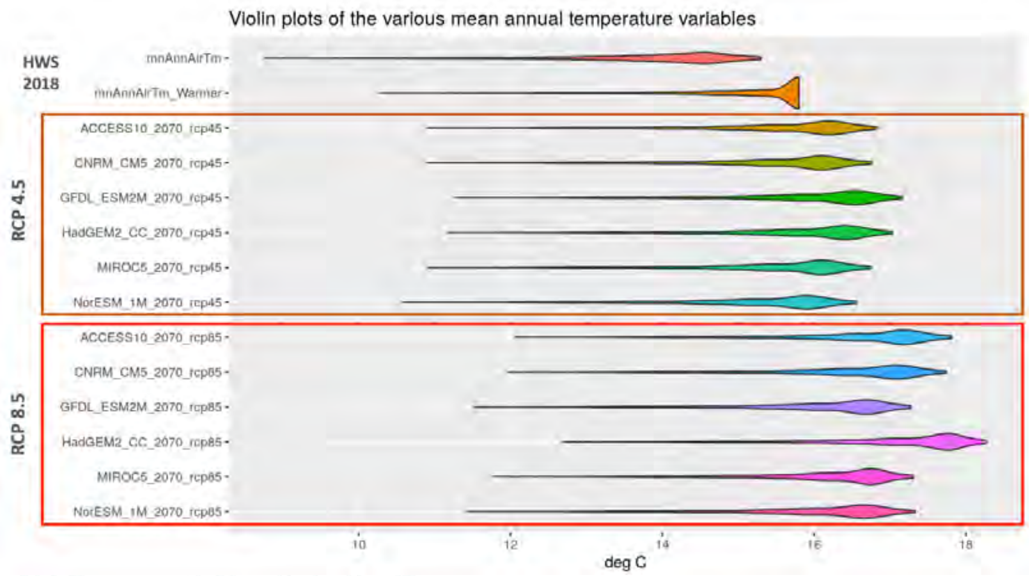


Figure 31. Violin plots of the various mean annual temperature variables of interest. The top two, mnAnnAirTm and mnAnnAirTm_Warmer, are the mean temperature variables used in our HSMs to represent CURR (current, nominally ~2016) and warmer business-as-usual-future (BAUF, circa 2070) conditions respectively, in the development process of the HWS 2018. The brown rectangle groups projections from the six VCP19 models, given a moderate emission pathway of RCP 4.5. The red rectangle groups projections from the six VCP19 models, given a high emission pathway of RCP 8.5. ***Summary: increases to mean annual air temperature by 2070 will likely be greater than we originally predicted.***

Mean annual run-off

Drying patterns), and changes to drying patterns, are spatially variable (Figure 32). 'Drying' is predicted to be greater in eastern parts of the Melbourne region and there may be small increases in mean annual runoff in western parts of the Melbourne region (Figure 32). While extreme 'drying' is less severe than that of original estimate (i.e. 'dryMeanQ'), flow conditions are, however, generally 'dryer' than originally predicted. See Appendix 3.

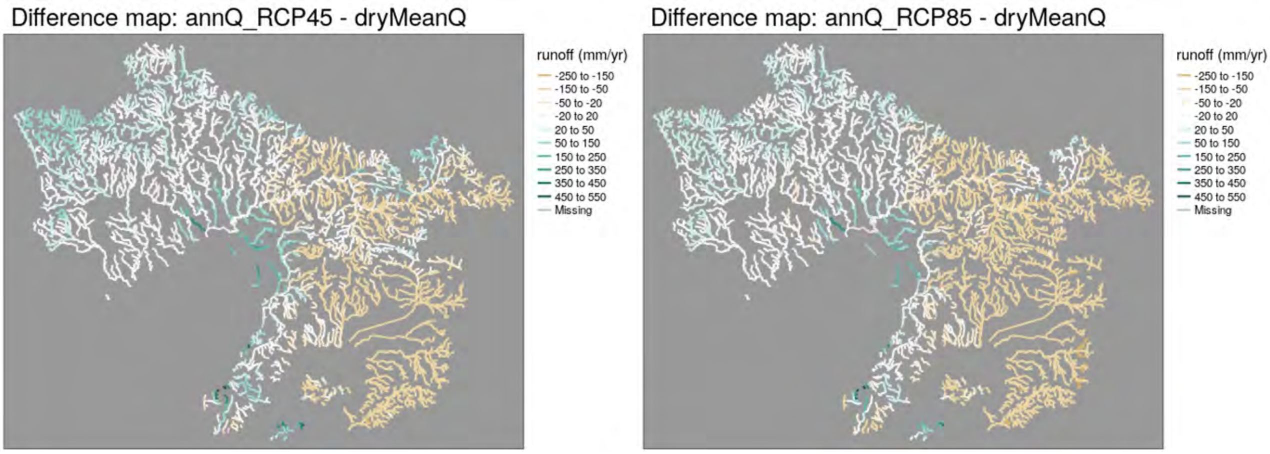


Figure 32. 'Difference' maps showing where projected mean annual runoff under the moderate emission pathway RCP 4.5(left) and the high emission pathway RCP 8.5 (right) differs from that of 'dryMeanQ'. On this diverging colour scale darker browns indicate runoff that is much lower than 'dryMeanQ', white indicates little runoff difference and deeper blue-greens indicate runoff much higher than 'dryMeanQ'. ***Summary: changes to mean annual flow are more variable than we originally predicted and the eastern Melbourne region is predicted to become "drier".***

Impact to in-stream values

The in-stream HSMs for platypus, fish and macroinvertebrates —developed as part of the Healthy Waterway Strategy 2018—predicted important changes in the suitability of habitat of instream biota in the face of combined climatic warming and drying. Using the latest climate change projections, we re-ran our original in-stream models for macroinvertebrates, fish, and platypus to understand how updated climate information may impact the trajectory of these in-stream values and in relation to the long-term targets.

For simplicity, we present the model predictions for macroinvertebrates, female platypus and for two native fish species, River blackfish (*Gadopsis marmoratus*) and Ornate galaxias (*Galaxias olidus*). We assessed the absolute differences in channel length within each value rating category (Very low, Low, Moderate, High, Very high) as well as any spatially explicit differences. Below we summarise the findings of these model re-runs but refer the reader to a full and thorough description of the method and results that is available in the HSM climate-change impact report (Chee, Coleman, et al. 2022).

For the purpose of the HWS mid-term evaluation, and this Science Inquiry Report, we chose to focus on the following GCMs when investigating climate change-induced changes in relevant instream values:

- ACCESS10_2070: as this is an Australian model produced by CSIRO, and
- HadGEM2_CC_270: as this model generally produces the most extreme (hottest and driest) climate outcomes – as it represents a conservative approach.

Macroinvertebrates

For macroinvertebrates, the updated predictions of channel length within each LUMaR rating category were not very different from the original predictions (Figure 33). For example, there was less than a 1% reduction in the length of the best quality (High and Very high rating) habitat for re-run models compared to the original models. While there were minimal overall differences, we observed the potential for spatially explicit increases and decreases across the Melbourne region (Figure 34) – these spatially explicit changes informed assessments undertaken in Part C - Region-wide assessment of management activities and their effectiveness to identify climate vulnerable and climate stronghold areas. It should be noted that HSMs are correlative and not process-explicit, and they do not represent acute or sub-lethal impacts to organisms and communities, including climate change-related declines in water quality.

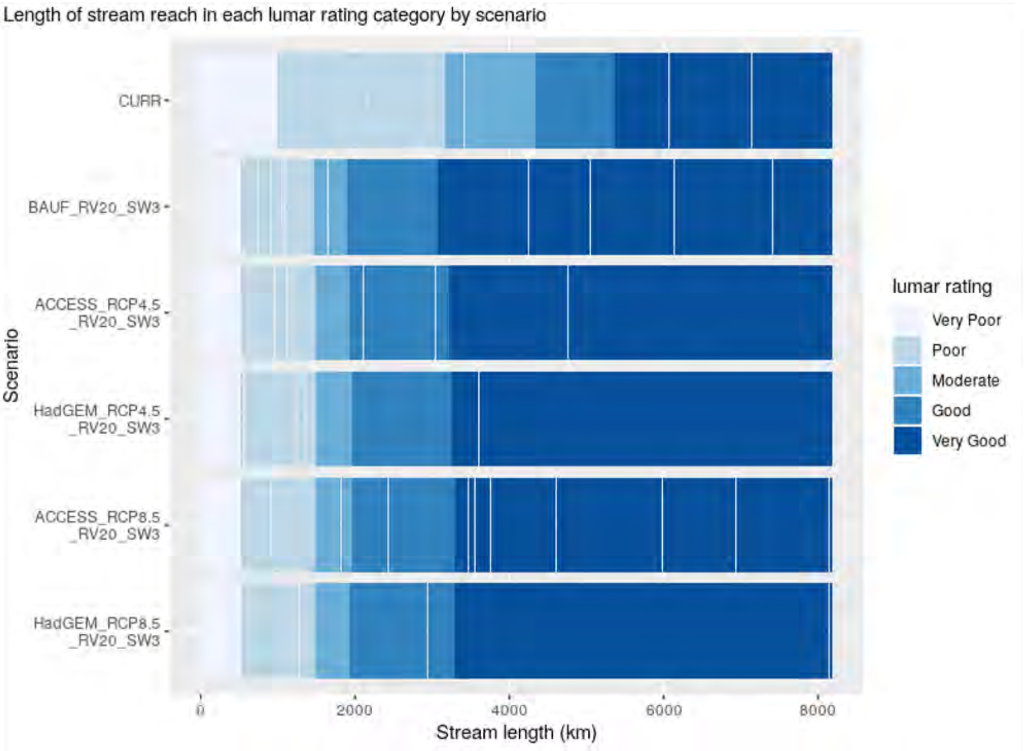


Figure 33. Summary stacked barplots of stream lengths in each LUMaR (lumar) rating category by scenario for climate change-impacted scenarios with climate change impacted scenarios with RV20_SW3 (revegetate riparian zones on both stream sides, to 20m width along all streams in the PPWP region AND treat all future and some existing impervious cover such that Attenuated Imperviousness in existing urban areas is reduced to 75% of 2016 levels). The intervals for the LUMaR rating categories are: Very Poor -0.3 - 0.05, Poor 0.05 - 0.35, Moderate 0.35 - 0.5, Good 0.5 - 0.65, Very Good 0.65 - 1.0.

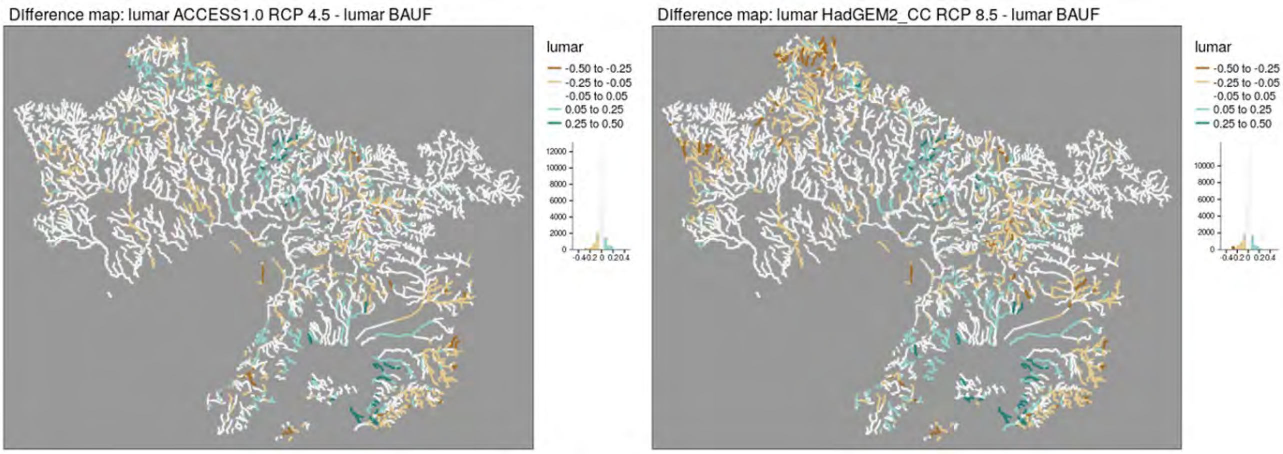


Figure 34. Difference maps showing where predicted LUMaR under ACCESS 1.0 RCP4.5 (left) and under HadGEM2_CC RCP8.5 (right) differs from that of the BAUF scenario used in HWS 2018. On this diverging colour scale darker browns indicate lower LUMaR values relative to BAUF, white indicates little difference and deeper blue-greens indicate higher LUMaR values relative to BAUF.

Platypus

For simplicity, we present the assessment for female platypus only. The potential impact of climate change for all platypus is available in HSM climate-change impact report (Chee, Coleman, et al. 2022). Climate change may pose an even greater risk than originally predicted, with a predicted further reduction in the best quality habitat (High and Very high) for female platypus of between 28-75% by 2070 (Figure 35). This is predicted to occur even with planned interventions that improve riparian vegetation and manage for stormwater. The majority of the reductions in predicted platypus habitat occur in regions that are currently considered “strongholds” for platypus (upper Yarra River catchments; Figure 36).

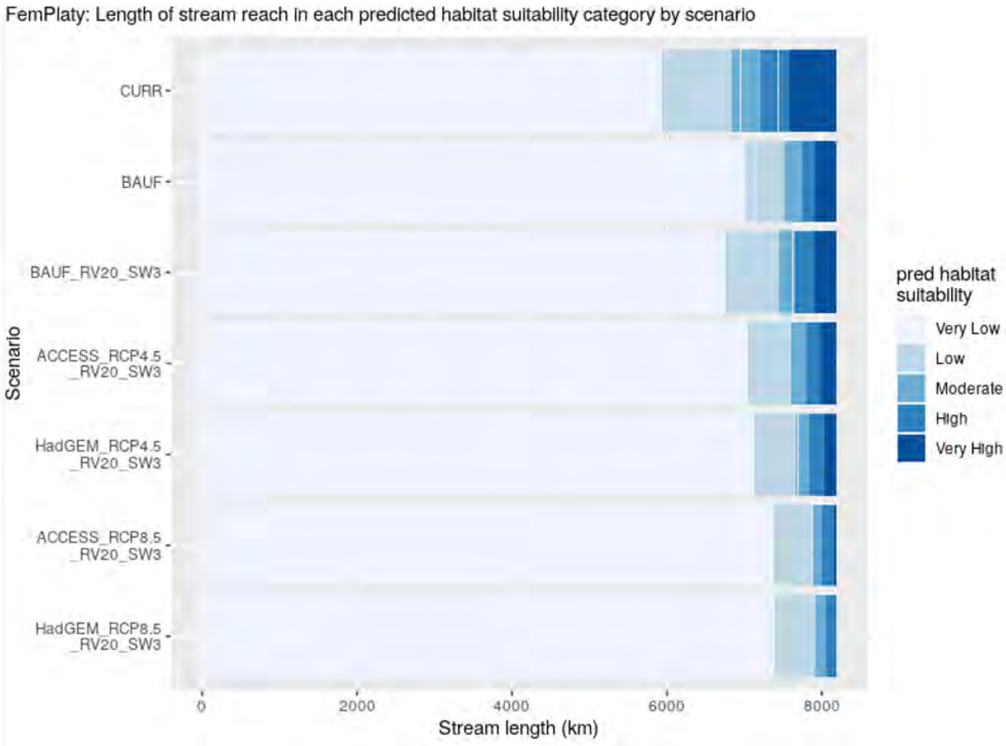


Figure 35. Summary stacked barplots for female-only platypus ('FemPlaty') of stream lengths in each predicted habitat suitability category by scenario for climate change impacted scenarios with RV20_SW3 (revegetate riparian zones on both stream sides, to 20m width along all streams in the PPWP region AND treat all future and some existing impervious cover such that Attenuated Imperviousness in existing urban areas is reduced to 75% of 2016 levels). The intervals for the predicted habitat suitability categories are: Very Low 0 - 0.10, Low 0.10 - 0.20, Moderate 0.20 - 0.30, High 0.30 - 0.40, Very High 0.40 – 1.0.

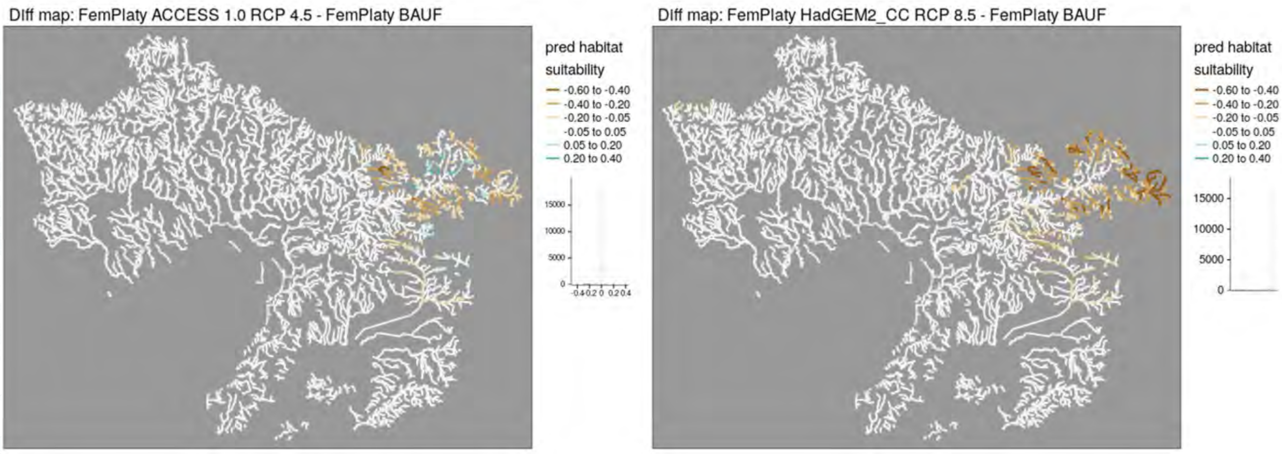


Figure 36. Difference maps showing where predicted habitat suitability under ACCESS 1.0 RCP4.5 (left) and under HadGEM2_CC RCP8.5 (right) differs from that of the BAUF scenario used in HWS 2018. On this diverging colour scale darker browns indicate lower predicted habitat suitability relative to BAUF, white indicates little difference and deeper blue-greens indicate higher predicted habitat suitability relative to BAUF.

Native fish

For River blackfish, the length of the best quality habitat (High and Very high) is predicted to decline by 10-54% more than predicted at the start of the Strategy (Figure 37). This decline is even greater for Ornate galaxias, with a decline in best quality habitat varying from 31-88% more than originally predicted (Figure 37). The largest declines in River blackfish habitat are in areas where they currently have a high probability of occurrence (Woori Yallock and Tarago River sub-catchments) (Figure 38). The updated predictions indicate that there are regions of improvement in Ornate galaxias habitat compared to the original predictions, but these improvements are mainly associated with the lower emission intensity scenario and centred in upper parts of the Werribee, Maribyrnong and Yarra catchments (Figure 38). Nonetheless, the updated predictions for Ornate galaxias indicate that declines in habitat suitability are generally more extensive than improvements (Figure 39).

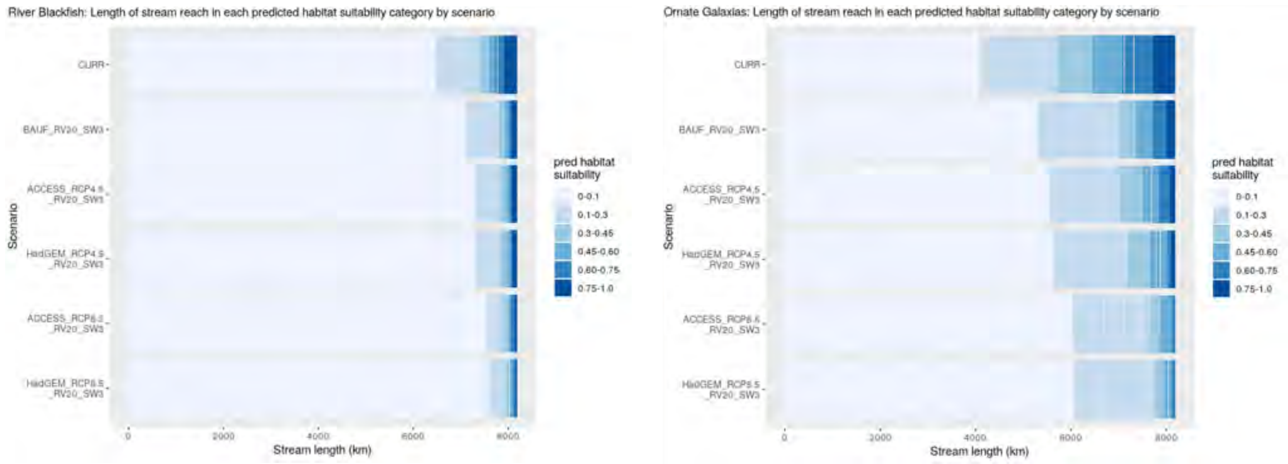


Figure 37. Summary stacked barplots for River blackfish (left) and Ornate galaxias (right) of stream lengths in each predicted habitat suitability category by scenario for climate change-impacted scenarios with RV20_SW3 (revegetate riparian zones on both stream sides, to 20m width along all streams in the PPWP region AND treat all future and some existing impervious cover such that Attenuated Imperviousness in existing urban areas is reduced to 75% of 2016 levels). The intervals for the predicted habitat suitability categories are: 0 - 0.10, 0.10 - 0.30, 0.30 - 0.45, 0.45 - 0.60, 0.60 – 0.75 and 0.75 - 1.0.

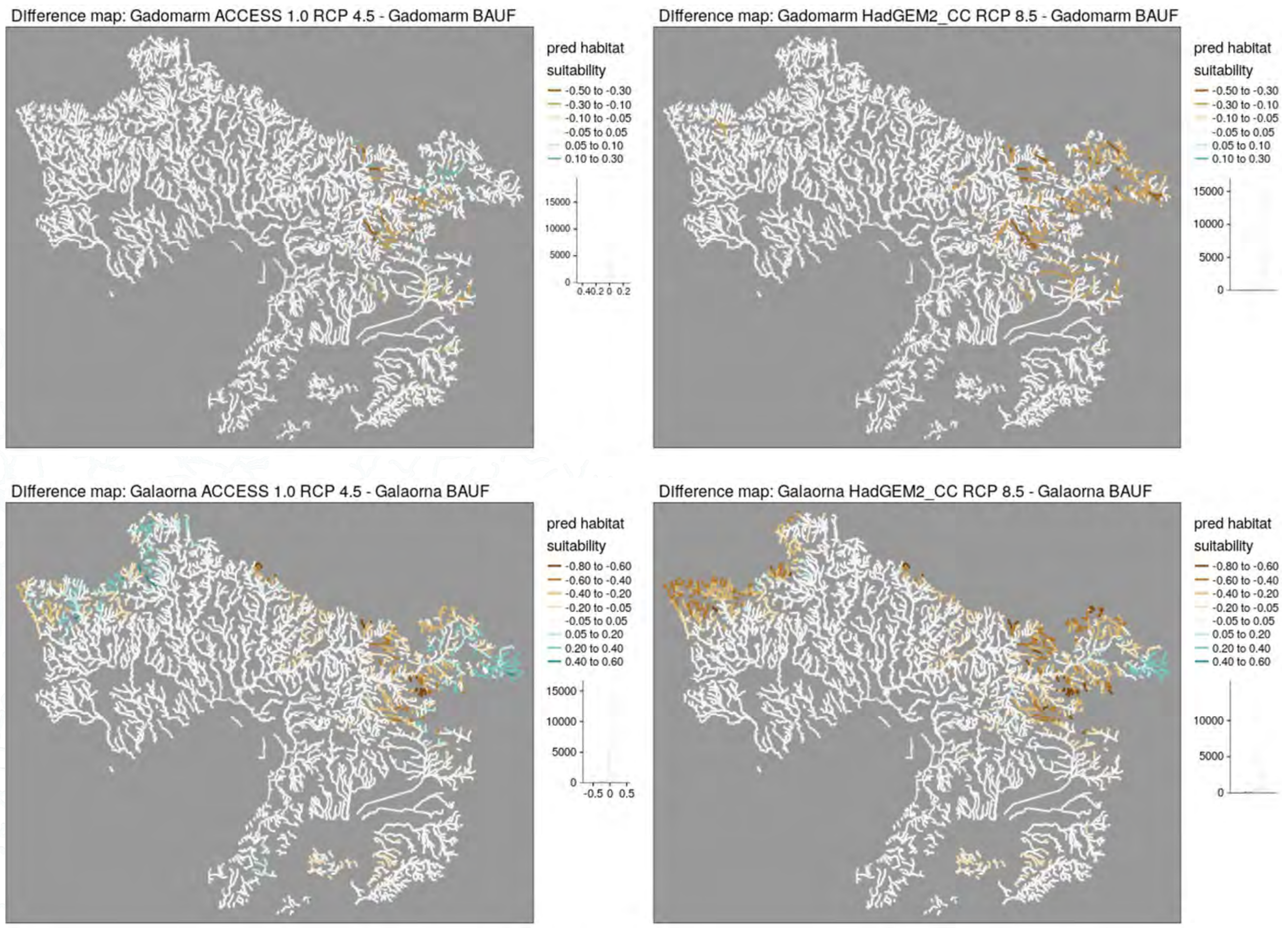


Figure 38. Difference maps showing where predicted habitat suitability under ACCESS 1.0 RCP4.5 (left) and under HadGEM2_CC RCP8.5 (right) differs from that of the BAUF scenario used in HWS 2018 for both River blackfish (top; Gadopsis marmoratus) and Ornate galaxias (bottom; Galaxias olidus). On this diverging colour scale darker browns indicate lower predicted habitat suitability relative to BAUF, white indicates little difference and deeper blue-greens indicate higher predicted habitat suitability relative to BAUF.

Rural related threats

Declining water availability (from extraction and changes in climate) and impacts associated with agricultural land (polluted runoff and water extraction) are threats that are relevant in the region.

As outlined above, climate change is predicted to lead to significant reductions in flows and impacts to key values. The long-term water resources assessment (Government of Victoria 2020) also presents clear evidence that water availability in rivers within all five catchments in our region is declining, primarily due to changes in cool-weather rainfall patterns (Figure 39). This study has highlighted that water for consumptive uses and changes in climate are increasing flow stress in rivers in all five catchments in our region.

The long-term water resource assessment (Government of Victoria 2020) has determined that there has been an average decrease of 14% in available water across the region over the assessed time period (1997-2020 compared to historical record) (Table 26). Competition between demand for consumptive use and the water for the environment are unfavourable for the environment in all systems other than the Bunyip and South Gippsland basins (Bass River catchment applicable in this basin) where sharing of the available water between consumptive and environmental uses has not changed over the assessable period. For the Yarra, Maribyrnong and Werribee the share of decline impacts the environment in order to maintain as much security as possible for consumptive use.

Table 26. Summarised results of the Long-term water resource assessment (Government of Victoria 2020).

Basin	Werribee	Maribyrnong	Yarra	Bunyip (Westernport)	South Gippsland (Bass River)
Decline in available water	18%	17%	16%	0%	12%
Effect on environmental share	-8%	-1%	-7%	No change	No change

Figure 39. Annual water availability in six rivers of the Melbourne region (Government of Victoria 2020).

Along with water extraction pressures as outlined above, agricultural practices can also lead to polluted runoff. These threats from agricultural land have been identified as increasing in three sub-catchments (Lang Lang River, Woori Yallock Creek and Stringygbark Creek) due to observed intensification of farming practices. This is likely to increase the risk of polluted runoff.

Progress towards managing threats

Water recovery targets for regulated flows identified in the HWS have largely not been achieved (Table 27). However, there has been some recovery volume has been achieved for the Werribee catchment.

Table 27. Catchment water recovery targets and progress as of 2022.

Catchment	Recovery target (by 2028)	Recovered to 2022
Werribee	5 GL/year	1.1 GL in 2020
Maribyrnong	7 GL/year	0
Yarra	10 GL/year	0
Dandenong	0	NA
Westernport	1 GL/year	0

The HWS Performance Objectives for non-regulated sub-catchments are qualitative and as such difficult to assess. The implementation inquiry provides some insights into the how well these performance objectives are tracking. There is a need to better understand the causes of flow stress (e.g. climate change and/or water use) and options for more targeted performance objectives to improve management, reporting and evaluation in the future.

Progress towards improved land management is on-track in two of these sub-catchments (Lang Lang River and Woori Yallock Creek) while the third (Stringybark Creek) was not identified as a priority area at the beginning of the strategy due to the level of degradation in the system being high (multiple low condition scores) with resultant low macroinvertebrate values. With respect to water quality impacts from agricultural practices, further pesticide and ecotoxicology studies are needed to improve understanding of the existing condition in key areas to inform the development of appropriate interventions beyond nutrient and sediment management.

Alignment between social and environmental threats

The threats described above are also relevant to social values in particular recreation and amenity. For example, recreational activities such as swimming, boating and fishing all benefit from good flow regimes and water quality.

Key changes to assumptions and the operating environment

The Central and Gippsland region sustainable water strategy (CGRSWS) released by the Department of Environment, Land, Water and Planning in 2022, provides the supporting policy to achieve the HWS water recovery targets. It aims to improve water efficiency and use of manufactured water with the aim of returning river water to Traditional Owners and the environment.

There is also a new Victorian Agriculture Strategy; Strong, Innovative, Sustainable: a new strategy for Agriculture in Victoria (Government of Victoria 2020) which has a focus on low emissions, climate change, markets and resilience. It is not clear whether it will guide improvements to water quality, runoff and water use.

Urban related threats

While climate change and water extraction for consumptive uses results in a significant water availability issue in rural and forested areas as described in the sections above, urban development leads to too much runoff into streams from impervious surfaces created from roads and houses. In addition to altering the flow regime, water quality (including litter) is impacted, and streams, floodplains and wetlands can be physically modified or removed from the landscape. This section covers these impacts as well as the impacts of wastewater. As outlined in the approach section above we have assessed where the threat has increased since 2018.

Stormwater

The HWS identifies urban development as one of the biggest threats to environmental values in our region and for the first time it set targets in priority areas to reduce stormwater runoff volumes in a subset of sub-catchment areas. While there have not been any major changes to the Urban Growth Boundary (UGB) the rate of urban development within the existing UGB has been rapid. Shifting from business-as-usual water quality management to managing runoff volumes requires a significant practice change. New greenfield and infill development in stormwater priority areas has generated around 1,479 ha of new impervious surfaces to date (since 2018), as reported on the HWS annual report website, which is equivalent to over 700 MCGs. This area will generate 7,900 ML per year of runoff. While we don't track new development outside the priority areas, based on existing Precinct Structure Plans there is likely to have been the equivalent amount of development in these areas as well. The HWS Annual Report tracks the stormwater harvest and infiltration targets in the stormwater priority areas and while there are plans in place to manage around 33% of the 10-year target at present only 7% of the additional runoff has been adequately managed through harvesting, evapotranspiration or infiltration. Figure 40 highlights the gap required to meet the 10-year harvest targets for each of the five major catchments across the region.

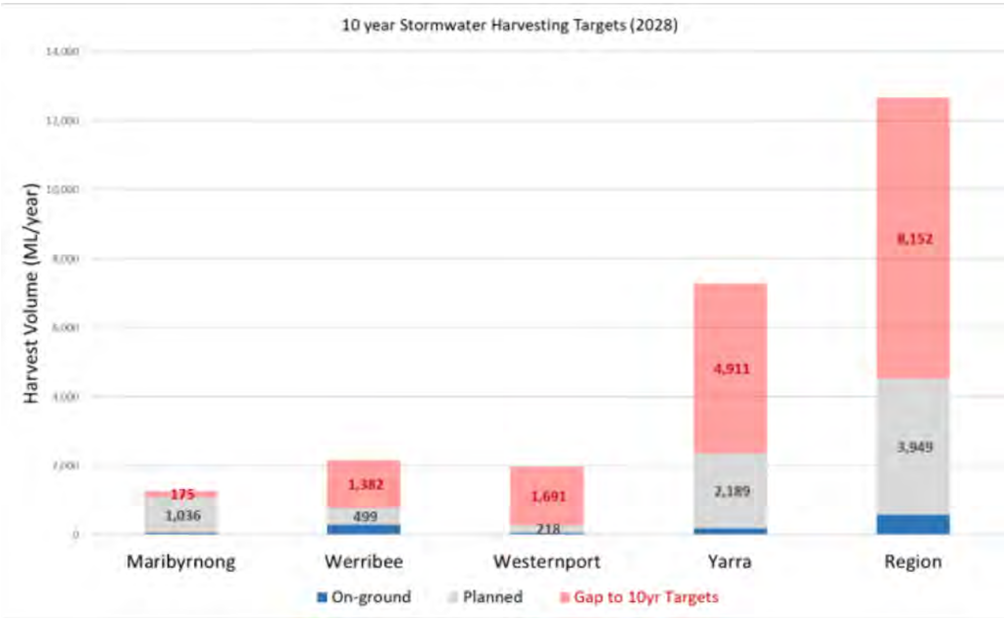


Figure 40. Status of stormwater harvesting targets for stormwater priority areas.

Directly connected imperviousness (DCI) is a stormwater impact indicator which was used to assess where the stormwater threat is increasing. Spatial data of sub-division approvals in priority areas were used to estimate where impervious surfaces have increased which is then combined with information on the location and effectiveness (based on MUSIC modelling) of stormwater control measures such as constructed wetlands. Results are presented in Figure 41 and show that DCI is increasing in many areas. This is largely because the current constructed and planned stormwater control systems in growth areas are not designed to meet the stormwater volume targets. The mid-term review threats analysis (*HWS Threats: A technical report to inform the mid-term evaluation*) used this data along with assumptions outside priority areas to identify at least 12 sub-catchments where the threat has increased since 2018.

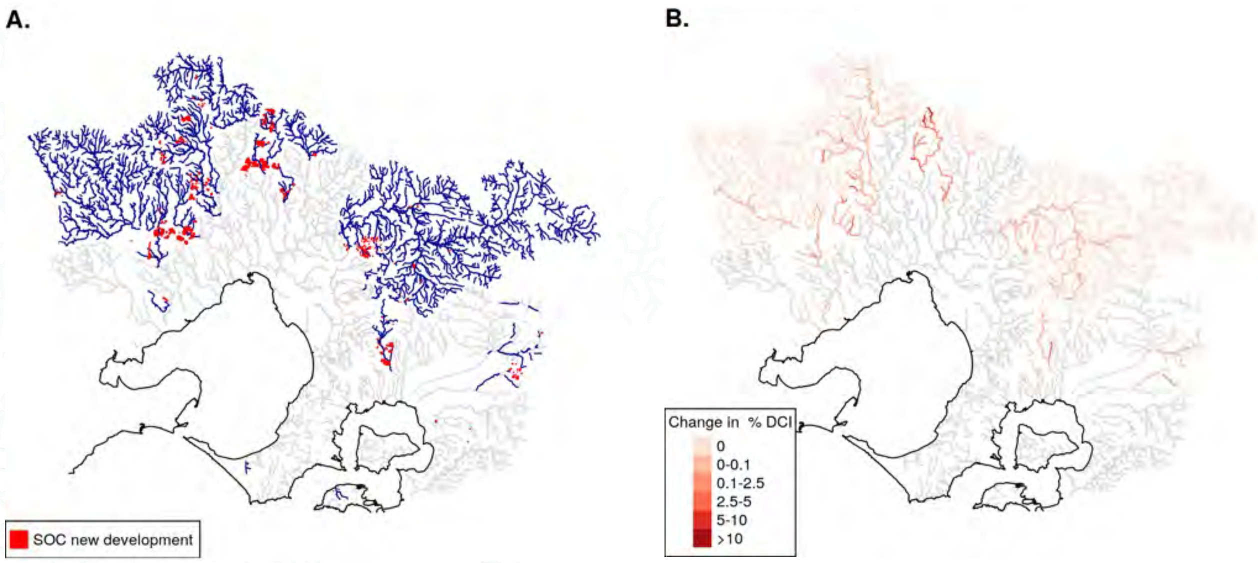


Figure 41. A. Distribution of 'Statement of Compliance' (SoC) new development polygons (red) within designated stormwater priority areas. B. Percentage change in DCI (Directly Connected Imperviousness; or attenuated imperviousness) relative to that of the CURR scenario used in the HWS 2018 as a result of developments covered by 2019-2022 Statements of Compliance. In both A and B, stream reaches outside stormwater priority areas are coloured grey.

Industrial areas

While best practice guidelines for managing water quality from urbanisation are in place, they are targeted at nutrients and sediments and do not adequately manage industrial areas that produce toxicants, heavy metals and other emerging contaminates. Based on sediment quality data, the threat from industrial areas has been rated as increasing in 11 sub-catchments.

The treatment options for managing industrial areas are different to typical residential areas and intervention to adequately manage this issue are not yet mature.

Loss of wetlands and headwater streams

The first HWS Annual Report Card reported the loss of some natural wetlands due to previously approved urban development and subsequent Annual Reports highlight additional natural wetlands under imminent risk. For example, Sewell's Road Swamp has been altered by urbanisation and effectively lost the natural values for which it was recognised in the 1990s. On-ground observations when walking on Country with the Werribee River Keeper with Melbourne Water and Wyndham City Council representatives confirm its status to be effectively lost. In total there are now four natural wetlands effectively lost since the HWS was launched in late 2018 (Table 28).

Table 28. Status of natural wetlands as reported in the HWS Annual Report.

Wetlands	Period	Protected	Future threat	Imminent risk	Effectively lost	Other	Total
Priority Wetlands (*n*)	2019						
	2020	101	2	15	3	129	250
	2021	104	1	14	4	131	254
	2022	102	3	14	4	131	254
Natural wetlands (ha)	2019						
	2020	2081.6	82.2	573.5	71.7	344	6253
	2021	2136.8	163.2	663.4	113.7	3175.9	6253
	2022	1994.5	104.7	415	117.7	3621.1	6253

On the positive side, 104 of 254 regional priority wetlands are protected, and the number under threat has not increased since 2018. In terms of area, there is a total of 6,253 ha of natural wetlands mapped in our region. Of this 2,137 ha are managed within a protected area network of public land (Parks Victoria parks and reserves, Melbourne Water sites of biodiversity significance, botanic gardens, etc.). Since 2018, 114 ha have been effectively lost; 663 ha is judged to be under imminent threat and 163 ha at future risk of urbanisation.

Piping or modification to waterways, particularly headwater streams is an on-going issue in urbanising areas. The threats technical report (*HWS Threats: A technical report to inform the mid-term evaluation*) outlines the assessment made of the extent of the issue and has highlighted there are potentially around 50 kms of headwater streams proposed to be piped and 209 kms of streams to be modified (Table 29) within the UGB. This issue largely stems from the increased volumes of runoff generated from impervious surfaces requiring streams to be enlarged and re-enforced to protect them from excessive erosion and to manage flooding.

Table 29. Potential extent of proposed channel modifications and piping of streams in urbanising areas.

Impact	Dandenong	Maribyrnong	Werribee	Western Port	Yarra	Total
Channel modifications	0	16	17	46	130	209
Piping	1	6	5	4	34	51

Litter

The threat of litter is assumed to be increasing in areas where new development has occurred. The threat is assumed to be stable in existing urban areas, although wet years can result in more litter being washed into waterways. Litter can threaten social and environmental values in several ways:

- Aesthetic Impact: Litter can detract from the beauty of an area, leading to a decline in the perceived value of the environment. This can affect people's sense of pride in their community
- Health and Safety Concerns: Litter can create health hazards, such as attracting pests or providing breeding grounds for bacteria. It can also pose safety risks, such as tripping hazards or the potential for fires if the litter is flammable
- Environmental Damage: Litter can harm wildlife and ecosystems, disrupting natural processes and potentially leading to long-term environmental degradation. This can affect people's sense of responsibility and stewardship toward the environment. The threat of entanglement to platypus is considered to be declining in rural areas where opera house nets have recently been banned, however there are 14 urbanising sub-catchments with existing platypus populations where the litter threat is increasing due to on-going urban development
- Community Cohesion: Litter can contribute to a sense of neglect and apathy within a community, and
- Economic Impact: Cleaning up litter incurs costs for local authorities and businesses, which can have wider economic implications for a community.

The work as part of the Port Phillip Bay Environmental Management Plan to quantify the volume of litter entering Port Phillip Bay along with a research project by RMIT currently underway to provide baseline litter data on six sub- catchments will help to refine our understanding of the threat of litter over the next few years.

Wastewater

The threat from wastewater discharges on environmental values has been rated as stable across the region, based on data that indicates that pollutant load discharges from sewage treatment plants (STPs) are not increasing. We also considered the regulation of STPs and forward plans to decommission a number of STPs during the life of the HWS in making this assessment. Septic tank impacts were assessed as declining as there is evidence of increased areas becoming connected to the reticulated sewer network. Emergency Relief Structure spills are also regulated and have been generally declining over the long term across the region.

Progress towards managing threats

In terms of performance objectives, progress towards targets for STPs are on-track as pollutant load discharges are not increasing above the baseline. Reporting on septic tanks is qualitative and describe on-going decommissioning of septics as houses are connected to the sewerage network. The increasing urban threat however is not surprising given the off-track status for the many of the stormwater performance objectives (Figure 40), particularly the infiltration targets. Performance objectives focused on industrial pollution are limited to only three sub-catchments which seems low given the threat status is rated as increasing in 11 sub-catchments. Performance objectives for protecting natural wetlands and headwater streams are regional and somewhat qualitative however they do describe some initiatives to improve protection. There are no sub-catchment specific performance objectives for managing litter to protect platypus in priority areas. Reporting on litter management is reported regional and is fairly high level.

Alignment between social and environmental threats

The threats described above are also relevant to social values. For example, litter is a threat to amenity values and poor water quality impacts recreational activities such as boating and swimming.

Key changes to assumptions and the operating environment

There are a few changes to the operating environment that will influence the urban threat, some will aid in mitigating the threat and others introduce more challenges. For example, while there has not been any changes to the urban growth boundary, there are some new precinct structure plan areas and lot densities within the urban growth boundary are increasing making it even more challenging to mitigate impacts due to limited space for treatment systems.

The Environment Protection Act 2017, as amended by the Environment Protection Amendment Act 2018, came into effect from 1 July 2021. It defines the general environmental duty which requires risks of harm to human health and the environment to be managed so far as is reasonably practicable. The Urban stormwater management guidelines (Publication 1739.1 June 2021) were also released and they form a key element of the state of knowledge underpinning the general environmental duty. The guidance includes objectives for harvesting and infiltration in priority and other areas that are expressed in terms of a percentage of total runoff. The objectives and priority areas align well with the HWS stormwater harvest and infiltration targets. The addition of targets for 'other areas' isalso a positive for the HWS as it gives direction on objectives outside the HWS priority areas which up until now did not have any flow related targets. Further work is required to embed these guidelines into the planning process to make them mandatory.

The new Central and Gippsland Sustainable Water Strategy (2021) supports the development of several strategies that in principle support the HWS stormwater harvesting and infiltration targets. The Integrated Water Management forums also provide an opportunity for collaboration across agencies to progress stormwater management.

Given the significantly off-track status of the stormwater harvest and infiltrate performance objectives (Figure 41), the assumption that targets would be achieved in priority areas in pace with development is questionable.

Vegetation and habitat related threats

This grouping of threats relates to pest plants, animals (herbivores and predators), recreational access, instream barriers and vegetation clearing. These threats primarily impact the physical habitat of rivers, wetlands and estuaries, including vegetation extent and quality and instream connectivity.

The threat status for animals was assessed for deer drawing on modelling and field data. Other herbivores and predators could not be assessed due to data limitations. Anecdotally the threat status of livestock accessing streams was generally thought to be decreasing as increasing areas of riparian land is managed. For example, since 2018 there has been 1,516 ha (~379kms) of vegetation established along waterways across the region which, if required, includes stock exclusion fencing. Deer is an emerging threat and rated as increasing in almost half the sub-catchments across the region, particularly those in the south and east (see Part A vegetation section for more details).

Weeds continue to threaten vegetation along waterways. In Part A, under the vegetation value section, we demonstrated that weeds are one of the key factors limiting vegetation condition and also demonstrated the improvements in quality resulting from weed management. In time the regional surveillance monitoring (i.e. VV21 data) will provide better evidence of the weed threat trajectory across the region. As a surrogate, the threat trajectory was assessed as increasing in sub-catchments where vegetation maintenance targets are significantly off-track. This includes 18 sub-catchments.

Motor bikes, cars and mountain bikes can increase tracks and vegetation disturbance leading to fragmentation and erosion. Recreational access in forested catchments was flagged as a potentially increasing threat however further data and analysis is required to quantify the extent of the impact. There are currently no specific performance objectives in the HWS aimed at managing this threat.

Instream barriers can inhibit fish movement and migration. As new waterway structures such as weirs are designed to be fish friendly, the threat is considered largely stable across the region and declining in several sub-catchments (Dandenong Creek lower, Yarra River lower, Darebin Creek and Maribyrnong River) where fishways have been constructed.

Illegal clearing of riparian vegetation is not considered to be a widespread threat in our region however confirmation of this is required. New aerial imagery datasets (i.e. NearMap) will enable this assessment to be made in the future, although it will require dedicated effort and resourcing to undertake the evaluation.

The threat posed by removal of large woody debris could not be assessed. While large wood was historically removed from streams this practice is now very limited to certain situations (e.g. protection of assets such as bridges). Further work is required to determine the extent of large woody debris removal.

Disease can also be a threat and in our region including phytophthora as well as chytrid fungus which is present and impacting frogs. The degree to which the chytrid fungus threat is increasing is not known and research has been commissioned.

Progress towards managing threats

There are several types of performance objectives that address threats in this group, some include quantitative targets (e.g. number of fishways to construct and area of vegetation to be managed), however, others are more qualitative e.g. deer. For example, as presented in the HWS Annual Report, fishways are on-track in all catchments except the Lang Lang River. There are a number of sub-catchments for rivers where the vegetation maintenance targets (e.g. pest plant and animal control) are off-track and this is being considered within the implementation inquiry. For wetlands and estuaries, it is currently difficult to assess how well threats are being addressed given the qualitative nature of the performance objectives. Finally, there are no performance objectives directed at managing recreational access threats in forested catchments.

Alignment between social and environmental threats

The threats described above are relevant to social values. For example, good quality vegetation is a condition that supports the amenity and recreational social values. There are a couple of environmental threats discussed above which can be in conflict with social values – for example, recreational access is both a potential environmental threat and a social value. Similarly large woody debris within streams is good habitat however can threaten social values of canoeing. Further work is required to better understand where these conflicts are occurring.

Key changes to assumptions and the operating environment

The Victorian deer control strategy and a peri-urban Melbourne Deer Control Plan for Melbourne should support increased investment in deer management in our region. Given the merger between the CMA and Melbourne Water the Catchment and Land Protection Act (CALP Act) will enable a stronger role in weed management. Biosecurity provisions are currently being reviewed by the Victorian Government.

Overall summary

Climate change

Overall, we likely underestimated the potential impact of climate change for the HWS long-term targets (10 to 50 years) and, to a lesser extent, the 10-year Performance Objectives. Air temperatures will likely be greater, and flow conditions generally drier, than originally predicted. Habitat suitability models for macroinvertebrates including updated climate change information were, overall, not very different from original predictions. However, climate change likely poses an even greater risk, than originally accounted for, for platypus and the climate-vulnerable native fish species (River blackfish and Ornate galaxias) assessed.

Other threats

Many threats are still increasing across the region (Table 30). Urbanisation, water availability and pest animals (largely deer) are the top 3 threats that have increased since 2018. Wastewater, instream barriers and streamside vegetation clearance (low confidence) are the only threats ranked as stable or decreasing in all sub-catchments. Many sub-catchments have multiple increasing threats which can often interact with each other. Forested sub-catchments have the fewest threats, although as outlined in the climate change section it is a significant threat, particularly fires.

A number of threats could not be assessed due to data limitations, particularly threats to social values and the confidence in some threat assessments was low, such as recreational access (Table 30).

Table 30. Summary of threat status across the region.

Threat group	Threat category	Social and environmental value	# Sub-catchments where threat has increased	Was the threat trajectory as expected?	Confidence
Rural related threats	Water availability	Both	42	No – greater than expected. Targets off-track. New evidence of declines.	Moderate
	Agriculture	Both	3	Yes	Low
Urban related threats	Urban flow (DCI)	Both	12	No – increases due to inability to mitigate	High
	Urban WQ (toxicants, industry)	Both	11	No – Priority areas not adequately identified	Moderate
	Wastewater (STPs)	Both	0	Yes	Moderate
	Septic tanks	Both	Not assessed	Not assessed	Not assessed
	Loss of natural wetlands and headwater streams	Both	15	No – not sufficiently included in the HWS	Moderate
	Litter (platypus)	Environmental	14	No - Priority areas not adequately identified	Moderate
	Litter (for social values)	Social	Not assessed	Not assessed	Not assessed
	Reducing waterway corridor width	Both	Not assessed	Not assessed	Not assessed
	Inappropriate light and noise	Both	Not assessed	Not assessed	Not assessed

Threat group	Threat category	Social and environmental value	# Sub-catchments where threat has increased	Was the threat trajectory as expected?	Confidence
Vegetation and habitat related threats	Weeds	Both	18	No – not meeting targets	Low
	Animals (deer)	Both	30	No - not sufficiently included in the HWS	High
	Animals (rabbits, overabundant wildlife)	Both	Not assessed	Not assessed	Not assessed
	Animals (predators – fish, cats, dogs)	Potential for conflicts	Not assessed	Not assessed	Not assessed
	Recreational access	Environmental	21	Needs further investigation	Low
	Vegetation clearing	Both	0	Needs further investigation	Low
	Instream barriers	Both	0	Yes	Moderate
	LWD removal	Potential for conflicts	Not assessed	Needs further investigation	Not assessed
Other threats to social values	Safety	Potential for conflicts	Not assessed	Not assessed	Not assessed
	Inappropriate facilities	Potential for conflicts	Not assessed	Not assessed	Not assessed

Limitations

There are three areas of limitations that are important to acknowledge regarding the updated climate change predictions.

HSM predictions using VCP19 mean annual temperature and BoM mean annual runoff projection are in the realm of extrapolation. Specifically, predictions involving air temperature are greater than the model was trained with – that is, we have not yet experienced air temperatures that are predicted to occur by 2070.

Our HSMs are correlative and not process-explicit. That is, they do not mechanistically model population and life-history processes that we know are important for population processes and persistence, such as reproductive rates, dispersal, and they do not represent impacts of acute disturbance events (e.g. bushfires, flood) or sub-lethal impacts to organisms and communities including water quality (e.g. pollution).

Cascading and compounding impacts have not been considered. For example, multiple extreme events can occur together or in sequence and can compound their impacts and also amplify other stressors.

With respect to other threats to environmental and social values, the main limitations were data availability for threats to social values. There are many threats to waterway values, and it is unlikely to be feasible to assess them all in detail. Further consideration to how threats are evaluated in the future is required so monitoring effort can be targeted to the highest risk threats.

PART C

Region-wide assessment of management activities and their effectiveness

Introduction

This section summaries the management activities that have been completed since the start of the Strategy – we refer to this as 'works-to-date' (WTD). It also incorporates the impact of unmitigated development activities that may have occurred in the absence of, and in addition to, management activities. Three management activities have been tracked and assessed: riparian forest revegetation, stormwater control, and the removal of in-stream barriers. These management activities compose the main interventions that are undertaken to benefit instream values for the HWS.

Approach, outcomes and summary

Riparian vegetation cover

Changes in riparian vegetation cover are based on the output mapping data used to report against the vegetation establish performance objectives. These polygons were compared against the 2016 forest cover data and are represented as attenuated forest cover (AF) in habitat suitability models. This is a measure of the amount of forest cover alongside as well as upstream of the stream segment – its value ranges from 0 (no forest influence) to 1 (complete forest influence) – see (Chee, Walsh, et al. 2022) for a full description of this metric. The estimated change in attenuated forest cover from WTD revegetation has been small (Figure 42). Increases of >0.4 are likely what is required to achieve detectable effects on habitat suitability, but very few reaches have achieved such increases (Figure 42 - Left). Only a small number of reaches experienced an increase in attenuated forest cover by >0.2. For example, the proportion of works sites with new vegetation ranged from 30% in the Dandenong catchment to 80% in the Werribee catchment. An explanation for this could be that revegetation has been in-fill planting to improve the understory and fill small gaps or there may been significant woody weed removal which would have been considered existing forest cover in the HSMs. These works will have an impact on improving quality over time but are possibly not contributing to extent targets in the way we assumed. This has implications for the models and potentially the performance objectives and requires further investigation.

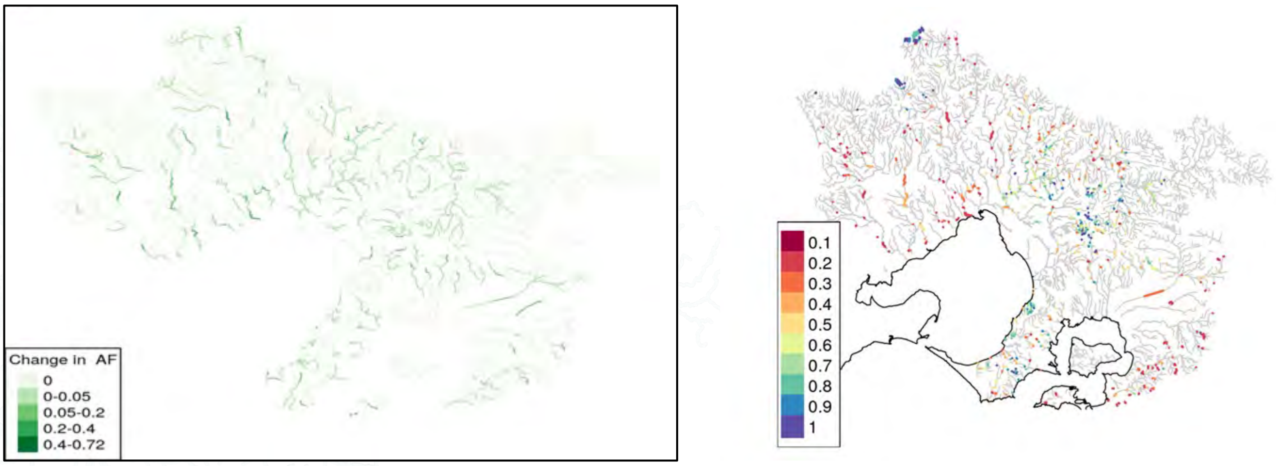


Figure 42. (Left) Estimated change in attenuated forest cover in 2022 due to revegetation since the start of the Strategy. (Right) proportion of new forest cover within mapped revegetation polygons. 1 = no additional forest cover, 0 = all new forest cover.

Stormwater management

Changes in stormwater condition based on management interventions has been represented by directly connected imperviousness (DCI), as indicated above in Part B (Progress towards managing threats). DCI is also referred to as attenuated imperviousness, particularly for the habitat suitability models used for the HWS development and elsewhere as part of the mid-term evaluation work. This is a measure of the influence of runoff from impervious surfaces in 2006 on the reach through the stormwater drainage system associated with urban land. It is computed as the ratio of attenuated impervious area in the catchment (using a half-decay distance of 9.4 m) and its values ranges from 0 (all stormwater is controlled) to 1 (no stormwater controlled). As indicated in Part B (Progress towards managing threats, there has been no overall reductions in DCI in stormwater priority areas (Figure 41). The greatest increases in DCI were found in areas of new development. It is important to highlight that DCI changes outside of stormwater priority areas were not explored, as can be seen in Figure 41.

Barrier removal

This is represented by the number of partial (<5 m in height) or full (>5 m in height) barriers that have been removed. Just under 50% (or 10 barriers) of partial barriers have been overcome since the start of the Strategy. However, only one of seven full barriers have been addressed since the start of the Strategy. See Appendix 8.

Effects to in-stream values

We investigated the effects of management activities on macroinvertebrates, platypus, and fish using habitat suitability models. The reach-scale predictions of habitat suitability were represented in two different ways:

- stacked barplots of predicted stream lengths categorised by value rating categories for each scenario of interest – this allowed us to view any large-scale or overall changes that may be occurring, and
- mapped reach-scale predictions of rating categories for each scenario of interest and differences between scenarios – this allowed is to view any spatially explicit changes that may be relevant to the mid-term evacuation of the HWS.

Macroinvertebrates

The stacked barplots of stream lengths in each LUMaR rating category allows us to compare the predicted impact of scenarios against one another, across an aggregate HWS region-wide scale (Figure 43). Despite the work-to-date, the length of streams in the 'Very Poor' and 'Poor' categories have increased slightly relative to the CURR scenario. But if the 10-year planned works are achieved, this is predicted to reverse the decline and substantially increase the length of streams in both the 'Good' and 'Very Good' LUMaR rating categories (Figure 43). For works-to-date, the changes are predominantly decreases in specific reaches in the sub-catchments of Kororoit Creek Lower, Jacksons Creek, Emu Creek, Merri Creek Upper, Darebin Creek, King Parrot and Musk and Yallock Drain in Bunyip Lower (Figure 44).

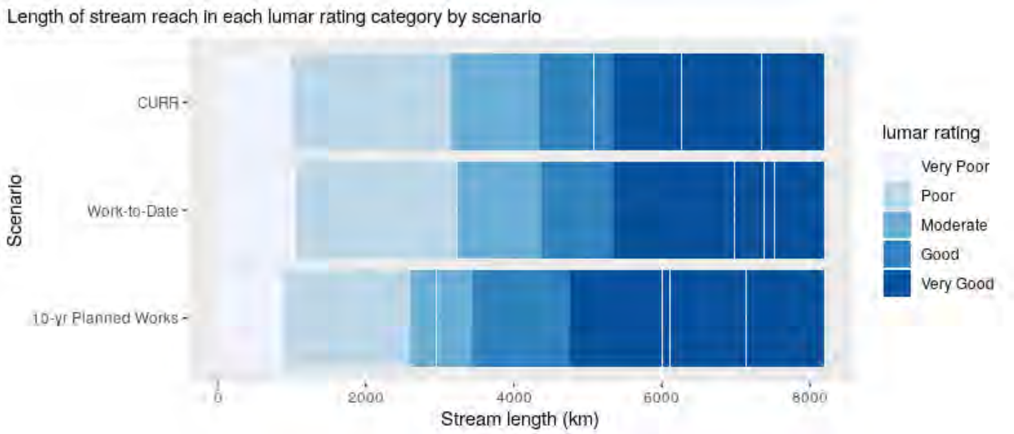


Figure 43. Stacked barplots of stream lengths in each LUMaR rating category by scenario. The intervals for the LUMaR rating categories are: Very Poor -0.3 – 0.05, Poor 0.05 - 0.35, Moderate 0.35 - 0.5, Good 0.5 - 0.65, Very Good 0.65 - 1.0.

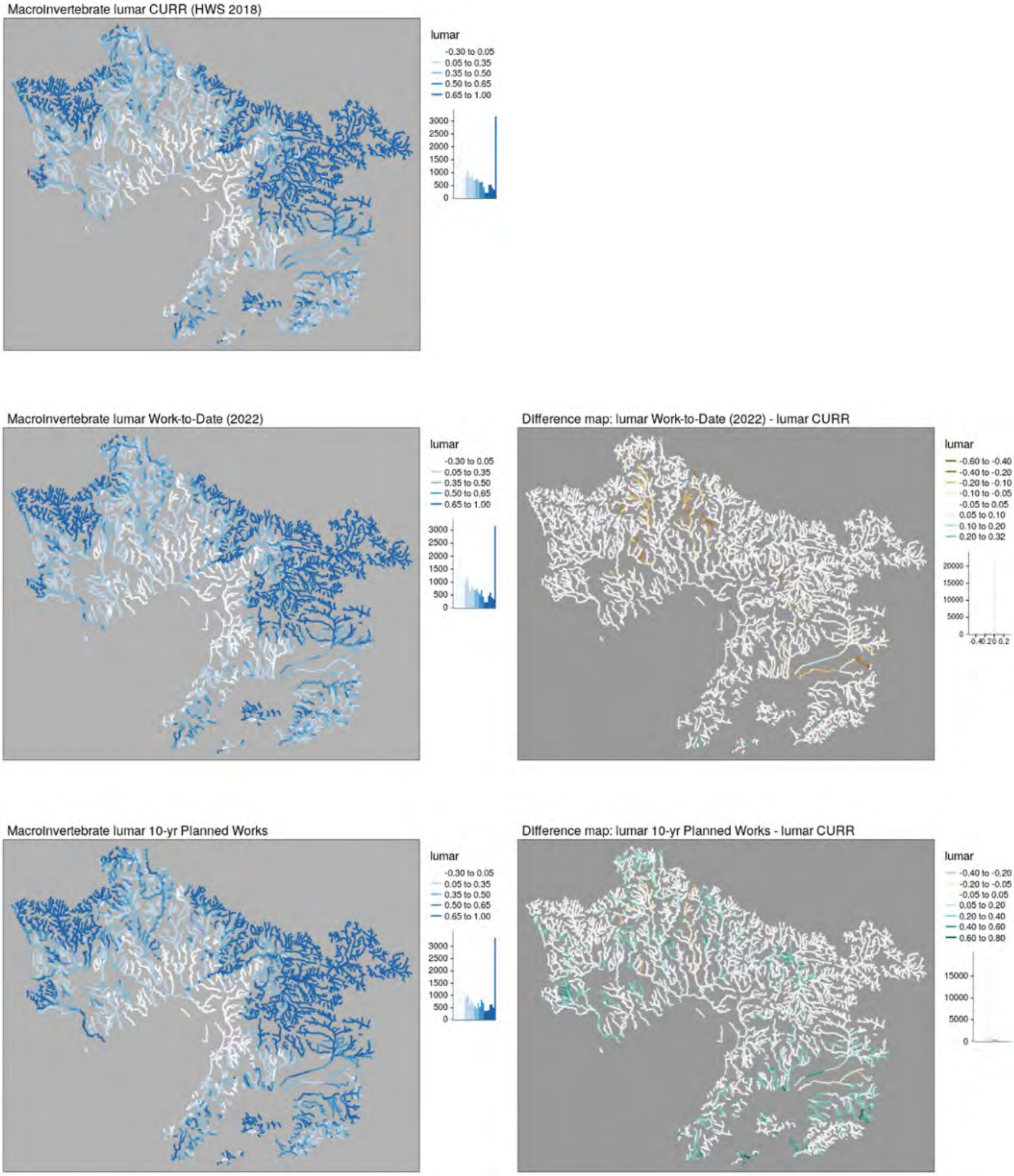


Figure 44. Mapped predictions of LUMaR values across the HWS region under the CURR scenario used in the HWS 2018 (top), the work-to-date scenario (middle-left) and the 10-year planned works scenario (bottom-left). Deeper blues indicate higher LUMaR values. 'Difference' maps show where predicted LUMaR under work-to-date (middle-right) and under 10-year planned works (bottom-right) differs from that of the CURR scenario used in HWS 2018. On this diverging colour scale darker browns indicate lower LUMaR values relative to CURR, white indicates little difference and deeper blue-greens indicate higher LUMaR values relative to CURR.

Platypus

Here, for simplicity, only the assessment for female platypus is presented. The potential impact of works-to-date for all platypus is available in the HSM Management Activities Technical Report (Chee, Walsh, et al. 2022). Despite the work-to-date, there is no overall discernible improvement in platypus habitat suitability relative to the CURR scenario (Figure 45). Further, there are no reach-specific changes of note (Figure 46). But if the 10-year planned works are achieved, this is predicted to substantially increase the length of streams in the 'Low' category, increase the length of≈streams in the 'Moderate' category and slightly increase the length of streams in the both the 'High' and 'Very High' categories (Figure 45). For 10-year planned works, the changes are predominantly small increases in reaches within the following sub-catchments: Deep Creek Upper, Jacksons Creek, Bunyip River Middle and Upper, Tarago River and Lang Lang River (Figure 46).

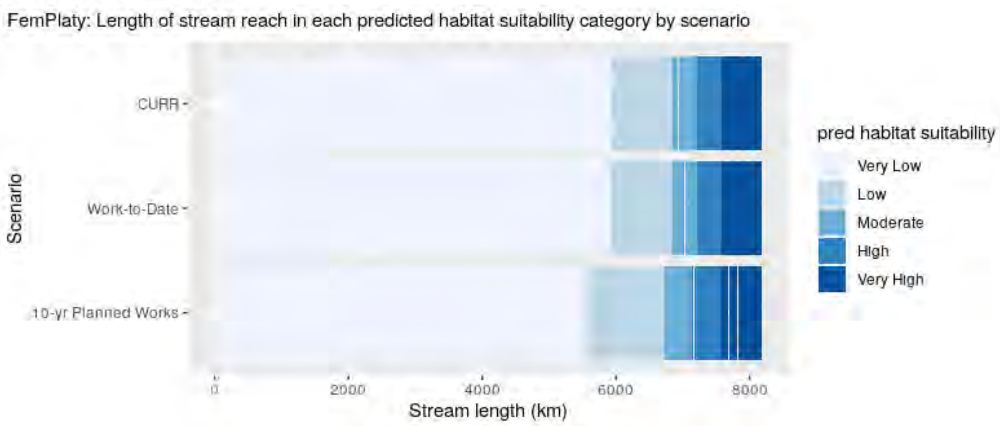


Figure 45. Stacked barplots of stream lengths in each habitat suitability category by scenario for female platypus. The intervals for the predicted habitat suitability categories are: Very Low 0 - 0.10, Low 0.10 - 0.20, Moderate 0.20 - 0.30, High 0.30 - 0.40, Very High 0.40 – 1.0.

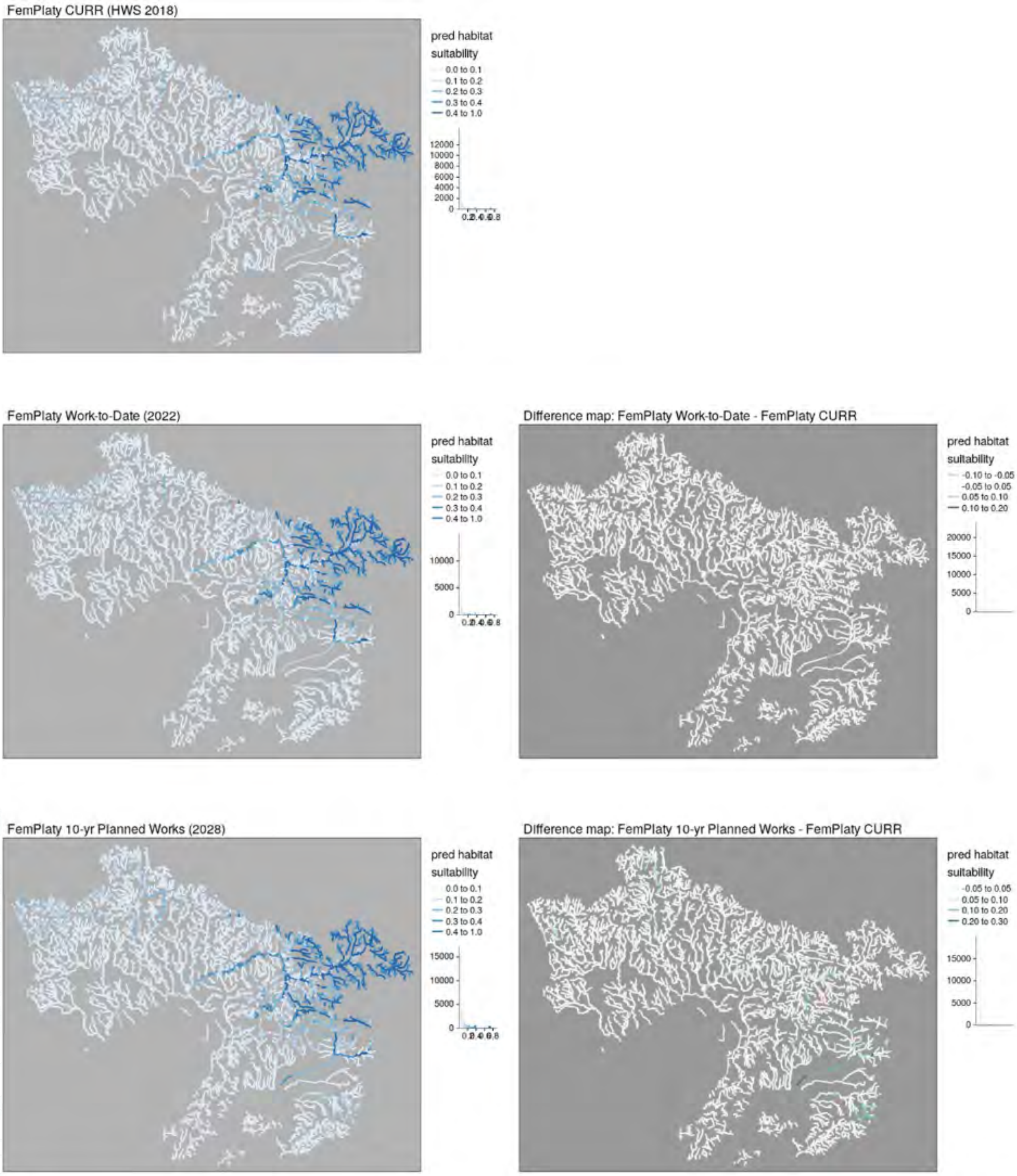


Figure 46. Mapped predictions of female platypus habitat suitability across the HWS region under the CURR scenario used in HWS 2018 (top), the work-to-date scenario (middle-left) and the 10-year planned works scenario (bottom-left). Deeper blues indicate higher predicted habitat suitability. 'Difference' maps show where predicted habitat suitability under work-to-date (middle-right) and under 10-year planned works (bottom-right) differs from that of the CURR scenario used in HWS 2018. On this diverging colour scale darker browns indicate lower predicted habitat suitability relative to CURR, white indicates little difference and deeper blue-greens indicate higher predicted habitat suitability relative to CURR.

Fish

The impact of management activities for fish were assessed in two different ways:

1. Changes in the stacked (summed) predicted habitat suitability probabilities across all 13 native species. The habitat suitability for the individual native fish taxa, with the probability ranging from 0 to 1, was summed to produce the stacked habitat suitability. For example, if a reach had the following habitat suitability for Short-finned Eel (habitat suitability probability = 0.6), Tupong (habitat suitability probability = 0.3), and Common Galaxias (habitat suitability probability = 0.3) then the stacked probability for this reach would equal 1.2. This was our native "species richness" index. Stacked habitat suitability was grouped into seven categories (see Figure 48).
2. Changes in predicted habitat suitability for individual species.

Both stacked and individual predicted habitat suitability probabilities were investigated because fish species do not respond analogously to all management interventions.

Native fish species richness

Relative to predictions at the start of the Strategy, the works-to-date scenario shows slight decreases in lengths of streams in the 2.0-3.0, 3.0-4.0 and 4.0-5.5 stacked probability categories, and a slight increase in lengths of stream in the 1.0-1.5 and 1.5-2.0 stacked probability categories (Figure 47).

Stacked probability values have improved in stream reaches in the management units of Little River Lower, Little River Upper, Jacksons Creek, Emu Creek, Deep Creek Lower, Deep Creek Upper and Darebin Creek (Figure 48). On the other hand, stacked probability values have declined in reaches in the management units of Woori Yallock Creek, Cardinia, Toomuc, Deep and Ararat Creeks, Tarago River and King Parrot and Musk Creeks (Figure 48).

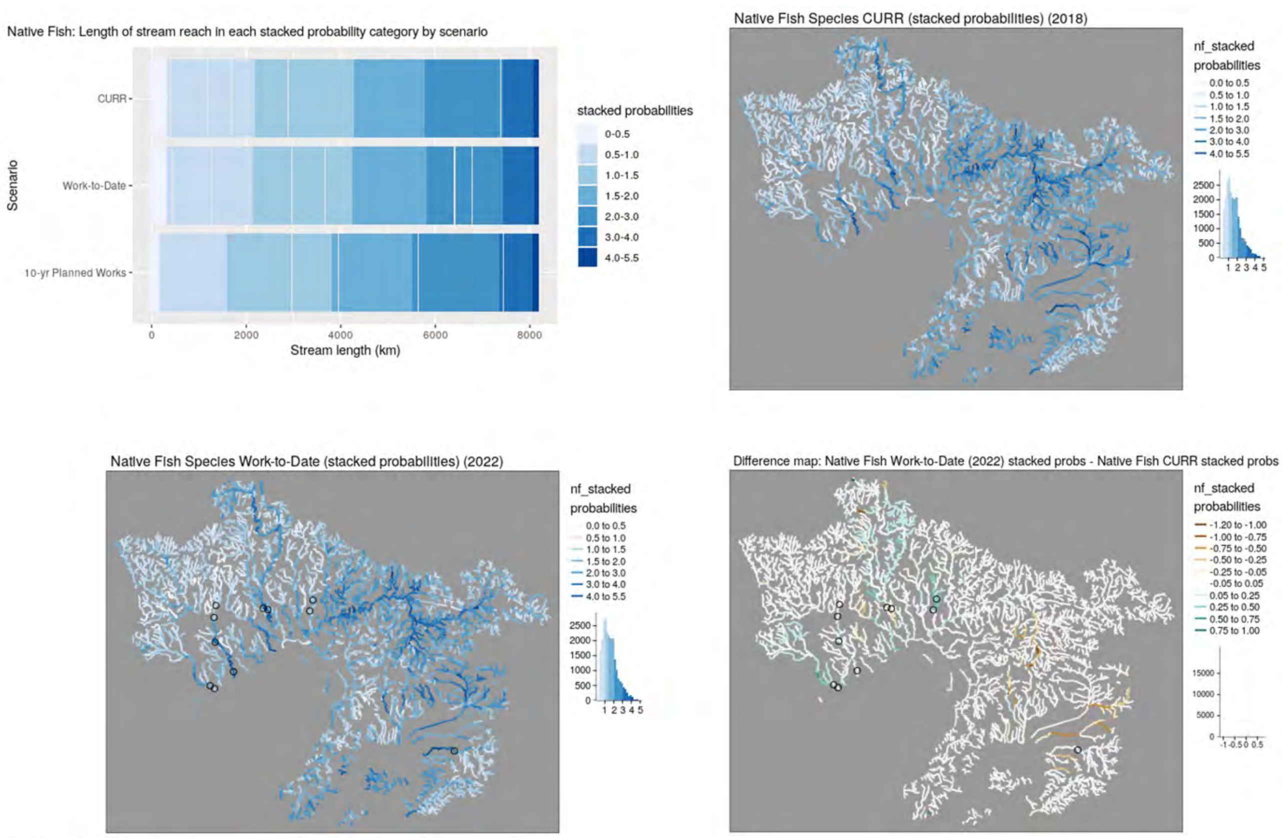


Figure 47. Top-left: Stacked barplot of stream lengths in each native fish species stacked probabilities category by scenario. The intervals for the stacked probabilities categories are: 0 - 0.50, 0.50 - 1.0, 1.0 - 1.5, 1.5 - 2.0, 2.0 - 3.0, 3.0-4.0 and 4.0 - 5.5. Top-right: Mapped predictions of native fish species stacked probabilities across the HWS region under the CURR scenario used in HWS 2018. Bottom-left: Mapped predictions of native fish species stacked probabilities across the HWS region under the works-to-date scenario. Deeper blues indicate higher predicted stacked probability values. Bottom-right: 'Difference' map shows where works-to-date stacked probabilities differs from that of the CURR scenario used in HWS 2018. On this diverging colour scale, darker browns indicate lower stacked probabilities relative to CURR, white indicates little difference and blue-greens indicate higher stacked probabilities relative to CURR.

Individual fish species

The various scenario outputs show that different fish taxa have variable responses to individual mitigating actions of revegetation, stormwater management and fishways, and to the three actions applied in combination – see Re-running HSM's with WTD + 10yr planned works (Chee, Walsh, et al. 2022). Revegetation seems to drive the strongest positive increase in habitat suitability for species like Short-finned Eel, Broad-finned Galaxias, Ornate Galaxias, Spotted Galaxias, Flatheaded Gudgeon, Tupong and Australian Smelt (Chee, Walsh, et al. 2022). Stormwater control largely had an equivocal effect, increasing the lengths of streams in some habitat suitability categories while decreasing the lengths of streams in other habitat suitability categories such that positive and negative changes mostly cancelled out (Chee, Walsh, et al. 2022). Barrier removal drove very strong positive increases in habitat suitability for Australian Grayling, substantial increases for Broad-finned Galaxias, Common Galaxias, Spotted Galaxias, and some increases for Short-finned Eel, Southern Pygmy Perch and Tupong.

Limitations

The appropriate data is lacking to comprehensively characterise on-ground changes in tree/forest cover that have come about since the start of the Strategy for the entire HWS region. For instance, there could be tree cover gains from revegetation activities undertaken by councils, not-for-profit organisations, community groups and private landholders that are not mapped and tracked. Likewise, there would be tree cover losses from human as well as natural disturbances such as vegetation clearing and fire, storm and wind-throw events. Further, our measure of vegetation cover improvement, attenuated forest cover, does not take into account vegetation quality.

Appropriate data to characterise changes in (total and effective) imperviousness that have come about since the beginning of the Strategy for the entire HWS region was lacking. Instead, the focus was on quantifying imperviousness changes in the HWS designated stormwater priority areas. Changes in directly connected imperviousness using Statement of compliance (SoC) data from 2019 to 2022 for the stormwater priority areas was estimated. Further, at the time of analysis, data on developments (greenfield and infill) that were built between 2016 and 2019 was lacking, so the estimate of the growth of stormwater impacts in this analysis is likely an underestimate of true urban growth in these areas.

WTD HSMs are also limited in the management actions that can be modelled. For example, the models include revegetation, stormwater management and fishways but they do not include erosion control, flow management or instream habitat enhancements.

PART D

Synthesis

Introduction

The intent of the values synthesis is to understand common spatial and temporal patterns across the region and between values. It integrates the threats analysis, particularly changes to climate predictions for in-stream values, to better understand likely future impacts. The synthesis is intended to make sense of the Science Inquiry results through synthesis and interpretation to identify focus area sub-catchments (spatial perspective) and management themes that are most relevant for the second half of the HWS. The sub-catchments and themes identified in this synthesis will be a focus of the Implementation Inquiry to better understand what is needed to ensure 10-year performance objectives are met by 2028.

It is important to note that the scope of the synthesis relates to environmental values, threats to environmental values (generalized with some areas of high uncertainty) and places (where quantitative POs are in place).

Approach

The synthesis drew on key environmental value evaluations presented in the various values papers, the threats paper, and habitat suitability modelling (HSMs) of existing baseline assessment. Additionally, the synthesis drew on new information on how HSMs of relevant values are predicted to change due to intervention works-to-date (WTD) and future climate change predictions: the approach followed, and outcomes of these updated HSMs, are available in the *Re-running HSM's with WTD + 10yr planned works* (Chee, Walsh, et al. 2022) and the *Re-running HSM's with climate-impacted projections* (Chee, Coleman, et al. 2022). The criteria used, in this synthesis, to apply the new WTD and climate change HSM information for relevant values are available in Table 3 within the Synthesis Methods document (Healthy Waterways Strategy Mid-term Evaluation Synthesis Methodology).

The availability of social value data was limited at the time of evaluation. However, we have evaluated social value information as best as possible in Part A and there are relevant recommendations for them.

Figure 48 provides an overview of the values synthesis process.

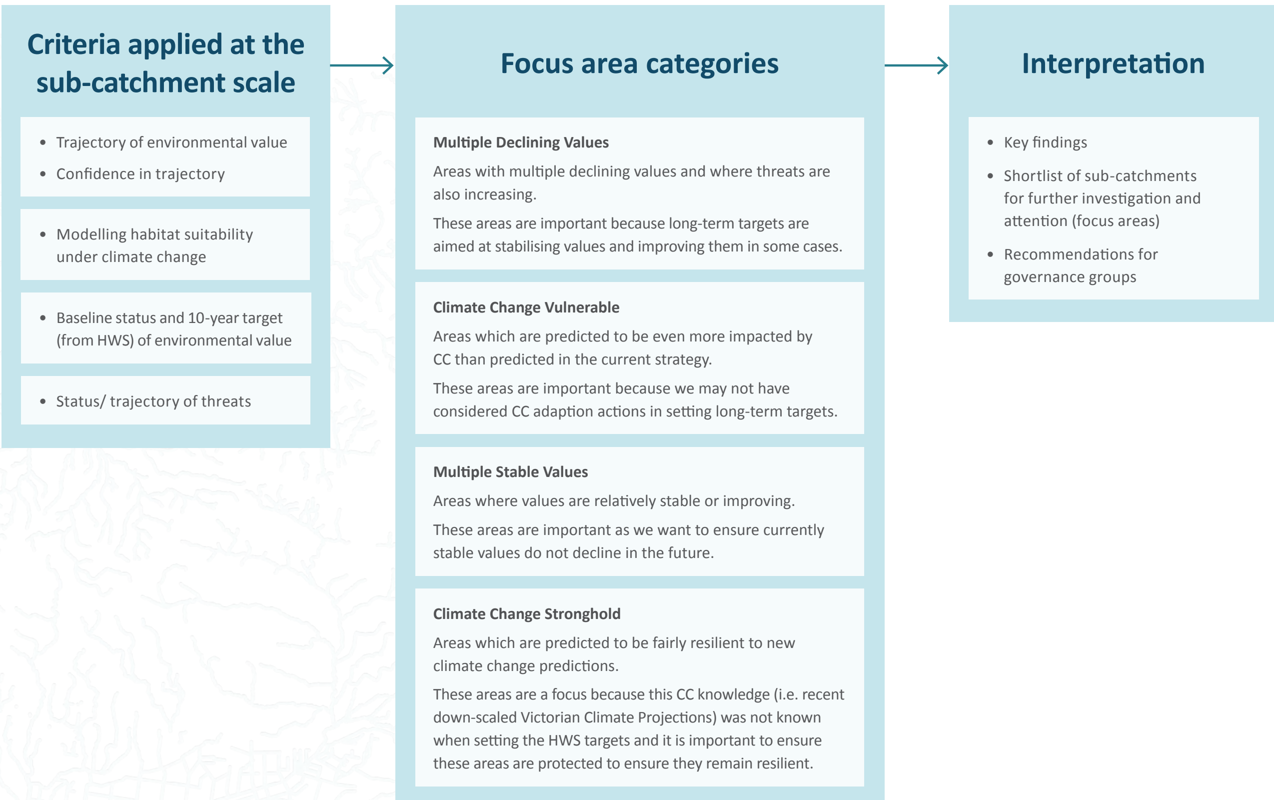


Figure 48. Overview of the values synthesis process.

Focus areas (i.e. sub-catchments) were selected based on a multi-step processes based on value trajectory, climate change predictions, the HWS sub-catchment baseline value status, and the status and trajectory of threats relevant for that sub-catchment and value.

First, sub-catchments were categorised according to their value trajectory. Value trajectories were categorised into stable/improving, potentially declining (for some values), and declining. The criteria used to assess trajectories are available in the Synthesis Methods document (Healthy Waterways Strategy Mid-term Evaluation Synthesis Methodology). Sub-catchments were flagged if they had multiple declining values (MDVs) or multiple stable values (MSVs). The criteria for assigning MDVs and MSVs categories are available Table 31 and described in greater detail within the Synthesis Methods document (Healthy Waterways Strategy Mid-term Evaluation Synthesis Methodology). Briefly, the trajectory of values were assessed at the sub-catchment level. It used multiple lines of evidence to make a judgement on relative stability of key values, where data exists, for the sub-catchment. Rivers and wetlands were included in the assessment process, however there was inadequate data for estuaries for all values. Importantly, sub-catchments were placed within the MDV category if there was a declining trend for macroinvertebrates in the main-stem of a river (e.g. Maribyrnong River) even if there was no evidence for other declining values – this is because macroinvertebrates are sensitive to changes in conditions, threats and management interventions, and thus declines in the main-stem likely reflects a broader deterioration in catchment conditions. Finally, if a sub- catchment flagged in the MSVs category had no evidence for increasing threats (see below for more detail), it was removed from the final focus area list.

Second, sub-catchments were classified according to their climate change vulnerability. The influence of climate change predictions for values spatial distribution (using habitat suitability models; HSMs) made in 2018 were compared with 'worst case' (HadGEM2_CC_RCP 8.5) updated climate change predictions using the VCP19 dataset. Due to time and data constraints, climate change vulnerability was only assessed for three key values using HSMs for platypus, fish (climate sensitive species: River Blackfish and Ornate Galaxias), and macroinvertebrates. Sub-catchments were included if one or more of these values were categorised as climate change vulnerable (CCV) or a climate change stronghold (CCS). The criteria for assigning these categories is available in Table 31 and described in greater detail within the Synthesis Methods document (Healthy Waterways Strategy Mid-term Evaluation Synthesis Methodology).

In some cases, a sub-catchment was identified as belonging to multiple categories. This is possible because (a) each assessment process used different criteria and (b) the climate change assessment occurred on species individually andat spatial scales smaller than sub-catchments. For instance, River Blackfish may be predicted to remain stable in the upper part of a sub-catchment but decline in lower parts of the same sub-catchment.

Third, a filtering process was applied so that only sub-catchments which had a moderate or higher sub-catchment baseline value score (i.e. HWS baseline) at the time of Strategy commencement in 2018 was considered as a focus area. Following this a sense check of the results identified the need to group the sub-catchments into those with moderate or greater underlying environmental conditions (Group A) and those with a high proportion of low or very low conditions (Group B). This provides information that may help prioritise effort based on findings of the Implementation Inquiry.

We emphasise that sub-catchments with baseline value or condition scores of low and very low are still important in the HWS and many sub-catchments have POs to improve conditions and values over time.

The threats analysis step used best available knowledge to explain drivers of decline and outline possible future threats. For each sub-catchment and value flagged in the MDVs category, the likely reasons of decline and evidence were documented. This was considered important in understanding focus areas for HWS implementation. Further, for each sub-catchment and value flagged in the MSVs category we assessed possible future threats as this is important for the second half of the HWS. If a sub-catchment flagged in the MSVs category had no evidence for increasing threats, it was removed from the final focus area list.

An overview of the criteria used for the values synthesis process is available in Table 31.

Table 31. Criteria used for assigning the following classifications to sub-catchments based on HWS value assessments: multiple declining values (MDVs), multiple stable values (MSVs), climate change vulnerable (CCV), and climate change stronghold (CCS).

MDVs – Multiple declining values	MSVs - Multiple stable values	CCV – Climate change vulnerable	CCS - Climate change stronghold
Areas with multiple declining values and where threats are also increasing. These areas are important because long-term targets are aimed at stabilising values and improving them in some cases. It's important to understand what is causing observed declines and whether we have POs in place to address issues. Importantly, sub-catchments were placed within the MDV category if there was a declining trend for macroinvertebrates in the main-stem of a river (e.g. Maribyrnong River) even if there was no evidence for other declining values – this is because macroinvertebrates are sensitive to changes in conditions, threats and management interventions, and thus declines in the main-stem likely reflects a broader deterioration in catchment conditions.	Areas where values are relatively stable or improving and threats may be increasing. These areas are important as we want to ensure currently stable/improving values do not decline in the future. These areas are important if progress is off-track or POs don't exist.	Areas which are predicted to be even more impacted by climate change than predicted in the current strategy. These areas are important because we may not have considered appropriate climate-change adaption actions in setting long-term targets. Off-track POs in these areas are important to focus attention on. Additional actions to protect these areas in the face of climate change may be needed.	Areas which are predicted to be fairly resilient to new climate change predictions. These areas are a focus because this climate change knowledge (i.e. recent down-scaled Victorian Climate Projections; VCP19) was not known when setting the HWS targets and it is important to ensure these areas are managed appropriately to ensure they remain resilient. It's important to know if we have POs in these areas which will protect them.

Outcome

Values trajectory analysis

The trajectories of values within each of the 69 HWS sub-catchments is available in Appendix 4. Synthesis assessment and interpretation at the sub-catchment scale was based on available value trajectory information. However, some sub-catchments had more available information for a wider array of values than others. Figure 50 illustrates the proportion of values (excluding values that have no targets) with available information on value trajectory. The most common values for which we had insufficient information to assess trajectory include riparian birds, wetland birds, frogs, and riparian vegetation. The largest environmental values data gaps were recorded in the Werribee catchment within the Cherry Creek (83% data gap) and Kororoit Creek Upper (67% data gap) sub-catchments (Figure 49). Mornington Peninsula North-Eastern Creeks sub-catchment also had a large (60%) data gap (Figure 49). Conversely, there were no environmental data gaps in the Woori Yallock Creek sub-catchment (Figure 49).

Figure 49. The proportion of environmental value data gaps for values which 10-year targets were set in the HWS.

Taking gaps in available datasets into consideration, most assessable sub-catchment and wetlands have been assessed as stable in the mid-term evaluation (Table 32).

Table 32. Proportion of sub-catchments or wetlands that have been assessed as stable for each value.

Value	Number of sub-catchments rated as stable/total number sub-catchments assessable (% of 69 sub-catchments)
Macroinvertebrates	50/69 (72%)
Platypus	61/69 (88%)
Fish	43/54 (62%)
Riparian Vegetation	Not assessable at sub-catchment scale
Riparian Birds	37/45 (54%)
Wetland Birds	18/25 priority wetlands (72%)

Focus area analysis

Forty-six focus areas were identified from the value synthesis (Figure 50). Seventeen focus areas were identified within the Yarra Catchment (Table 33), seven in the Werribee Catchment (Table 34), seven in the Maribyrnong Catchment (Table 35), five in the Dandenong Catchment (Table 36), and ten in the Westernport Catchment (Table 37). Further information on the focus area sub-catchments is available in the catchment descriptions below.

Multiple declining values were evident in sixteen of the 69 sub-catchments (23%) across the region (Figure 51), with declining trajectories for macroinvertebrates and fish values being the most common reason for the MDV rating. Decreased water availability and increased urbanization, including unmitigated stormwater runoff, were the dominant increasing threats in sub-catchments with multiple declining values.

Eighteen sub-catchments were categorised as currently having multiple stable values (Figure 51). Increasing threats in these sub-catchments, however, represent a risk to achieving long-term targets for values that were set at the beginning of the Strategy. Decreased water availability and unmitigated stormwater runoff were the dominant increasing threats in sub-catchments with multiple stable values. Recreational access was rated as increasing in many sub-catchments with multiple stable values; however, there is a low confidence in this threat rating and its links with values other than riparian vegetation. Deer was also rated as an increasing threat in many sub-catchments. However, the only value it is a direct threat for (vegetation) could not be accurately assessed.

Eighteen sub-catchments were categorised as being climate change vulnerable (Figure 53). Despite this, fourteen sub-catchments are thought to act as climate change strongholds for one or more of the assessed aquatic species (Figure 52).

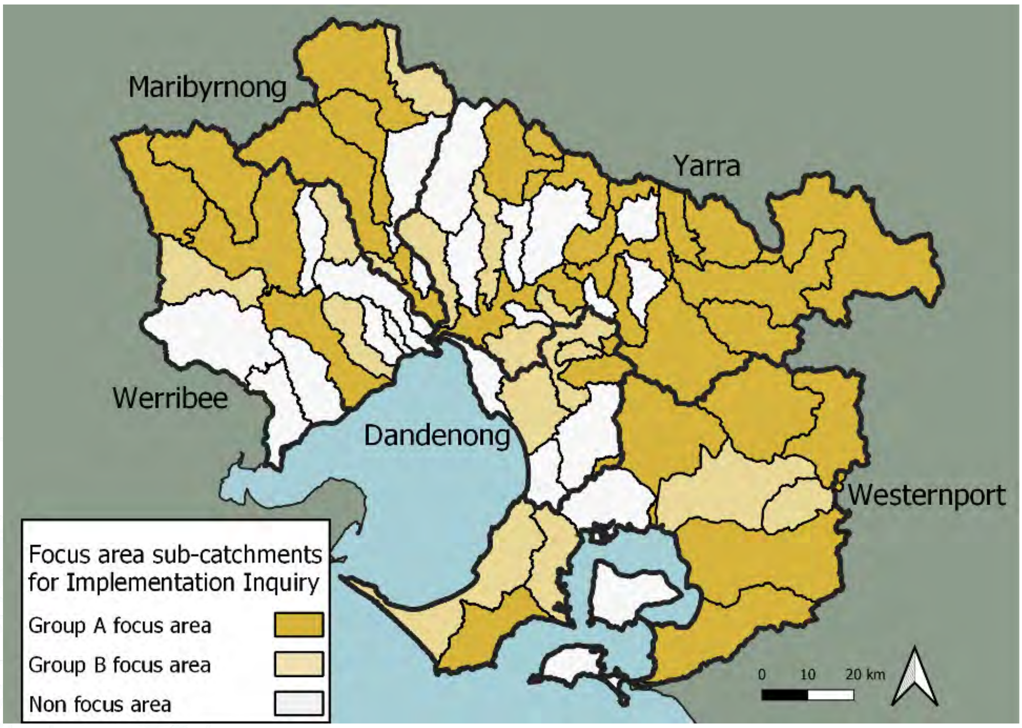


Figure 50. Sub-catchments identified as focus areas for the implementation inquiry as part of the HWS Science Inquiry. Sub-catchments are shown as those with moderate or greater underlying environmental conditions (Group A) and those with a high proportion of low or very low conditions (Group B). This provides information that may help prioritise effort based on findings of the implementation inquiry.

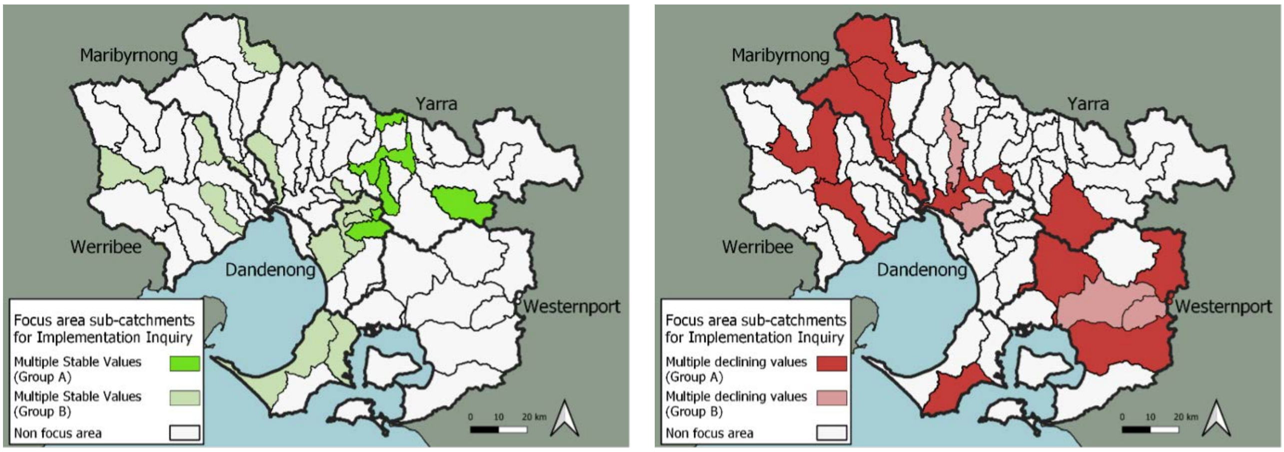


Figure 51. Sub-catchments identified as having multiple stable (left) and multiple declining (right) values.

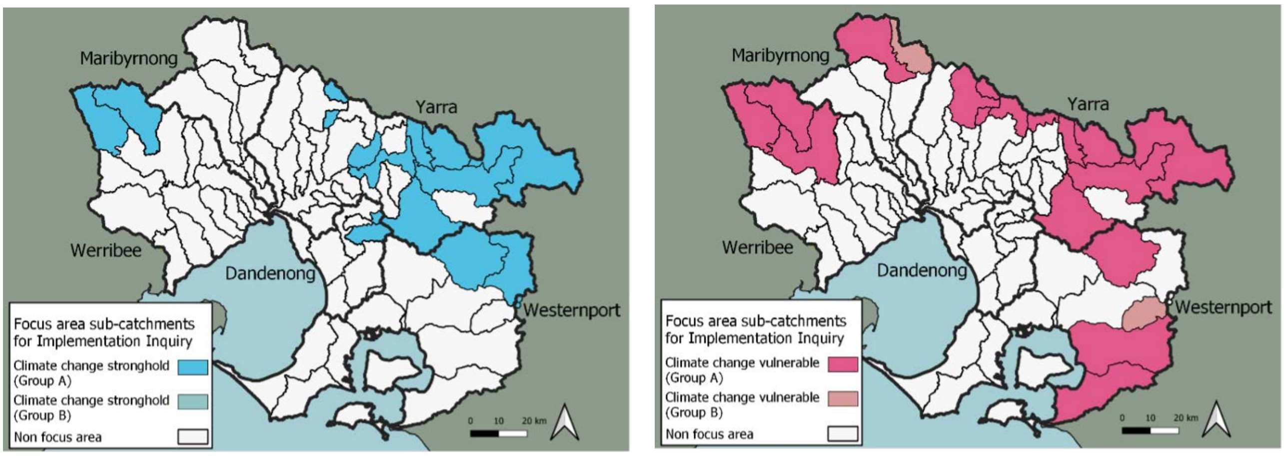


Figure 52. Sub-catchments identified as being (a) climate change strongholds (CCS; left) and (b) climate change vulnerable (CCV; right) for one or more of four aquatic species: macroinvertebrates, River Blackfish, Ornate Galaxias, and platypus. Classifications were based on differences between "baseline" habitat suitability models and models which include updated precipitation and temperature information from the 2019VCP climate change projections. Sub-catchments are shown as those with moderate or greater underlying environmental conditions (Group A) and those with a high proportion of low or very low conditions (Group B). This provides information that may help prioritise effort based on findings of the implementation inquiry. Note: there are no Climate change stronghold focus areas in Group B.

Yarra

Table 33. Focus Area sub-catchments identified within the Yarra Catchment.

Sub-catchment	MDVs	MSVs	CCV	CCS	Group
Diamond Creek (Source)			X		A
Little Yarra River and Hoddles Creek		X			A
Olinda Creek		X			A
Plenty River (Source)			X	X	A
Plenty River Upper			X		A
Steels and Pauls Creek (Source)		X	X		A
Watsons Creek				X	A

Sub-catchment	MDVs	MSVs	CCV	CCS	Group
Watts River (Rural)			X	X	A
Watts River (Source)			X	X	A
Woori Yallock Creek	X		X	X	A
Yarra River Lower	X*				A
Yarra River Middle		×		X	A
Yarra River Upper (Rural)			X	X	A
Yarra River Upper (Source)			X	X	A
Darebin Creek	X				B
Gardiners Creek	X				B
Mullum Mullum Creek		X			B

**Denotes sub-catchments that were included in MDV as it had a declining trend for macroinvertebrates in the main-stem of a river.*

Darebin Creek, Gardiners Creek, Woori Yallock Creek, and Yarra River Lower sub-catchments all had multiple declining values (Table 33). Macroinvertebrates and riverine fish are declining in the Darebin Creek and Woori Yallock Creek sub-catchments, with localised urban impacts thought to be the main cause of decline. Riparian birds and frogs are declining in the Gardiners Creek sub-catchment, however, the cause of decline could not be identified beyond existing urban impacts. Macroinvertebrates are declining in Yarra River Lower with catchment urbanization likely the cause; however, further investigation is required. Five sub-catchments were identified as having multiple stable values (Table 33) with platypus, riverine fish (insufficient data for Mullum Mullum Creek) and macroinvertebrates stable in all. Values in nine sub-catchments are thought to be climate change vulnerable (Table 33). Ornate Galaxias is climate change vulnerable in seven of these sub-catchments, with River Blackfish and platypus considered climate change vulnerable in three sub-catchments. Climate change strongholds were identified in eight sub-catchments (Table 33), with most of these sub-catchments situated in the upper parts of the Yarra catchment. In particular, Yarra River Upper (Source) was a stronghold for macroinvertebrates, River Blackfish, Ornate Galaxias and platypus.

Werribee

Table 34. Focus Area sub-catchments identified within the Werribee Catchment.

Sub-catchment	MDVs	MSVs	CCV	CCS	Group
Lerderderg River			X	X	A
Werribee River Lower	X*				A
Werribee River Middle	X*		X		A
Werribee River Upper			X	X	A
Kororoit Creek Upper		X			B
Parwan Creek		X			B
Skeleton Creek		X			B

**Denotes sub-catchments that were included in MDV as it had a declining trend for macroinvertebrates in the main-stem of a river.*

There has been a sustained long-term decline in macroinvertebrates in the Werribee River Middle and Werribee River Lower sub-catchment at monitoring sites along the main-stem of the Werribee River. Skeleton Creek is thought to have stable values for riparian birds, macroinvertebrates, frogs, riverine fish, and platypus. See Appendix 6. Three sub-catchments were considered to be climate change vulnerable for at least one value. Lerderderg River and Werribee River Upper are considered climate change strongholds for macroinvertebrates. See Table 34 in Appendix 7.

Maribyrnong

Table 35. Focus Area sub-catchments identified within the Maribyrnong Catchment.

Sub-catchment	MDVs	MSVs	CCV	CCS	Group
Deep Creek Upper	X		X		1
Emu Creek	X				1
Jacksons Creek	X				1
Maribyrnong River	X*				1
Moonee Ponds Creek		X			2
Taylors Creek		X			2
Boyd Creek		X	X		2

**Denotes sub-catchments that were included in MDV as it had a declining trend for macroinvertebrates in the main-stem of a river.*

Macroinvertebrates and riverine fish are declining in Deep Creek Upper and Jacksons Creek sub-catchments, with water availability and urban impacts implicated as the major causes of decline. The Maribyrnong River main- stem has experienced a sustained decline in macroinvertebrates over time, associated with urbanization in the greater catchment. Macroinvertebrates, as well as platypus, were categorised as declining in the Emu Creek sub-catchment. However, there is currently no eDNA monitoring data from lower parts of Emu Creek, where platypus are known to reside near the confluence with Deep Creek (Platypus: A Technical Report To Inform The Healthy Waterways Strategy Mid-term Evaluation), and this lack of data may underlie the apparent decline of platypus in the Emu Creek sub-catchment. Three sub-catchments have multiple stable values but these had low scores value and condition scores in 2018. See Table 35 in Appendix 6. The Deep Creep Upper and Boyd Creek sub- catchments were considered climate change vulnerable (Table 35) due to a predicted decline in macroinvertebrates and Ornate Galaxias (Appendix 7). No sub-catchments in the Maribyrnong Catchment were considered climate change strongholds for the values assessed (Table 35).

Dandenong

Table 36. Focus Area sub-catchments identified within the Dandenong Catchment.

Sub-catchment	MDVs	MSVs	CCV	CCS	Group
Corhanwarrabul, Monbulk and Ferny Creeks		X		X	A
Dandenong Creek Upper		X		X	A
Blind Creek		X			B
Dandenong Creek Lower		X			B
Dandenong Creek Middle		X			B

Although values such as riparian and wetland birds are declining in some sub-catchments (Appendix 4), no sub-catchments in Dandenong were identified as having multiple declining values (Table 36). Importantly, a number of data gaps hindered trajectory assessment of some values (Appendix 4) we were unable to assess riparian vegetation in all sub-catchments and we could only assess riverine fish in Corhanwarrabul, Monbulk and Ferny Creeks sub-catchment. Despite data limitations, five sub-catchments were categorised as having multiple stable values. Dandenong Creek Upper and Corhanwarrabul, Monbulk and Ferny Creeks sub-catchments were considered climate strongholds for macroinvertebrates (Table 36).

Westernport

Table 37. Focus Area sub-catchments identified within the Westernport Catchment.

Sub-catchment	MDVs	MSVs	CCV	CCS	Group
Bunyip River Middle and Upper			X	X	A
Cardinia, Toomuc, Deep and Ararat	X				A
Lang Lang River	X		X		A
Mornington Peninsula South-Eastern Creeks	X				A
Tarago River	X			X	A
Bass River			X		B
Bunyip Lower	X				B
King Parrot and Musk Creeks	X		X		B
Mornington Peninsula North-Eastern Creeks		X			B
Mornington Peninsula Western Creeks		X			B

In all six sub-catchments with multiple declining values (Table 37), both macroinvertebrates and fish have declining trajectories. Platypus are also thought to be declining in two of these five sub-catchments (Cardinia, Toomuc, Deep and Ararat Creeks and Lang Lang River sub-catchments). The cause of declines in these sub-catchments are largely uncertain, but urbanization, as well as water availability, were noted as the likely and most common causes of decline. Mornington Peninsula North-Eastern Creeks and Mornington Peninsula Western Creeks sub-catchments were categorised as having multiple stable values (Table 37). Lang Lang River, King Parrot and Musk Creeks and the Bass River sub-catchments were considered climate vulnerable for macroinvertebrates. The Bunyip River Middle and Upper sub-catchment was considered climate vulnerable for River Blackfish and Platypus but also a climate stronghold for macroinvertebrates. The Tarago River sub-catchment was also considered a climate stronghold for macroinvertebrates.

Overall summary

Forty-one focus area sub-catchments were identified across the region:

- Sixteen sub-catchments (twelve in Group A, four in Group B) were categorised as currently having multiple declining values (MDVs),
- Eighteen sub-catchments (six in Group A, twelve in Group B) were categorised as currently having multiple stable values (MSVs),
- Eighteen sub-catchments (sixteen in Group A, two in Group B) were categorised as being climate change vulnerable (CCV),
- Fourteen sub-catchments (all in Group A) were categorised as being climate change strongholds (CCS).

For MDV focus areas, the most likely reason for declines in values were also typically flagged as increasing threats (see Part B). Most of the MSV sub-catchments had increasing threats which could lead to future declines if these threats are not mitigated. The most common threat in MDV and MSV sub-catchments were related to adverse environmental conditions resulting from decreased water availability and increased urbanization including unmitigated stormwater runoff. Recreational access and deer were noted as increasing threats in many of the focus area sub-catchments; however, there is a low confidence in the links these threats have with key values.

Limitations

WTD HSMs incorporated predicted improvements of recent interventions. However, it must be noted that these interventions won't realistically be expected to lead to immediate in-stream benefits. For example, the largest benefits of riparian revegetation will only become apparent once saplings grow to sufficient size. Focus area sub- catchments do not consider social values largely because threats to social values are not yet well characterised.

PART E

Intervention techniques applied in our region

Introduction

Interventions are on-ground and administrative actions undertaken to protect or improve the condition of a waterway or address a threat to waterway values. A review of intervention techniques was undertaken as part of the Science Inquiry and is detailed in *Interventions: A Technical Report to Inform the Healthy Waterways Strategy Mid-term Evaluation* (Melbourne Water 2023). The purpose was to develop a shared understanding of the range of interventions applied through the HWS and investigate the effectiveness and appropriateness of the interventions in different settings.

Approach

The investigation into interventions was focussed on providing foundational information in response to key evaluation question 4a. *To what extent are interventions appropriate and effective for achieving outcomes?*

The following definitions are provided to clarify how certain terms were applied in the evaluation.

Intervention maturity - the length of time and extent to which an intervention has been applied in the HWS region to allow learnings for improvements to be made (e.g. interventions that have been extensively applied across the region for more than 10 years are considered as having high maturity).

Appropriateness - The degree to which the design and implementation of interventions meets the needs of HWS partners and the broader community they serve (e.g. how appropriate is it to use deer control methods in peri-urban areas?).

Effectiveness – Achievement of interventions in supporting condition and value objectives (e.g. how effective is the weed control method in reducing or removing weeds?).

The HWS did not outline how strategy performance objectives (10-year implementation targets) would be implemented through the collaborative delivery model. The review of intervention techniques addressed this by developing a list of interventions through consultation with Melbourne Water staff and relating these to HWS conceptual model 'management levers', to provide a consolidated understanding of the techniques in use for the HWS.

Information was then collated for each intervention in the form of a stocktake to provide foundational information for HWS delivery partners about:

- what is being applied and why?
- how common the use of the intervention is and what different techniques are being used?
- the learnings from any related research or monitoring programs in the region
- information on the effectiveness and appropriateness of the intervention for achieving HWS outcomes.

Over 120 technical reports and published papers were reviewed to inform the stocktake, drawing on 20 years of research and monitoring undertaken through the Melbourne Water Research Practice Partnerships and other relevant research programs undertaken in the region. This was supplemented with published papers from other parts of Australia or overseas for certain interventions where research and monitoring in the region was limited.

Standards have been developed to guide the synthesis of information and evaluation of intervention techniques and these are available in the Interventions technical report. The standards include the performance categories of low, medium, high, and unable to assess for the following criteria:

- Maturity of intervention (length of time the intervention has been used in HWS catchments)
- Level of effectiveness (effectiveness in meeting the objectives for HWS), and
- Level of appropriateness (appropriateness for application in waterways in the region).

In this report we present an overview of the HWS interventions and their groupings, key findings on the application and maturity of interventions and we identify interventions that require further consideration based on the lessons learned through Melbourne Water's research and investigations into the effectiveness of works. The Interventions technical report (*Interventions: A Technical Report to Inform the Healthy Waterway Strategy Mid-term Review*) provides more detail on the level of application of interventions and details of their effectiveness and appropriateness.

Outcomes

HWS interventions

The list of interventions currently in use for the HWS is set out in (Table 38). Interventions are categorised in 18 groups linked to the environmental and social values conceptual models developed for the HWS. In total 81 intervention techniques from 16 of the intervention groups were reviewed in terms of their level (maturity) of application, effectiveness and appropriateness in the context of the HWS. Administrative and 'other' interventions were excluded from the Science Inquiry review of interventions.

Table 38. List of interventions currently used in implementing the HWS.

Conceptual model management lever	Intervention group	Intervention technique
Vegetation management	Vegetation establishment and maintenance	Tube stock, Direct seeding, Reprofiling, Thinning, Burning, Fencing
	Weed control	Physical, Chemical, Alternative chemical, Thermal, Biological
Pest animal and abundant wildlife management	Pest animal control	Baiting, Lethal, Exclusion fencing, Biological, Ripping, Noise
Urban stormwater and pollution management	Stormwater infiltrate	Streetscape WSUD (raingardens, passively watered street trees, swales) Lot scale (raingardens, leaky rainwater tanks, green roofs) Regional (smart tanks / technology of flow release (Monbulk &, Sunbury), constructed wetlands
	Stormwater harvest	Similar as above but with different objectives
	Industrial pollution management	Lot and streetscape swales and raingardens, Property containment measures, Precinct toxicant traps, Stormwater treatment wetlands, Diversion to sewer
	Litter management	Floating litter traps, Street sweeping, Gross pollution traps, Litter vacuum General litter management
	Sediment control	Site controls, Sediment ponds/traps, Desilting
	Wastewater management	Wastewater treatment plants, Septics, Sewerage network management
Waterway management structures and operation	Instream barrier management	Barrier removal, Fishways, Barrier operation change
	Channel modification	Bank protection, Grade control, Large Woody Debris reintroduction / fish hotels, Daylighting / naturalisation, Artificial estuary opening
Water license and entitlement management	Instream flow management	Environmental Flow release, Metering
	Floodplain / wetland flow management	Pumping, Levee modification, Structure (weirs and pipes)
Agriculture and runoff management	Rural land management	Headwater stream protection, Riparian buffer /swales, Fencing (multi-purpose), Off-stream stock water, Track management, Erosion control, Farm dam management, Fertilizer management, Effluent management, Constructed WQ systems, Shade and shelter belts
	Forestry runoff management	Road silt management, Buffer strips, Drainage crossing points

Conceptual model management lever	Intervention group	Intervention technique
Community facilities	Access management	Paths, Canoe platforms, Improving existing access, New open space, Visitor facilities, Signage
Foundational	Administrative	Policy, Strategy, Guidelines, Compliance & enforcement, Licencing, Education
	Other	Translocation of species

Application and maturity of intervention techniques

Intervention techniques were reviewed to ascertain the level of application across the region and maturity of their use. Just under half (44%) of the 81 intervention techniques reviewed were assessed as high for application and maturity, meaning they have been used across the region for 10 years or longer and represent interventions that are 'tried and tested'. Many of the interventions in the Sediment control, Pest animal control, Wastewater management, Rural land management, Forestry management intervention groups fell into this category.

25% of the interventions were assessed as moderate application and maturity with their use gaining momentum over the past 10 years. Interventions in this category included those in the Stormwater infiltrate, Stormwater harvest and Industrial pollution management groups. The maturity of these interventions likely reflects an increase emphasis in the current and previous HWS on addressing stormwater flows and urban and industrial water quality.

Interventions were assessed as low maturity if they had limited application within the region, or if the intervention was still in the research and development phase (i.e. being trialled through a research or a pilot program). Twelve of the 16 intervention groups had at least one intervention technique assessed as 'low maturity', and overall 30% of intervention techniques were assessed as low maturity. Interventions still in the research and development phase included litter vacuums, precinct toxicant traps, smart tanks, levee modification, structural flow interventions, noise (pest animal control) and thermal weed treatment.

Effectiveness and appropriateness of intervention techniques

The investigation into interventions originally intended to assess and provide a high-level evaluation of the effectiveness and appropriateness of HWS interventions in response to key evaluation question 4a. However, a preliminary analysis and review of the literature revealed that interventions were more commonly reported as partially effective or having mixed results (i.e. effectiveness varied between studies or results being inconclusive or dependent on the site context or intervention design).

Instead, as part of the foundational work we summarised the available evidence from studies conducted in the Melbourne region and where there was sufficient evidence, we identified a preliminary list of interventions for further consideration.

Based on the results from our investigation, we identified three categories of intervention to flag through the Science Inquiry with the following characteristics (see Table 39):

1. *Interventions that could benefit from improvements to design/implementation and or maintenance*. HWS partners may want to consider how to adjust or refine techniques in response to the findings from research. Eleven interventions were included in this category.
2. *Interventions that have been tested through research and pilot programs and found to be effective, but to date have not been adopted widely*. HWS partners could consider if there are opportunities to apply these interventions more broadly. Fourteen interventions were included in this category.
3. *Interventions with evidence indicating they have limited or low effectiveness or may not be appropriate for application*. HWS partners may want to consider stopping or changing the way these interventions are applied. Only two interventions were included in this category, however the Interventions technical report highlights a further seven interventions that may require careful consideration, subject to further review of the evidence.

The detailed findings and learnings for each intervention within the three categories are set out in Appendix 9. The remaining interventions were assessed as suitable to keep applying as needed. The Interventions technical report provides further details and references for all findings.

In addition, the following high-level lessons learned emerged from the research and literature regarding the effectiveness of interventions.

- Interventions are likely to be more effective when used in combination with other interventions.
- Maintenance in the form of follow up activity is crucial to ensure the effectiveness of an intervention is maintained over time.
- Trials and pilot programs are an important aspect of developing new intervention techniques and can be used to understand the benefits, costs and risks in different settings prior to committing to broad scale application.

Table 39. Interventions for further consideration by Melbourne Water and partners.

Intervention group	Intervention	Maturity of intervention in region	1. Potential to improve intervention	2. Tested through research/pilot programs but not widely adopted	3. Reconsider due to limited effectiveness/ appropriateness
Vegetation establishment and maintenance	Tubestock planting	High	✓		
	Direct seeding	Low		✓	
	Reprofiling (saltmarsh)	Low		✓	
Weed control	Chemical weed control	High	✓		
	Alternative chemical control	Low		✓	
Pest animal control	Ripping near waterways	High			✓
	Lethal control (deer)	Moderate		✓	
	Exclusion fencing (deer/rabbits)	Low		✓	
Instream barrier management	Fishways	High	✓		
	Barrier operation change	Low		✓	
Channel modification	Daylighting / naturalisation	Moderate	✓		
	LWD introduction / fish hotels	Low		✓	
Floodplain wetland flow management	Structural flow intervention, Partial levee removal and Pumping	Low / Moderate		✓	

Intervention group	Intervention	Maturity of intervention in region	1. Potential to improve intervention	2. Tested through research/pilot programs but not widely adopted	3. Reconsider due to limited effectiveness/ appropriateness
Stormwater infiltrate and harvest	Smart tanks	Low		✓	
	Stormwater wetlands	Moderate	✓		
	Raingardens	Moderate	✓		
	Green roofs	Low		✓	
	Leaky tanks	Low		✓	
	Passively watered street trees	Moderate	✓		
Industrial pollution management	Property containment measures	Moderate	✓		
	Precinct toxicant traps	Low		✓	
	Swales and raingardens	Low		✓	
Litter management	Litter vacuum	Low		✓	
Sediment control	Online treatment wetland (tertiary system)	High			✓
Rural land management	Riparian buffers/ swales	High	✓		
	Gully erosion control	Moderate	✓		
Access management	Signage	High	✓		

Overall summary

The review of interventions has provided a consolidated set of information on the types of interventions applied through strategy implementation. A review of effectiveness and appropriateness of interventions and the lessons learned from monitoring and research has helped to identify a sub-set of interventions for further consideration by Melbourne Water and partners. This includes 11 interventions with the potential for improvements, 14 interventions that have been trialled or tested through research but have not yet been widely adopted and two interventions with evidence of limited effectiveness or appropriateness. Future research is needed to understand how the effectiveness of different intervention techniques could potentially be impacted by climate change. Local empirical studies on climate implications for interventions are needed to ensure current and future intervention investment is good value for money. We anticipate further consideration of interventions may take place as part of the response to the mid-term evaluation and through asset service planning processes.

Limitations

There have been several limitations to the review of interventions including:

- The stocktake represents a high-level assessment and evaluation of the effectiveness and appropriateness of different intervention techniques used in the HWS region. It does not represent an in-depth literature review
- The assessment was limited by the information and research provided or could be accessed at the time of the evaluation. In some cases, information was sourced from grey literature, which is not subjected to the same level as peer review as published literature, and
- Due to time constraints, there has been limited opportunity to seek further input from on-ground practioners. The intention is to continue updating the intervention report over time with input from other agencies.

PART F

Knowledge gaps

Introduction

Melbourne Water's research, monitoring and investigation programs build a knowledge base that informs and refines strategic decision-making and policy development and improves the efficiency of actions to protect and improve waterways and wetlands, monitor investment outcomes and respond to risks and opportunities. Development of this understanding is considered in the context of progressive urban growth, climate change and economic uncertainty and is consistent with the principles outlined in the Victorian Waterway Management Strategy (2013).

Monitoring, investigation and research priorities for the Healthy Waterways Strategy were documented during the development of the Monitoring, Evaluation, Reporting and Improvement (MERI) Framework and associated Monitoring and Evaluation Plans (MEPs) for the region, rivers, wetlands and estuaries. The MERI process provides a framework for continuous improvement and learning, and ensures correct data is gathered throughout the 10-year duration of the strategy so a robust evidence base can be drawn on to assess progress against the key value and condition targets, effectiveness and impact of strategy actions, and identify improvement opportunities.

During the development of the HWS 41 Key Research Areas were identified. See Appendix 10). Melbourne Water's Waterways and Wetlands research program outsources most of its projects through collaboration with researchers and other natural resource management agencies (Figure 53). Two major research partnerships account for the majority of research, namely the Melbourne Waterway Research-Practice Partnership (MWRPP) with The University of Melbourne and the Aquatic Pollution Prevention Partnership (A3P) with RMIT University. Since 2018, Melbourne Water has delivered over 50 research projects with our research partners. See Appendix 11.

> 50 projects since Healthy Waterways Strategy 2018

Figure 53. Overview of Melbourne Water's Waterways and Wetlands Research Program.

Knowledge sharing and research adoption activities are central to delivering the research program and are incorporated early in the research project development and implementation process.

Continuous improvement in delivering waterways research was supported by an independent review of the MWRPP and A3P, completed in December 2022. The review identified a broad range of substantial benefits to Melbourne Water and stakeholders and recommended that the Partnerships continue along with a number of improvement opportunities (e.g. strengthening our approach to capturing the benefits from our research).

This section outlines how knowledge gaps were identified, what they are and how they will be prioritised for investment over the next five years.

Approach

Knowledge gaps from the mid-term review were initially captured from Science Inquiry discussion papers for values, threats and interventions, as well as research project fact sheets and reports developed to inform the Science Inquiry. The limitations sections of the mid-term review in Parts A – E also identified some of these knowledge gaps. This process captured over 180 new knowledge gaps, that were subsequently categorised as relating to either 'monitoring', 'investigations' or 'research' needs (See Appendix 13 and Appendix 14). The distinction between these categories is not always clear, therefore, the capture and categorisation of knowledge gaps was also cross-checked with discussion paper authors and researchers.

For the monitoring and investigation categories, a number of themes emerged and specific knowledge gaps were mapped against these themes.

Knowledge gaps that required further research were mapped against the Research Themes and Key Research Areas (KRAs) documented in the HWS. A summary of the outcomes of current research projects is presented alongside new knowledge gaps identified through this evaluation (Table 41). Key Research Areas were updated and cover the breath of all new and old research knowledge gaps

Given the large number of knowledge gaps identified through the inquiry, a prioritisation process was developed, and this will be used prior to the mid-term review response report to decide which knowledge gaps to address first over the next five years. See Appendix 12.

Summary of knowledge gaps

Monitoring and Investigations

Monitoring and Investigations that are delivered as part of the Healthy Waterways Strategy MERI Framework, can be broadly categorised into those relating to 'Environmental and Social Values' and those relating to 'Waterway Conditions and Threats'.

Surveillance monitoring for values and conditions are some of the key underpinning datasets which supports Strategy evaluation and this data was used extensively in addressing the key evaluation questions of the mid-term review. Comparison of these programs against the Rivers MEPs during the mid-term review indicates either adequate data or at least some new data, for most key values and conditions. The notable exceptions are data for fish, physical form and litter, that are also lacking for wetlands and estuaries (Table 40). On the other hand, while there has been a notable increase in data collection for wetlands, only some or limited data is available since the release of the Healthy Waterways Strategy. Of particular note, is the lack of data for estuaries – especially birds, vegetation and connectivity (in addition to fish and litter mentioned above). It is also recognised that data for social values and conditions is still lacking and methods and indicators are still in development.

Table 40. Progress towards delivering Monitoring and Investigation programs outlined in the Healthy Waterways Strategy Monitoring, Evaluation, Reporting and Improvement (MERI) Framework Monitoring and associated Monitoring and Evaluation Plans (MEPs).

Key Values									
Assets	Platypus	Macro-invertebrates	Fish	Birds	Frogs	Vegetation	Amenity	Community Connection	Recreation
Rivers	[yellow]	[green]	[red]	[green]	[yellow]	[yellow]	[yellow]	[yellow]	[yellow]
Wetlands	n/a	n/a	[yellow]	[yellow]		n/a	[yellow]	[yellow]	[yellow]
Estuaries	n/a	n/a	[red]	[red] *	n/a	[red] *	[yellow]	[yellow]	[yellow]

Key Values										
Assets	Vegetation	Water regime	Stormwater condition	Water Quality	Physical form	Connectivity	Access	Recreational Water Quality	Litter	Participation
Rivers	[yellow]	[yellow]	[yellow]	[green]	[red]	[green]	[yellow]	[green]	[red]	[green]
Wetlands	[yellow]	[yellow]	[yellow]	[yellow]	[yellow]	[yellow]	[yellow]	n/a	[red]	[yellow]
Estuaries	[red] *	[yellow]	[yellow]	[yellow]	[yellow]	[red]	[yellow]	n/a	[red]	[green]

**Data collection has been commissioned or commenced.*

- [red] No new data since HWS released
- [yellow] Some new data or limited data
- [green] Adequate data available for mid-term evaluation

In addition to the need to ensure these long term survellience monitoring programs are implemented, particularly where new monitoring programs have not yet started, additional knowledge gaps were identified during the mid-term review. These were categorised into the following and divided into near- and long-term priorities to provide further information to inform the prioritisation process:

- **Key values data gaps** – specific values and locations where data is lacking and has limited the mid-term evaluation. Additional data collection is critical for future evaluations

- **Understanding threats and conditions**– relates to gaps in understanding the extent, impact and trajectory of threats and conditions in specific areas where confidence in our mid-term assessment low
- **Understanding drivers of key value trajectories** – where improved knowledge of the causal factors relating to key value trends across the region is required and in particular the contribution of management interventions versus environmental factors (e.g. climate), and
- **Monitoring methods and indicators** – relates to the need to improve monitoring methods and indicators for key values, conditions and threats to increase efficiencies, accuracy and adoption of latest knowledge and research.

While detail behind these knowldege gaps is outlined in the background technical papers, they have been collated across multiple papers, grouped where possible and summarised below.

A list to the original knowledge gaps and their resultant grouping can be found in the Science Inquiry Recommendations.

Key values data gaps

Ensure data gaps for key values that were raised during the mid-term evaluation process are addressed including:

Value/ Condition	Near-term (i.e. for remainder of current HWS and to inform the development of the next strategy)	Long-term (on-going)
Multiple values	Undertake additional data collection and investigations to confirm key value trends and address data gaps for platypus, macros, fish, birds and frogs.	
	Develop database and data management processes for vegetation, fish and platypus, in alignment with other databases such as the macroinvertebrate database. This should include eDNA.	
Fish		Consider initiating fish population health studies, including using genetic techniques, to help understand impacts of population fragmentation and support business cases for fishways
Birds	Review wetland bird monitoring to focus on a smaller sub-set of representative regional priority wetlands.	

Understanding threats and conditions

Continue to monitor key conditions and threats across the region and in particular improve knowledge where confidence in the threat trajectory in focus sub-catchments was low. Specifically:

Value/ Condition	Near-term (i.e. for remainder of current HWS and to inform the development of the next strategy)	Long-term (on-going)
Multiple values	Refine key value conceptual models based on new knowledge about relationships between waterway conditions, threats and management actions.	
	Investigate low confidence threats (e.g. recreational access, pest plants, agriculture, and vegetation clearing) in priority sub-catchments where threat is rated as increasing and develop improved indicators to assess the level of threat for the region.	
	Consider parallel approaches to assessing climate change impacts (in addition to Habitat Suitability Models) that can represent the impacts of extreme events such as fire, heatwaves, 'rain bombs', floods, and storm surges.	
Water Quality	Adopt a consistent litter monitoring method and implement this approach across the region. Develop metrics, condition ratings and targets for sub-catchments to inform the next strategy.	

Value/ Condition	Near-term (i.e. for remainder of current HWS and to inform the development of the next strategy)	Long-term (on-going)
Fish	Improve mapping of barriers to key value (e.g. platypus, fish) movement for the next strategy	
Platypus		Investigate links between macroinvertebrate condition (abundance, not just diversity) and platypus, and integrate into current monitoring and reporting where possible.
Vegetation	Use aerial imagery analysis and/or remote sensing data to assess wetland extent and streamside vegetation loss or gain across the region.	
Urbanisation	Improve tracking of impervious area changes outside of stormwater priority areas and predictions of future development (e.g. 10-year outlooks), including development densities, in order to update impervious area predictions.	
Wetlands	Consider the regular collection of vegetation cover data for constructed stormwater wetlands for use in maintenance planning tools.	
	Progress the development of the Natural wetland protection framework and tool (Jacobs 2022) by improving data such as spatial information, quantum and cost of management actions, expert opinion and economic analysis and seek to imbed the use of the tool in drainage scheme planning.	
	Adopt the use of standard IWC assessments in wetland investigations undertaken for development planning, to expand and improve the data on natural wetland condition	
	Continue toxicant monitoring at environmentally sensitive natural wetlands (e.g. Ramsar, Sites of Biodiversity Significance etc.) and potentially use this information to develop targets for the next strategy.	
Flow regime	Review distribution of flow gauges in upper catchment reaches (perennial and non-perennial streams) and consider the addition of more to better understand impacts of climate change on flow regimes. Consider options for water quality monitoring at a range of these sites, including integration and optimisation with long-term water quality monitoring network.	
Headwater streams	Investigate the status of headwater streams at risk of being impacted by urban development and provide guidance for their protection.	

Understanding drivers of key value trajectory

Improve knowledge of the casual factors associated with key value trends and the contribution of management interventions versus environmental factors (e.g. climate). Specifically consider:

<table>
<tr><th>Value/ Condition</th><th>Near-term (i.e. for remainder of current HWS and to inform the development of the next strategy)</th><th>Long-term (on-going)</th></tr>
<tr><td>Multiple values</td><td>Investigate location-specific issues for environmental values such as aquatic macroinvertebrates, birds, frogs and vegetation (e.g. reasons for observed declines, validation of early data, assessing contamination risk etc.) at identified locations using a multiple lines of evidence approach.</td><td></td></tr>
<tr><td>Birds</td><td colspan="2">Quantify the benefits of revegetation for riparian birds relative to broader environmental variation (e.g. continental rainfall fluctuations).</td></tr>
<tr><td>Fish</td><td></td><td>Investigate how conditions and threats explain the observed patterns from the fish occupancy models to support refinement of the fish conceptual models.</td></tr>
<tr><td>Platypus</td><td>Investigate the relationship between in-stream habitat and platypus population condition at specific sites.</td><td></td></tr>
<tr><td rowspan="3">Vegetation</td><td rowspan="2"></td><td>Investigate the cause and extent of low regeneration of vegetation at some sites.</td></tr>
<tr><td>Develop a climate adaptation approach for revegetation that considers the need for prioritisation of more vulnerable locations and species in the Melbourne region and the considers the use of climate adapted provenances.</td></tr>
<tr><td colspan="2">Understand the impacts of weeds and pest animals (such as deer, stock and rabbits) on restored and remnant habitats.</td></tr>
<tr><td>Wetlands</td><td>Finalise wetland Habitat Suitability Models for frogs, birds and fish, including acquisition and maintenance of all associated spatial datasets such as impervious cover, vegetation cover, wetland extent etc. Develop decision support tools like zonation to aid in exploring management scenarios for wetlands.</td><td></td></tr>
<tr><td>Flow regime</td><td>Investigate flow regimes in the region, with a focus on unregulated systems, to better understand drivers of flow stress, the impact on environmental values (e.g. platypus, river blackfish) and the range of management options available. Develop performance criteria for tracking progress in the Healthy Waterways Strategy.</td><td></td></tr>
</table>

Monitoring methods and indicators

Improve methods and indicators for monitoring key values, conditions and threats to increase efficiencies, accuracy and adoption of latest knowledge and research. Specifically:

Value/ Condition	Near-term (i.e. for remainder of current HWS and to inform the development of the next strategy)	Long-term (on-going)
Multiple values	Continuously improve metrics and monitoring methods across rivers, wetlands and estuary monitoring programs for environmental values (such a birds and vegetation), social values and related conditions. Ensure improvements are managed and adequately tested to be comparable so that the integrity and continuity of the dataset if retained.	
Social Values	Improve the social values monitoring program; include expanding the scale and demographic representation of survey data and investigating additional metrics to incorporate into the social values 'calculation' framework (e.g. spatial visitation data).	
Birds		Compare the effectiveness of community-based bird surveys relative to consultant-based counts.
Platypus		Evaluate and refine methods for assessing platypus population abundances over time, including potential effect of practitioner changes, sampling effort, and alternative metrics to CPUE.
Vegetation	Improve alignment of the Vegetation detailed monitoring method with the Restoration Outcomes Monitoring Protocol (ROMP) method and include assessment of in-stream vegetation.	
	Reassess the high-quality vegetation priority areas using the latest available data to inform development of the next strategy.	
Wetlands	Develop a targeted low-cost water level monitoring network to monitor stormwater wetlands and assess inundation level and by-pass frequency to improve measures of stormwater wetland performance. Consider real-time monitoring and control of hydraulic structures to manage wetland performance.	
Physical Form	Implement a physical habitat/form monitoring program and the development of condition indicators and metrics for the next HWS.	
Water Quality	Apply findings from the Yarra River Quantitative Microbial Risk Assessment to high-value aquatic recreation sites in the Yarra River and other key locations across the region. Work with research partners to trial the use of pathogen concentrations, rather than faecal indicators, for future monitoring of recreational water quality. Use these new datasets to evaluate options for developing site-specific objectives that better represent health risk as an alternative to the state-wide objectives in the Environment Reference Standard.	
	Consider integrating the use of passive samplers and sediment sampling at a range of ambient water quality monitoring sites to increase the types of chemicals that can be screened (e.g. pesticides, pharmaceuticals). Ensure adequate coverage and frequency to characterise threats and inform target setting in 2028, particularly in high-value areas with limited historical data. Explore new integrated metrics for setting and reporting water quality targets.	

Photo credit: Nick Clemann

Research

Table 41 summarises the research that has been carried out over the last five years and integrates the new Key Research Areas identified above. The table also summarises the future research needs based on the knowledge gaps identified throughout the mid-term review process.

This demonstrated that most Key Research Areas had at least some research projects of relevance during 2018-2023, with many Key Research Areas having multiple projects of relevance. See Appendix 11.

Key Research Areas that have not been addressed in the first half of the Strategy period were:

- **Hydrology and Environmental Flows**
  - Developing improved approaches to flow data collection and data management to support flow management decisions.
- **Liveability, community engagement, and social research**
  - Refining our conceptual models and developing tools to support investment in waterway works for recreation and amenity.
  - Understanding the compatibility between social and environmental values and whether management actions are required to balance potentially competing objectives.
  - Increasing community awareness and connection to waterways so we have informed, engaged partners.
- **Port Phillip and Western Port**
  - Undertake priority research projects identified in the Ramsar management plans for Port Phillip and Westernport region.

New knowledge gaps identified through the mid-term review process were then mapped against existing research themes and Key Research Areas. This step indicated where new Key Research Areas were required or where existing Key Research Areas could be modified to reflect mid-term review research needs.

Proposed updates to key research areas

Based on the Healthy Waterways Strategy knowledge gaps synthesis and Key Research Area mapping process described above, it is proposed that the following new Key Research Areas be added to those currently described in the Healthy Waterways Strategy. The updated Key Research Areas may incorporate both existing and future research projects, but better reflect the research needs for the Healthy Waterways Strategy.

Streamside Vegetation and Instream Habitat

- Develop remote sensing monitoring methods to better understand changes in vegetation condition and extent across the entire region.

Wetlands and Estuaries

- Understanding the potential impacts of climate change on wetland health and mitigation options.
- Develop remote sensing monitoring methods to better understand changes in wetland condition across the region.

Stormwater Management and Flooding

- Understanding and managing the threat of urbanisation to floodplain function, wetlands and headwater streams.

Water Quality

- Understanding and managing the impacts of treated and untreated wastewater on waterway health.

Other Biodiversity and Waterway Functions

- Understanding the impacts of barriers to dispersal across the landscape on key values.
- Developing methods, metrics and strategic management frameworks for waterway function as a key environmental value.

In addition to these new Key Research Areas, the following changes to the wording of existing Key Research Areas are proposed (i.e. words underlined are added):

- That the 'Water Quality' theme be re-named to 'Pollution' to better reflect the range of water quality risks that are of concern (e.g. Herbicide use along riparian zones)
- Improve our understanding of how to design systems to prevent flooding and protect waterway health whilst accommodating the impacts of climate change
- Understanding the environmental impacts of pollutants, including contaminants of concern and litter, to inform risk-based management of waterway values and conditions across the region
- Improved understanding of instream habitat conditions, threats (including climate change) and processes across the region to inform works planning, and
- Understand the impact and effective management of pest plants and animals on riparian vegetation and instream habitat.

Table 41. Summary of research outcomes and additional knowledge gaps identified in the mid-term evaluation for Riparian Vegetation and Instream Habitat, Stormwater management and flooding, Pollution, Hydrology and Environmental Flows, Liveability, community engagement, and social research, Wetlands and Estuaries, Other Aquatic Biodiversity, and Port Phillip and Western Port.

Research Theme (Recently updated wording underlined)	**Research Outcomes 2018-2023** (Some research outcomes span multiple research themes but are only listed once)	**Additional mid-term review research gaps** (Will be prioritised alongside original HWS research gaps)
Riparian Vegetation and Instream Habitat • Understand the potential impacts of climate change on riparian vegetation communities and opportunities to effectively build resilience or transition vegetation communities. • Understand the impact and effective management of pest plants and animals on riparian vegetation <u>and instream habitat</u>. • Develop decision support tools to support improved investment in riparian and instream habitat activities and locations. • Identify critical constraints to revegetation success and opportunities to improve vegetation outcomes. • Improved understanding of instream habitat conditions, threats (<u>including climate change</u>) and processes across the region to inform works planning. **Proposed New Key Research Area** • Develop remote sensing monitoring methods to better understand changes in vegetation condition and extent across the entire region.	**Improved Habitat Suitability Models for instream values** – Developed improved stream network and environmental prediction information. **Benefits of works-to-date and under climate change** – Used new climate change information and data on works-to-date in the HSMs to understand the potential implications for key environmental values across the region. **Climate resilient revegetation** – Modelled the risk of climate change to 31key revegetation species to inform MW revegetation guidelines under a changing climate. **Outcomes from riparian revegetation** – Developed and trialled a method for assessing the outcomes of riparian revegetation projects (ROMP). **Remote sensing of vegetation extent and condition** – Investigated remote sensing methods to understand changes in vegetation to complement field-based assessments. **Managing deer impacts on vegetation and water quality** – Developed models to predict the distribution, density and vegetation impacts from deer across the region. Also reviewed options for non-lethal management of deer. **Incorporating instream vegetation in our strategies** – Conducting research on the relationships between flow, channel form and instream vegetation. **Channel form and floodplain protection** – Conducting research on the relationships between flow, urbanisation, floodplain connection and channel form to inform opportunities to protect stream channels from urban growth. **Direct seeding as a complementary revegetation tool** – Evaluated direct seeding as a cost-effective revegetation technique and developed guidelines. **Propagation of key vegetation species** – Developed methods for the propagation of critical native plants (Gahnia, Pteridium, Lepidosperma). **Instream channel features needed to fully realise revegetation benefits** – Better understand retentive structures to realise the ecological benefits of organic matter inputs from riparian vegetation. **Value and protection of headwater streams** – Investigated the role of small headwater streams in urban, rural and forested catchments.	**Improved Habitat Suitability Models for instream values** – Continue to develop and refine instream Habitat Suitability Models (HSMs) for aquatic macroinvertebrates, fish and platypus to support the identification of the most cost-effective waterway management actions, strategic target setting, the MERI framework and stakeholder strategy co-design in future Healthy Waterways Strategies. **Climate resilient revegetation** – Forecast climate change impacts on a broader suite of vegetation species (including remnant native vegetation, common revegetation species and weeds), validate climate resilient revegetation approaches through establishment of climate plots across climatic gradients in Melbourne and develop a new management framework that builds resilience and adaptation of riparian revegetation to projected future climatic conditions. **Impacts of climate change on fishway design** – Understand how climate change could impact the function and design of fishways to ensure that they continue to provide passage for target fish species in future decades. **Outcomes from riparian revegetation** – Gain a deeper understanding of the outcomes of our riparian revegetation practices (ROMP) as well as the benefits for other environmental values (e.g. riparian birds). **Remote sensing of vegetation extent and condition** – Continue to test and establish cost effective remote sensing monitoring methods to better understand changes in vegetation condition and extent across the region, including impacts of vegetation clearing and outcomes from revegetation. **Value and protection of headwater streams** – Understanding implementation barriers for headwater stream and wetland protection, including quantification of their water quality, ecological, social and cultural benefits, historical rates of loss, and the development of guidelines for protection from urban development. **Integrated vegetation management to reduce chemical use** – Trial integrated vegetation management practices (e.g. alternative herbicides, heat, mowing) to reduce reliance on chemical use along waterways. **Incorporating instream vegetation in our strategies** – Continue research on the relationships between flow, channel form and instream vegetation to inform opportunities to manage and project instream vegetation habitat in the next Healthy Waterways Strategy.

Research Theme (Recently updated wording underlined)	**Research Outcomes 2018-2023** (Some research outcomes span multiple research themes but are only listed once)	**Additional mid-term review research gaps** (Will be prioritised alongside original HWS research gaps)
Stormwater management and flooding • Improve our understanding of how to design systems to prevent flooding and protect waterway health whilst accommodating the impacts of climate change. • Improving the stormwater treatment performance and determine the optimal maintenance of WSUD systems. • Understanding the costs and benefits of various stormwater management interventions for biodiversity, amenity and recreational outcomes. • Develop improved technologies and systems to support stormwater harvesting and re-use. • Identifying and addressing institutional and structural barriers to implementation of Integrated Water Management. • Develop decision support tools to inform the most effective stormwater treatment systems and locations to protect waterway biodiversity, amenity and recreation. **Proposed New Key Research Area:** • Understanding and managing the threat of urbanisation to floodplain function, wetlands and headwater streams	**'Smart' water storages** – Implementing a distributed network of 'smart' tanks and urban lakes aimed at reducing localised flooding and improving environmental flows. **Performance of stormwater wetlands** – Includes developing indicators of performance. Understanding the treatment, harvesting, maintenance and environmental flow benefits of 'smart' stormwater wetlands. **Ability of stormwater wetlands to remove microplastics** – Commenced research to understand how stormwater wetlands remove microplastics and to understand the risks from microplastics. **Passively irrigated street trees** – Understanding the stormwater treatment and urban greening benefits of passively irrigated street trees, including testing a range of designs in contrasting contexts. **Managing stormwater in existing and new urban areas** – Assessed the benefits to stream health of a large-scale retrofit of stormwater control measures in an existing urban area (the Little Stringybark Creek catchment) and established monitoring for the Sunbury IWM project. **Benchmarking and transitioning 'water sensitivity' of cities** – Developed a method to benchmark cities in regard to 'water sensitivity', set visions with stakeholders and implement transition strategies **Economic evaluation of Integrated Water Management projects** – Developed a comprehensive economic evaluation framework for Integrated Water Management projects and programs to support business cases. **Tools and products to support Integrated Water Management** – Guidance documents and other tools and products to support integrated urban and water planning in new ('greenfield development') and existing ('infill development') urban areas.	**Barriers to the management of urban stormwater** – Understanding the barriers to the implementation of HWS stormwater Performance Objectives. **Implications of climate change for stormwater management** – Better understand how flow changes associated with climate change will influence the threat of urban stormwater. **Real-time monitoring and control of WSUD assets** – Continue to investigate opportunities for real-time monitoring and control of WSUD systems, including rainwater tanks, urban ponds and stormwater wetlands. **Passively irrigated street trees** – Demonstrate the stormwater capture and infiltration potential of a fully functional 'leaky' streetscape with passively irrigated street trees. **Impacts of urbanisation on wetlands** – Better understand impacts of urbanisation on wetlands and to define appropriate buffer distances and the measures required to maintain and improve values. **Waterway setbacks for multiple benefits** – Explore opportunities to develop site specific waterway setbacks that protect floodplain functioning, including reduced localised flood risks, in urbanising areas. **Measuring the performance of stormwater wetlands** – Continue to improve our understanding of the treatment of toxicants by stormwater wetlands, including emerging contaminants of concern, as well as the effect of toxicants on wetland performance e.g. biofilms, sediment bacterial communities. **Managing industrial pollution with structural solutions** – Further develop and trial dry weather toxicant treatment assets in stormwater drains draining industrial pollution hotspots. **Upscaling and mainstream Integrated Water Management** – Identifying approaches and opportunities to upscale and mainstream Integrated Water Management practices across the region.

Research Theme (Recently updated wording underlined)	Research Outcomes 2018-2023 (Some research outcomes span multiple research themes but are only listed once)	Additional mid-term review research gaps (Will be prioritised alongside original HWS research gaps)
Pollution • Understanding the environmental impacts of pollutants, including contaminants of concern and litter, to inform risk- based management of waterways across the region. • Quantifying ecosystem services in waterways for improving water quality to better account for the benefits of healthy waterways. • Develop improved water quality indicators and monitoring methods to better understand the impacts of pollutants on waterway health. • Developing tools and approaches to assist in strategic planning of pollution management to protect biodiversity, amenity and recreation in waterways across the region. • Understanding and managing public health risks from recreation along waterways in the region. • Understanding the impact of climate change on water quality and management implications for the protection of aquatic biodiversity, amenity and recreation along waterways. **Proposed New Key Research Area:** • Understanding and managing the impacts of treated and untreated wastewater on waterway health.	**Climate change and water quality** – Used new climate change information and water quality modelling (Source Model) to understand the impacts of climate change on water quality across the region. **Synthesis of water quality issues and opportunities** – Summarised pollution data to understand contaminants, sources, hotspots and management. **Impacts of urban construction** – Quantified the amount and quality of sediment delivered to streams and wetlands during construction. **Emerging contaminants** – Conducted risk assessments to identify emerging contaminants of concern, developed methods to sample and measure them. **Impacts of treated and untreated wastewater** – Developed indicators of treated and untreated wastewater discharges to waterways. **Continuous improvement in chemical use** – Reviewed chemicals frequently used near waterways and conducted an ecological and human health risk assessment and considered alternative chemicals or practices. **Water quality benefits of gully revegetation and stock exclusion** – Tested the water quality benefits (sediments, nutrients, faecal microbes) of revegetation and stock exclusion along gullies on rural land. **Managing industrial pollution** – Surveyed urban streams and drains in industrial areas to characterise pollutants. Tested different filter media to remove industrial pollutants from dry weather flows in stormwater drains. **Catchment studies to identify management priorities** – Developed complementary water and sediment quality survey methods and ecotoxicology tests to determine levels of pollution stress. **Low -ost water quality sensors** – Developed and tested low-cost water quality sensors (e.g. water level, salinity, temperature, turbidity) and modelling to isolate major sources of pollution in stormwater drains. **Managing public health risks** – Conducted an assessment of the risks of different types of aquatic recreation along the Yarra River. **Managing the risk of bifenthrin use** – Understanding the levels and ecological effects of the synthetic pyrethroid Bifenthrin (e.g. used to control termites) on aquatic organisms in new urban estates to inform structural and non-structural mitigation measures.	**Climate change and water quality** – Improve understanding of the likely implications of climate change on the levels and ecological impacts of contaminants in waterways. **Quantitative passive sampling of contaminants** – Refine passive sampling methods for contaminants to move from presence/absence to quantitative. **Low -ost sensors for monitoring urban construction** – Development of low-cost monitoring systems to understand risk of sediments to waterways from urban construction. **Chemical indicators of treated and untreated wastewater** – Validate chemical indicators of sewage and quantify risks associated with wastewater, including recycled water and Emergency Relief Structure (ERS). **Risks to waterways from recycled water use** – Understand risk to waterways from increased use of recycled water for environmental flow purposes and use in residential and agricultural areas. **Quantifying the benefits of rural land management** – Improved metrics used to estimate the effectiveness of site scale interventions. **Contaminants in rural areas** – Better understand threats from pesticides and other sediment contaminants in high value areas. **Litter & environmental values** – Better understand the entrapment from litter for values beyond platypus (e.g. fish, birds) to inform priorities. **Non-structural tools for industrial areas** – Investigate the benefits of non-structural strategies (education and enforcement) to manage pollution from industrial areas. **Toxicant risk assessment framework** – Further develop and apply the A3P toxicant risk assessment framework. **Catchment studies** – Strengthen the multiple lines of evidence framework to understand major stressors where values are declining. **Chemical use** – Continue to review and refine chemicals used near waterways to reduce impacts to the environment and human health. **Litter management** – Develop a litter management prioritisation framework to guide litter management interventions

Research Theme (Recently updated wording underlined)	Research Outcomes 2018-2023 (Some research outcomes span multiple research themes but are only listed once)	Additional mid-term review research gaps (Will be prioritised alongside original HWS research gaps)
Hydrology and Environmental Flows • Developing improved approaches to flow data collection and data management to support flow management decisions. • Understanding and mitigating climate change effects on the hydrology of waterways, estuaries and wetlands. • Improving our understanding of the responses of key environmental values to flow regimes to refine our environmental flow objectives. • Developing tools and frameworks to assist improved decision-making in the management of flows to meet environmental flow objectives. • Investigate opportunities for managing stream flows in urban catchments to protect and improve aquatic biodiversity, amenity, recreation and reduce flooding. • Improved understanding of the hydrology of floodplains, wetlands and estuaries, including groundwater-surface water interactions to protect and improve aquatic biodiversity. • Improved understanding of the flow requirements of estuaries to develop and refine environmental flow objectives. • Explore opportunities to integrate methods for determining ecological flows objectives in urban and rural streams to improve approaches to objective setting across both stream types.	**Climate change and stream flows** – Used new climate change information for the region (e.g. VCP19 projections) and water quality modelling (i.e. Port Phillip and Westernport Source Model) to understand the potential impacts of climate change on flow across the region. **Benefits of billabong watering along the lower Yarra River** – Worked with the Wurundjeri Woiwurrung Narrap team to assess the vegetation and broader ecological benefits of watering billabongs along the lower Birrarung (Yarra River) to inform environmental watering regimes. **Benefits of watering regimes in the Yellingbo Conservation Nature Reserve** – Assessed the vegetation and broader ecological benefits of watering regimes in the Yellingbo Conservation Nature Reserve that supports threatened species including the helmeted honeyeater and Leadbeater's possum. **Upstream migration of threatened Australian grayling** – Assessed the relationship between the upstream migration of the threatened Australian Grayling and environmental conditions, including flows in the Bunyip River catchment. **Fate of infiltrated stormwater from biofiltration systems** – Measured the volume and underground flow path of water infiltrated by the Wicks Reserve (The Basin) biofiltration system to understand the potential for this asset type to restore dry weather flows to adjacent waterways.	**Climate change and stream flows** – Improve understanding of the likely ecological implications of climate change (warming, drying, more intense rainfall events) on the hydrology of waterways across the region. **Incorporation of flow stress predictors in our Habitat Suitability Models** – Incorporate further hydrological predictors to refine instream Habitat Suitability Models (e.g. farm dam flow stress metric). **Multi-species interactions associated with environmental flows** – Better understand the benefits of environmental flows when multi-species interactions (meta-community perspective) are accounted for in environmental flow plans. **Traditional Owner-led billabong management** – Further investigate historical wetting and drying cycles, vegetation communities and fire regimes to enhance future Wurundjeri-led management of Birrarung's billabongs.

Research Theme (Recently updated wording underlined)	Research Outcomes 2018-2023 (Some research outcomes span multiple research themes but are only listed once)	Additional mid-term review research gaps (Will be prioritised alongside original HWS research gaps)
Liveability, community engagement, and social research • Refining our conceptual models and developing tools to support investment in waterway works for recreation and amenity. • Defining public health and wellbeing benefits of waterway, stormwater and urban cooling programs to support investment decisions. • Understanding the compatibility between social and environmental values and whether management actions are required to balance potentially competing objectives. • Understanding demographics, preferences, values and water awareness of our customers to inform waterway works planning and delivery. • Understanding, involving and supporting volunteers in waterway management to facilitate shared waterway objectives. • Increasing community awareness and connection to waterways so we have informed, engaged partners. • Understanding aboriginal cultural values of waterways and establish a framework to better integrate these values in waterway management decision-making.	**Litter monitoring methods** – Developed and tested new litter monitoring methods to identify litter hotspots, understand major types and sources of litter, prioritise areas for management, and in future Healthy Waterway Strategies to set strategic targets and track progress towards those targets. **Community engagement with waterways before, during and after Covid-19 restrictions** – Used a combination of community surveys and mobile phone human movement data to understand the levels of community engagement with and perceptions of, Melbourne's 'blue' and 'green' spaces (e.g. waterways, local parks) before, during and after the Covid-19 pandemic. **Managing WSUD on private land** – Assessing the performance, levels of maintenance and household perspectives of water sensitive urban design (WSUD) assets (e.g. rainwater tanks and raingardens) on private land, using contrasting management scenarios e.g. Aquarevo, Little Stringybark Creek catchment, Coburg Hill. **Impact of digital technology for citizen science** – Surveyed citizen scientists involved in the Frog Census and Birdlife Australia programs in the region to understand reasons for their involved in these programs, the pros and cons of using digital technology to participate in these programs (e.g. Frog Census App) and opportunities to increase participation, retention rates and participant satisfaction. **Knowledge sharing with Traditional Owners** – Drafted knowledge sharing protocols between Melbourne Water and three Traditional Owner (TO) groups in the region, to support TO-led research and waterway management capacity building. **Indigenous-led approaches to urban water design** – Commenced research led by the Boon Wurrung Foundation and Monash University to learn about ways to repair urban landscapes for their cultural values.	**Human wellbeing and wetland health as a potential new social value in the next Healthy Waterways Strategy** – Better understand the relationship between human wellbeing and wetland health to inform the potential adoption of wellbeing as a social value in future Healthy Waterways Strategies. **Strengthening our understanding of the links between social conditions and values** – Undertake further investigations to better understand these causal links between conditions (e.g. litter and access) and how that impacts social values (perceptions and realities) to improve Healthy Waterways Strategy conceptual models that underpin prioritisation of actions to increase social values across the region. **Threat of recreational access to key environmental values** – Better understand the threat of recreational access to waterways on key environmental values, including riparian birds to better balance social and environmental values protection across the region.

Research Theme (Recently updated wording underlined)	Research Outcomes 2018-2023 (Some research outcomes span multiple research themes but are only listed once)	Additional mid-term review research gaps (Will be prioritised alongside original HWS research gaps)
Wetlands and Estuaries • Developing strategic decision-making tools and frameworks for the prioritisation of management interventions for wetlands and estuaries. • Improving our understanding of management techniques that are most effective for protecting and improving the ecological health of wetlands and estuaries. • Developing improved monitoring, assessment and reporting methods to understand environmental conditions and values of wetlands and estuaries. **Proposed New Key Research Areas:** • Understanding the potential impacts of climate change on wetland health and mitigation options. • Develop remote sensing monitoring methods to better understand changes in wetland condition across the region.	**Habitat Suitability Models for wetland values** – Developed improved waterbodies spatial information layer and associated environmental prediction information to support the development of wetland Habitat Suitability Models for frogs, fish and birds that will enable predictions of current condition, condition under future urban growth and climate change and setting environmental value targets for wetland assets in future Healthy Waterways Strategies (equivalent to how the instream HSMs were applied in the current HWS). **Developing environmental DNA (eDNA) methods for aquatic biodiversity monitoring** – Further developed and applied eDNA monitoring methods to support the HWS MERI framework, including protocols for detecting frogs, birds and aquatic plants in wetlands and for detecting threatened or invasive species (e.g. threatened invertebrates, freshwater mussels, Australian Mudfish, Smooth Newt).	**Habitat Suitability Models for wetland values** – Continue to develop and refine wetland Habitat Suitability Models for frogs, fish and birds that will enable predictions of current condition, condition under future urban growth and climate change, and develop decision support tools like zonation to aid in prioritisation of management scenarios for wetlands and setting environmental value targets for wetland assets in future Healthy Waterways Strategies. Further develop the environmental data library to include wetland Habitat Suitability Model predictors we expect to be influential, such as measures of impervious cover within the catchment areas of waterbodies. **Remote sensing of wetland loss and condition** – Continue to investigate cost effective remote sensing data collection techniques for wetland extent and condition assessments (e.g. inundation, vegetation cover) to support Habitat Suitability Model development and final strategy evaluation of wetland condition and loss. Further develop the wetland remote sensing change detection methodology to determine its accuracy and applicability to flag wetlands where substantial changes in open water may have occurred and could be subject to follow up investigations. **Predicting climate change impacts on wetlands** – Consider other approaches to assessing potential climate change impacts on wetlands (e.g. extreme events such as fire, heatwaves, 'rain bombs', floods, and storm surges) that complement the wetland Habitat Suitability Models. **Review our suite of regionally significant wetlands** – Once the wetland Habitat Suitability Models are finalised, conduct further analysis of regionally significant wetland representativeness across the region with respect to key environmental values, as well as investigating the potential for waterbodies or regions to be refuge areas for particular species during dry conditions. **Managing the impacts of invasive fish species** – Identify opportunities for reducing the risk of invasive fish such as Carp and Mosquito Fish in areas of high environmental value.

Research Theme (Recently updated wording underlined)	**Research Outcomes 2018-2023** (Some research outcomes span multiple research themes but are only listed once)	**Additional mid-term review research gaps** (Will be prioritised alongside original HWS research gaps)
Other Aquatic Biodiversity • Improving our understanding of critical ecological processes and ecology of key species to improve our conceptual and quantitative models. • Understanding the unintended consequences of our management activities on aquatic biodiversity to inform works planning and programming to reduce impacts on environmental values. • Understanding areas of high biodiversity significance (e.g. Melbourne Water's Sites of Biodiversity Significance, Ramsar) and appropriate management responses to manage key threats to environmental values. **Proposed New Key Research Areas:** • Understanding the impacts of barriers to dispersal across the landscape on key values. • Developing methods, metrics and strategic management frameworks for waterway function as a key environmental value.	**Risk of pollution to sites of environmental sensitivity** – Conducted risk assessments and screened for pollutants at 40+ environmentally sensitive waterways sites in the region, to understand the threat of aquatic pollution and identify priorities for management. **Status of threatened aquatic macroinvertebrates** – Used a combination of traditional and eDNA survey methods to assess the current status of threatened aquatic macroinvertebrates in the region, including the Donna Buang and Kallista stoneflies and the Dandenong and Sherbrooke amphipods. **Status and management opportunities for less understood aquatic life** – Reviewed ecological, distribution, threats and management opportunities information for aquatic fauna where information was lacking, including River Blackfish, freshwater mussels and freshwater crayfish.	**Waterway function as a new key environmental value in the next Healthy Waterways Strategy** – Investigate and develop monitoring methods and metrics to enable the inclusion of waterway function as a key environmental value in future waterway strategies, as well as helping to prioritise waterway management interventions and setting of strategic targets that can be part of the HWS MERI Framework. **Status of threatened aquatic macroinvertebrates** – Increase our understanding of the distribution of threatened aquatic macroinvertebrates, including clarifying taxonomic uncertainty of the amphipods. **Water quality, hydrology and riparian birds** – Strengthen our understanding of the relationship between water quality, hydrology and riparian birds to help update our conceptual models and prioritisation of management interventions. **Increasing our knowledge to protect threatened platypus** – Investigate the relationship between platypus populations, water quality and macroinvertebrate communities (abundance and diversity), as well as increasing our understanding of the carrying capacity and minimum habitat patch size required to support a self-sustaining platypus population. **Potential risks from anti-microbial resistance to waterway health** – Understanding the risk of Antimicrobial Resistance (AMR) to waterway health from agricultural sources to inform the need for management interventions. **Barriers to the dispersal of key environmental values** – Understanding the impacts of barriers to dispersal across the landscape on key values (including under a changing climate and following disturbances) to evaluate the need for interventions that increase population connectivity (e.g. barrier removal, road underpasses, translocations).

Research Theme (Recently updated wording underlined)	Research Outcomes 2018-2023 (Some research outcomes span multiple research themes but are only listed once)	Additional mid-term review research gaps (Will be prioritised alongside original HWS research gaps)
Port Phillip and Western Port • Undertake priority research projects identified in the Port Phillip Environmental Management Plan. • Undertake priority research projects identified in the Western Port Environment Science Review and synthesis report. • Undertake priority research projects identified in the Ramsar management plans for the Port Phillip and Westernport region.	**Amounts and sources of sediment to Western Port** – Measured and modelled the amounts and major sources of sediment to Western Port to understand the locations and types of management interventions (e.g. riparian revegetation, rural land management, coastal protection), that are most likely to protect and improve critical seagrass habitats in Western Port. **Restoration of seagrass meadows** – Developing and trialling methods for seagrass propagation and planting, along with tools to predict locations where seagrass restoration is likely to be most effective, to accelerate recovery of critical seagrass habitats in Western Port. **Restoration of mangroves** – Developing and trialling methods for mangrove propagation and planting across Western Port and Port Phillip to restore critical mangrove habitats to support ecosystem health and coastal protection. **Restoration of coastal vegetation under a changing climate** – Mapping past, present and predicted future distribution of coastal vegetation (mangroves, saltmarsh) across Western Port, to identify opportunities to protect coastal vegetation under sea level rise. **Risks from and major sources of toxicants to Western Port** – Screened waterways, including stormwater wetlands, across Western Port to understand the types and concentrations of toxicants and evaluate the risks to waterway and bay health – including the development of locally relevant tests to assess toxicity to early life stages of fish. **Amounts and major sources of microplastics to Western Port** – Commenced research to understand the levels and major sources of microplastics discharged from waterways into Western Port to evaluate the risks from microplastics to the health of the bay. **Using environmental DNA (eDNA) to survey benthic biodiversity in Western Port** – Sampled sediment across >100 sites across Western Port and used eDNA techniques to determine spatial patterns in benthic biodiversity (microbial and invertebrate).	**Amounts and sources of sediment to Western Port** – Increasing our understanding of the amounts and major sources of sediment to Western Port to support the prioritisation of interventions to reduce sediment loads to Western Port under urban growth and climate change and to meet the SEPP sediment target. **Restoration of seagrass meadows** – Refining propagation and planting methods to support scaling-up and mainstreaming of seagrass meadow restoration in Western Port and Port Phillip. **Risks from and major sources of toxicants to Western Port** – Complete the development of locally relevant tests to assess toxicity of priority pollutants (based on a risk assessment of chemicals detected across Westernport streams and wetlands) to early life stages of fish. **Amounts and major sources of microplastics to Western Port** – Complete research to understand the levels and major sources of microplastics discharged from waterways into Western Port to evaluate the risks from microplastics to the health of the bay.

PART G

Relationship to other strategies, legislation and plans

Threats and actions that that impact on or have benefits to waterways have a flow on impacts that cumulatively effect receiving waters such as embayments. This section provides information that aligns the HWS actions to their contribution to the Port Phillip Bay Environmental Management Plan (PPB EMP) priority actions and the sediment targets that have been set for Western Port in the Environmental Reference Standards Table 5.21 (Environment Protection Authority, Victoria 2021).

Alignment with the Port Phillip Bay EMP

The PPB EMP (2017-2027) has multiple 'priority actions' that align with the HWS performance objectives and targets. Greatest alignment between the HWS and the PPB EMP occurs in the actions detailed under Water Quality (in blue in Figure 54). Ensuring nutrient inputs do not increase is of particular importance for the protection of Port Phillip Bay; the two greatest contributions to nutrients in the bay being the Western Treatment plant and catchment inflows, particularly from the Yarra catchment. A key goal for the PPB EMP is to achieve no net increase in nutrient loads to Port Phillip Bay by 2027. This is a significant challenge given the urban growth that is predicted for the region.

VISION	A healthy Port Phillip Bay that is valued and cared for by all Victorians						
GOALS	Stewardship of the Bay is fostered across community, industry and government		Water quality is improved to ensure environmental health and community enjoyment of the Bay			The Bay's habitats and marine life are thriving	
PRIORITY AREAS	Connect and inspire	Empower action (work together)	Nutrients and pollutants	Litter	Pathogens (human health)	Habitat and marine life	Marine biosecurity
STRATEGIES	Improve appreciation and understanding of Bay values and connections to catchment	Improve collaboration and partnerships across community, industry and government	Ensure nutrient and sediment loads do not exceed current levels and pollutant loads are reduced where practicable	Reduce litter loads to the Bay	Minimise risks to human health from pathogens	Conserve and restore habitats and marine life	Manage risks from marine pests
PRIORITY ACTIONS	**1.1** Work with Aboriginal groups to improve understanding of Aboriginal cultural values and interests in the Bay and support connections to Country	**2.1** Build capacity and knowledge within community and industry networks	**3.1** Effectively maintain existing stormwater infrastructure and programs to mitigate loads to the Bay, or secure via equivalent means	**4.1** Establish a baseline estimate of the volume of litter entering the Bay and support clean up activities	**5.1** Improve understanding of links between pathogen concentrations and human health for swimming and consumption of shellfish	**6.1** Monitor indicator species and key habitats at priority locations	**7.1** Prevent introduction and dispersal of marine pests
	1.2 Develop and deliver programs to inspire greater appreciation of the Bay's values	**2.2** Empower the broader community to get more actively involved in caring for the Bay	**3.2** Prevent increases in nutrient loads from wastewater systems and where practicable reduce loads of other pollutants	**4.2** Support capability and capacity building programs that target litter prevention, including reduction of microplastics	**5.2** Adopt a risk-based approach to mitigate sources of pathogens found in the Bay	**6.2** Improve understanding of ecological processes, threats and pressures	**7.2** Monitor priority locations for early detection of marine pest introductions
	1.3 Build understanding of management responsibilities and programs for the Bay and its catchments	**2.3** Support stronger partnerships across community, industry and government to ensure aims and outcomes are aligned	**3.3** Ensure all urban and rural land use effectively controls impacts from stormwater and runoff, and that controls are in place to manage increases in loads	**4.3** Identify and prioritise litter sources and pathways, and take actions to prevent litter entering the Bay	**5.3** Improve monitoring and reporting to better detect and communicate human health risks from pathogens	**6.3** Improve overall extent and condition of the Bay's natural ecosystems	**7.3** Respond rapidly to new introductions of marine pests

Figure 54. PPB EMP goals and priority actions. Greatest alignment with the HWS is achieved in the Water Quality actions shown in blue.

Table 42 details the links between HWS Performance Objectives and the related actions in the PPB EMP and provides some information on how the HWS performance is tracking in 2022. Asterisks indicate where qualitative performance objectives exist and no judgement of progress is made.

Table 42. Relationship between HWS performance objective themes and the relevant actions from the Port Phillip Bay EMP demonstrating that the progress towards the HWS targets is directly contributing to multiple EMP actions. Where numeric targets in the HWS are set, progress to 2022 is indicated.

HWS Theme	Link to relevant PPB EMP Action	Werribee	Maribyrnong	Yarra	Dandenong
RPO-18: waterway health assets including stormwater treatment systems, are maintained	3.1	* (meeting KPI's)	*(meeting KPI's)	*(meeting KPI's)	*(meeting KPI's)
Maintain Sewage Treatment Plant Loads	3.2	On-track	Slightly off-track	On-track	N/A
Reduce ag run-off	3.3	On-track	On-track	On-track	On-track
Stormwater harvest	3.3	On-track	On-track	Slightly off-track	N/A
Stormwater infiltration	3.3	Significantly off-track	On-track	Significantly off-track	N/A
Treat existing development	3.3	N/A	*	*	*
Reduce industrial run off	3.3	N/A	*	*	N/A
Sediment from construction is controlled	3.3	N/A	*	*	N/A
RPO-17: Water quality in waterways and bays is improved by reducing inputs of sediment and other pollutants from urban construction and development.	3.3	*	*	*	*
RPO-24: Risk-based programs to mitigate urban pollution to protect bays and waterways.	3.3	*	*	*	*
RPO-26: assess volume and source of litter AND **RPO-27**: littering and illegal dumping is reduced	4.1 4.3	* *	* *	* *	* *
Reduce impacts from septic tanks	5.2	*	N/A	*	*
Maintain for recreational use	5.2	On-track	Significantly off-track	Slightly off-track	On-track

** Indicates where non-numeric targets exist and reports are provided annually. N/A is where it was deemed not applicable to have a performance objective. Meeting KPI's for stormwater treatment wetlands means that vegetation cover assessments of wetland assets (as a proxy for water quality treatment) are meeting the expected outcomes set in the MW investment plan.*

Alignment with the Western Port sediment load targets

A key threat to the protection of multiple values in Western Port is sedimentation of seagrass beds. Sediment inflows from the catchment settles on seagrass beds that are known to be valuable both intrinsically and as nurseries for fish, and ecosystem services such as improved water quality, coastal protection, and carbon sequestration.

Table 43 details the links between HWS performance objectives and the sediment load target for Western Port and provides some information on how the HWS performance is tracking in 2022. Asterisks indicate where qualitative performance objectives exist and no judgement of progress is made.

Table 43. Relationship between HWS performance objective themes and the Western Port sediment load targets (Environment Protection Authority, Victoria 2021) demonstrating that the progress towards the HWS targets is directly contributing loads objectives. Where numeric targets in the HWS are set, progress to 2022 is indicated.

HWS Theme that links to Western Port sediment load target	Westernport PO's
RPO-18: waterway health assets including stormwater treatment systems, are maintained	* (meeting KPI's)
Reduce ag run-off	On-track
Stormwater harvest	On-track
Stormwater infiltration	Significantly off-track
Sediment from construction is controlled	*
RPO-17: Water quality in waterways and bays is improved by reducing inputs of sediment and other pollutants from urban construction and development.	*
RPO-24: Risk-based programs to mitigate urban pollution to protect bays and waterways.	*

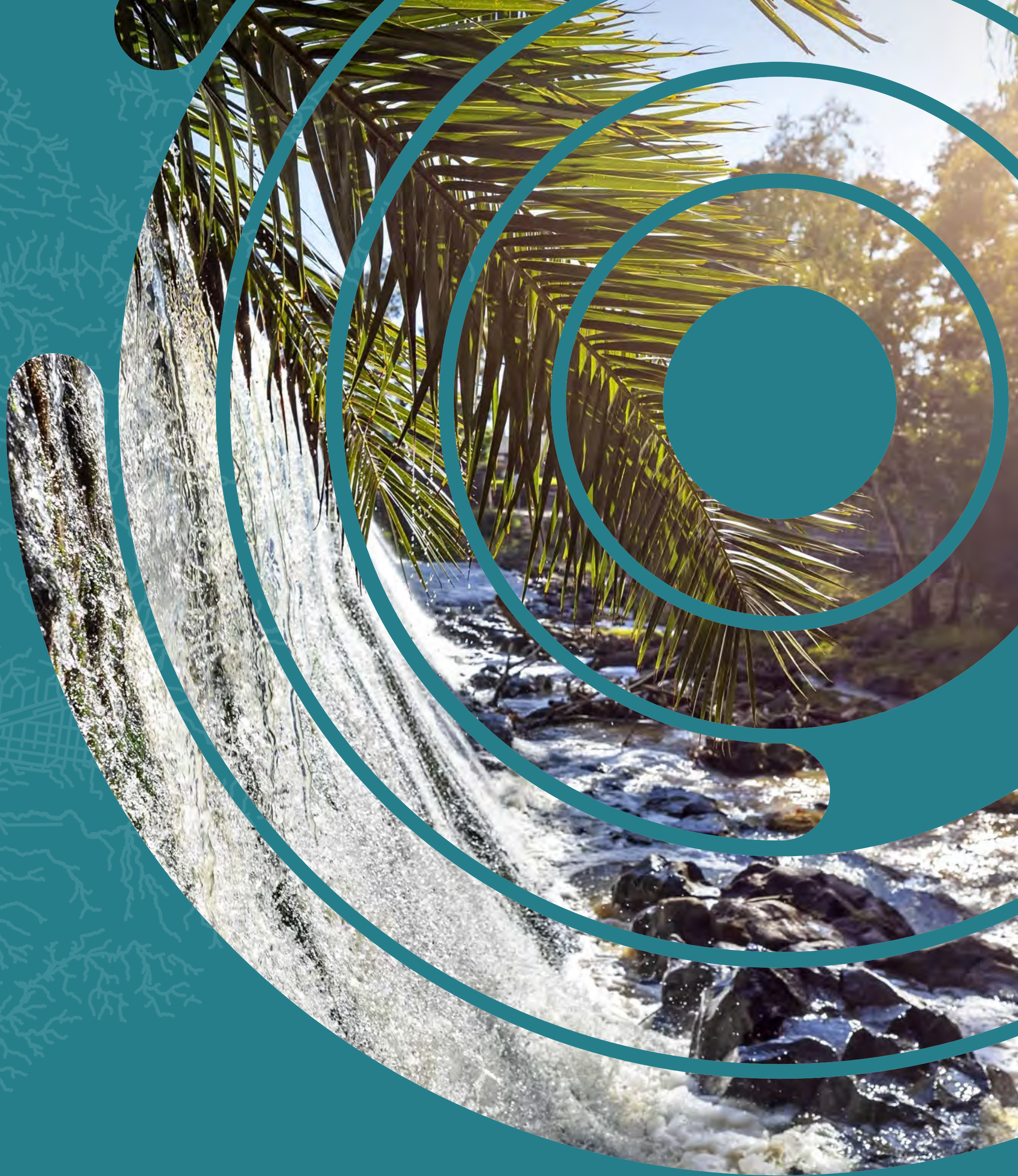
** Indicates where non-numeric targets exist and reports are provided annually. Meeting KPI's for stormwater treatment wetlands means that vegetation cover assessments of wetland assets (as a proxy for water quality treatment) are meeting the expected outcomes set in the MW investment plan.*

Overall summary

Overall, the HWS articulates multiple actions that link to the PPB EMP, particularly to the overall goal of no net increase in nutrient and sediment loads to Port Phillip Bay. However, as recognised in the analysis presented in other sections of this document, there are increasing threats in the catchment, particularly from urban growth, that are not being mitigated by the HWS.

Since the PPB EMP was released in 2018 and Environmental Reference Standards developed in 2020, new Urban stormwater management guidance (EPA publication 1739, (Environment Protection Authority 2021) has been developed. This new guidance has retained targets to reduce nutrient and sediment load from new development (compared with non-mitigated urban loads) by 80% for sediment, 45% for phosphorus and nitrogen and has set higher standards for stormwater priority areas to harvest and infiltrate water so as to essentially retain pre-development flow conditions. Litter reduction targets of 80% are also part of this new industry guidance. Broadly, the successful implementation of this policy is likely to be effective in mitigating increasing loads from urbanisation. However, currently no mandatory implementation of new guidance is in place, so greenfield developments are not necessarily meeting the higher standards in stormwater priority areas. Efforts to determine the best lever(s) to implement new guidance is being explored by DEECA, EPA and Melbourne Water. Additionally, despite industry guidance being available and targeted enforcement occurring ad hoc, the control of sediment on-site during the construction phase is well recognised as an ongoing threat and has been a recent research focus for the MW/Melbourne University Research Practise Partnership.

The Source catchment model developed by eWater (EWater, https://ewater.org.au/products/ewater-source/) has been built and calibrated for the Port Philip and Westernport region. It is intended that this model will be updated and re- run later in 2023 to quantify the sediment and nutrient loads that have been generated by recent La Niña rainfall patterns. This will provide a reasonable estimate of the actual loads that have been generated recently but will not necessarily model the effectiveness of the HWS interventions with respect to estimating the contributions these are having on improving water quality in the Bays. There is potential for the model to be used to explore this further should resources be made available to do so.



PART H

Overall summary and recommendations

Key values

The mid-term review set out to use available data, modelling and analyses to determine (where possible) whether key values and conditions are on the target trajectory at the mid-point of strategy implementation with a focus on the following key evaluation questions:

- 3a. To what extent are key values on the target trajectory?
- 3b. What other spatial and temporal trends and patterns for key values are of significance for implementation?, and
- 2a. What environmental conditions (e.g. water quality) and external conditions (e.g. policy) help explain current key value trends?

It was not possible to address all key evaluation questions for all key values of rivers and wetlands and there was no analysis of data specific to estuaries in this inquiry. The findings for some values are limited by a lack of data, or because of the introduction of new monitoring and data collection methods which meant that complete datasets were not available at the time of the evaluation (see Table 44).

Table 44. Overview of the scale and extent of evaluation for key values.

Key value	KEQ 3a	Scale/extent of assessment	KEQ 3b	KEQ 2a
Platypus (rivers)	✓	All (69) sub-catchments	✓	✗
Fish (rivers)	✓	54/69 sub-catchments	✓	✗
Macroinvertebrates	✓	All (69) sub-catchments	✗	✓
Riparian vegetation	✗	Not assessed	✓	✓
Riparian birds	✓	37/69 sub-catchments	✓	✗
Wetland birds	✓	25/249 priority wetlands	✓	✓
Frogs	✓	KEQ 3a: 49/69 sub-catchments KEQ 3b: All (69) sub-catchments	✓	✗
Community connection	✓	11/14 management units	✓	✓
Recreation	✓	11/14 management units	✓	✓
Amenity	✓	11/14 management units	✓	✓

An overall summary of the findings for each value are provided below:

Macroinvertebrates – The evaluation found Macroinvertebrates to be on-track to meet long-term targets across most of the region (50/69 sub-catchments). However, there is a high to moderate chance that long-term targets for macroinvertebrates will not be met in 19 of the 69 sub-catchments. Modelling of works to date predicts habitat suitability to be declining in reaches across a number of sub-catchments and limited areas where improvements are predicted. Overall, the works to date modelling predicts a net decline in macroinvertebrate habitat suitability for 94 km of waterway, with 20km of this decline from the very high and high rating categories. This is of concern as full implementation of strategy targets for revegetation, stormwater harvesting and infiltration by 2028 is predicted to result in an additional 933km of reaches in high or very high categories. There are a range of conditions that help explain the trends in macroinvertebrates however, a combination of reduced stream flows and urban development are likely to underlie declines across multiple sub-catchments, including main-stem river sites (Yarra, Maribyrnong and Werribee). This is supported by information suggesting improving the natural flow regime, either by reducing diversion pressure or by disconnection of urban stormwater has improved macroinvertebrates at particular sites.

Platypus – The evaluation found Platypus to be on-track to meet long-term targets across most of the region (61/69 sub-catchments). Three sub-catchments were found to be off-track and there is a high chance that long term targets will not be met. A further two sub-catchments are also of concern, with more information required to determine their trajectory with confidence. Drought and inappropriate flow regimes are thought to underlie declines across multiple sub-catchments. Critically, climate change may pose an even greater risk to platypus than originally predicted and planned interventions may not be enough to halt their long-term decline.

Fish – There is a high chance that long-term targets for fish will not be met in 11 of the 54 assessable sub-catchments, with almost half of these sub-catchments situated in the Westernport region. Modelling of works to date indicates changes to native fish habitat suitability have been mixed, with improvements for some species and declines for other species such as the River Blackfish. Despite this mixed response, there has been a predicted overall decline in native fish habitat suitability.

Riparian vegetation – Despite data limitations in assessing temporal changes to vegetation condition across the region and comprehensively address all the key evaluation questions, we were able to use multiple lines of evidence to demonstrate that the condition of vegetation is improving along reaches that are being actively managed. There are some areas of potential decline based on recent survey data, however this needs confirmation. Threats such as weeds and deer persist across the region. While weed loads are high in most sites the proportion of highly invasive weeds is low (20%) in sites in good condition. New areas of high-quality vegetation have been identified at 120 sites with 25 sites not currently included in HWS 2018 vegetation priority areas.

Riparian birds – Long-term bird surveillance monitoring enabled evaluation of the trajectory in 45 of the 69 sub-catchments. The majority of these (37/45) were assessed as 'On-track' and many sub-catchments improving in condition. Two sub-catchments were assessed as 'Off-track' (Watsons Creek and Watts River (Source) both of which have significant forested areas of which some was burnt in the 2009 'Black Saturday Fires'. These sub-catchments need to be re-evaluated in future years to determine whether the declines are of concern.

Wetland birds – Updated baseline and current assessments using MW's wetland bird index were used as the basis of the evaluation. There was sufficient data to evaluate 25 of 249 priority wetlands of which 18 were assessed as 'on track'. This assessment is consistent with a longer-term assessment (i.e. over the past 20 years) which has shown that the bird communities are relatively stable (14 of the 19 wetlands – stable). There were two wetlands which have a high chance of long-term targets not being met: Paradise Road Ponds at the WTP and Truganina Swamp - these are cause for concern as they are large wetlands providing important migratory shorebird bird habitat.

Frogs – An interim frog assessment was completed at the sub-catchment scale, due to insufficient data for a wetland-scale assessment as originally planned in the Wetland MEP. Of the 49 (out of 69) sub-catchments that could be assessed, 45% were rated as declining (6/49) or potentially declining (16/49). Declines were not confined to one part of Melbourne. Declines in positive records of Growling Grass Frog, Brown toadlet and the Southern Toadlet are generally widespread and include sub-catchments not generally associated with rapid urbanization. This general decline mirrors the trajectory of frogs elsewhere (regionally and globally) and it is plausible that we have underestimated the decline in frogs across the HWS region.

Social values – The evaluation of social values is based on Melbourne Water's perceptions survey. Social values could not be evaluated at the sub-catchment scale due to data limitations and as such assessment was scaled up to 14 management units of which 11 had enough data to be evaluated for key evaluation question 3a.

Community connection – (satisfaction with activities such as outings, picnics, cafes, volunteering, festivals and cultural activities). Two management units were assessed as on-track (Yarra River Upper and Cherry, Kororoit, Laverton and Skeleton Creeks) and the remaining were slightly off-track. This result is not cause for concern at this stage as most of satisfaction percentages have stabilised or improved since 2018.

Recreation – (satisfaction with activities such as bird watching, boating, walking, cycling, fishing, swimming). Three management units were assessed as on-track (Yarra River Lower, Yarra River Upper and Werribee and Little River Middle and Upper). While the remaining 8 management units are slightly off-track it is not cause for concern at this stage as most of the satisfaction percentages have stabilised or improved since 2018.

Amenity – (satisfaction with activities such as nature appreciation, escaping to a quiet place, relaxation and feeding the ducks). Three management units were on-track (Maribyrnong River upper, Mornington Peninsula and Werribee and Litter River Middle and Upper). While the remaining five were slightly off-track this is not cause for concern at this stage as most of the satisfaction percentages have stabilised or improved since 2018.

Threats

The mid-term review has identified flow stress as the most concerning threat to waterways in our region caused by urbanisation, climate change and water extraction. These stressors impact different components of the flow regime and can be compounding. There is a need to better understand drivers of flow stress (e.g. climate change versus water extraction) in un-regulated systems including impacts on environmental values and available management options.

New flow-based targets outlined in the Strategy in stormwater priority areas are aimed at addressing flow related threats from urbanisation. The approach requires a significant change to traditional water quality focused management, and the evaluation findings indicate strategy implementation has not kept up with the pace of development. Other impacts associated with urbanisation such as building over wetlands and headwater streams and emerging contaminants have also been identified as being of significant concern in this evaluation. While there are regional performance objectives aimed at addressing these threats, additional sub-catchment or wetland specific performance objectives could help focus management effort in priority areas.

Deer were also identified as an increasing threat to waterways in the region with particular concerns about impacts to vegetation. While there are vegetation related performance objectives (at both local and regional scale), there is a need for increased management and more quantitative annual reporting.

Recreational access has been flagged as a potentially increasing threat, however, there is low confidence in the assessment and further investigation is required.

Weeds continue to threaten vegetation along waterways, although there is low confidence in the assessment. Nonetheless, weed management has been linked to improvements in vegetation quality in the region. In time the regional surveillance monitoring (i.e. VV21 data) will provide better evidence of the weed threat trajectory across the region.

Threats to social values was not formally assessed in the mid-term evaluation and has been identified as a gap that needs to be addressed by the end-of-Strategy evaluation.

Management effectiveness for environmental values

The impact of management activities (riparian revegetation, stormwater control, in-stream barrier removal) on in-stream environmental values was investigated using habitat suitability models. There has been minimal improvements in the model parameters representing riparian revegetation and in-stream barrier removal. Further, directly connected imperviousness, which represents stormwater control, increased overall, which combined resulted in an overall deterioration in habitat suitability for macroinvertebrates, platypus and native fish species. However, the expected outcome for 10-year planned works will lead to a substantial increase in habitat suitability for all values.

Focus areas

The value synthesis identified 46 focus area sub-catchments across the region. 29 of these sub-catchments were identified as having a declining trajectory for multiple environmental values or as being climate-change vulnerable for environmental values over the long term (by 2070); there is a concern that HWS value targets in these sub-catchments may not be met. On the other hand, 29 sub-catchments were also identified as currently having multiple stable environmental values or as being a climate-change stronghold for environmental values over the long term (by 2070). However, most of the sub-catchments with multiple stable environmental values had increasing threats which could lead to future declines if these threats are not mitigated. The most common threat in sub-catchments with declining environmental values were related to decreased water availability and increased urbanisation including unmitigated stormwater runoff.

Interventions

A stocktake of management actions being undertaken as part of the HWS has documented the maturity of actions, key lessons from recent monitoring and evaluated the appropriateness and effectiveness of many specific techniques. Overall, there are eight management levers containing 18 intervention groups and 81 techniques. The outcomes suggest that two intervention techniques are inappropriate and should not be continued (i.e. on-line constructed wetlands and ripping near waterways). There are a number of techniques which require careful consideration in the project design phase (such as thermal weed control and noise deterrent for deer control), a number where improvements to techniques are available (mainly for stormwater management and weed control) and others where we should start to implement actions more broadly such as instream habitat enhancements and precinct scale toxicant traps in industrial areas.

Knowledge gaps

Knowledge gaps from the mid-term evaluation were captured from the technical papers for values, threats and interventions and research project fact sheets. This process captured over 180 new knowledge gaps, that were categorised as 'monitoring', 'investigations' or 'research'. New Key Research Areas were identified, and several key recommendations have been made around addressing data gaps for key values, conditions and threats and investigations that are needed to improve our understanding what is driving key value trajectories. Addressing these knowledge gaps is critical for the final strategy evaluation in 2026 and for setting the direction for the next HWS in 2028.

Recommendations

Introduction and approach

The recommendations were gathered and consolidated from HWS Mid-term Evaluation Technical Reports that were relevant to the nine key HWS values (macroinvertebrates, platypus, fish, riparian vegetation, riparian birds, wetland birds, frogs, community connection, recreation, amenity), threats (Part B), interventions (Part C), the values synthesis (Part D), and the research project fact sheets and reports developed to inform the Science Inquiry. Through the consolidation process, recommendations were categorised into 'Monitoring and investigation' knowledge gaps, 'Research' knowledge gaps and 'Implementation program improvements'. They were consolidated and summarised where commonalities were found across the multiple sources. To prevent the loss of useful information through the process, the original recommendations, the consolidation process, and the resultant categorisation were tracked.

Recommendations were grouped in the following themes:

- Knowledge gaps - Monitoring and investigations
- Knowledge gaps - Research, and
- Implementation program improvements (to be considered for incorporation into the Implementation Inquiry).

Outcome

The recommendations stemming from the Science Inquiry will be considered alongside those coming from the Implementation Inquiry Report and will be responded to and prioritised through the formal response. To help with developing the response, the recommendations below have been split into near and long-term recommendations.

Knowledge gaps – Monitoring and investigations

Value/ Condition	Near-term (i.e. for remainder of current HWS and to inform the development of the next strategy)	Long-term (on-going)
Knowledge gaps	**S-1.1** Prioritise Monitoring and Investigations knowledge gaps through the process outlined in the Mid-Term Evaluation Science Inquiry and develop a monitoring and investigation plan to include in the Healthy Waterways Strategy Mid-Term Evaluation Response Report.	

Knowledge gaps – Research

Value/ Condition	Near-term (i.e. for remainder of current HWS and to inform the development of the next strategy)	Long-term (on-going)
Knowledge gaps	**S-2.1** Prioritise Research knowledge gaps through the process outlined in the Mid-Term Evaluation Science Inquiry and develop recommendations to be included in the Response Report.	

Implementation program improvements

Use latest knowledge to continuously improve program delivery. Specifically:

Value/ Condition	Near-term (i.e. for remainder of current HWS and to inform the development of the next strategy)	Long-term (on-going)
Traditional Owners	**S-3.1** Support a self-determined review process by Traditional Owners, aiming for this to be progressed over the next 12 months.	
Focus Areas	**S-4.1** Focus Implementation Inquiry on priority themes and focus sub-catchments emerging from the science synthesis.	**S-4.2** Investigate management options in climate vulnerable sub-catchments to improve resilience for identified species or communities.
Multiple	**S-5.1** Urgently develop strategic management plans for key threatened species such as Growling grass frog, Southern toadlet, Yarra pygmy perch and key macroinvertebrate species, including the consideration of translocation as an option following disturbance events.	**S-5.2** Prioritise the implementation of long-term intervention monitoring programs for key works such as vegetation establishment and maintenance, fishway performance and stormwater interventions to validate and support programs.
Vegetation	**S-6.1** Prioritise locations for deer management using modelling and field data and consider developing targets and metrics for annual reporting.	**S-6.4** Update Melbourne Water's revegetation guidelines to include climate change mitigation actions, new information on chemical use, bird habitat design and amenity outcomes such as shading.
	S-6.2 Identify sites that could be used for direct seeding to build capacity in applying this technique that has the potential to increase the efficiency of revegetation efforts at suitable sites.	
	S-6.3 Improve the success of revegetation outcomes by ensuring adequate mid-storey vegetation and native groundcover is established and maintained in revegetated areas.	
Fish	**S-7.1** Continue to invest in in-stream barrier removal and fishways. Evidence suggests that fishways are an effective management lever to support migratory species when they are well maintained and functioning.	
	S-7.2 Investigate opportunities for a more pro-active approach to fish and platypus habitat restoration and whether new POs in priority locations should be considered for the next strategy.	
Platypus	**S-8.1** Investigate opportunities to improve habitat (10-40 km additional) upstream of existing urban areas (i.e. above Princess Freeway) for the existing platypus community in Cardinia Creek, and change the riparian vegetation (increase extent) targets if appropriate.	**S-8.3** Consider developing POs for improving connectivity at major storages and managing the threat of litter on platypus in priority locations.
	S-8.2 Investigate the feasibility of re-introducing platypus to Toorourrong Reservoir.	
Frogs	**S-9.1** Review location of POs for Bibron's toadlet and add new priority sub-catchments where data indicates populations are more likely to be present.	

Value/ Condition	Near-term (i.e. for remainder of current HWS and to inform the development of the next strategy)	Long-term (on-going)
Social Values	**S-10.1** Develop social values POs and targets for priority wetlands. Consider the potential for conflicting impacts between social and environmental values on different wetland typologies.	
	S-10.2 Consider additional funding and incentive mechanisms to improve interpretative signage along waterways to provide information on plants, animals and cultural values.	**S-10.5** Improve outcomes for social values by considering the strategic provision of facilities such as toilets, bins and seating and more community events, including opportunities for communities to be involved in management activities (e.g. clean-up and tree planting days).
	S-10.3 Continue to support citizen science programs such as Waterwatch, Frog Census and Estuary Watch and ensure adequate training on monitoring design and data analysis is undertaken to ensure data collected can be used effectively. Ensure recognition events are conducted regularly to acknowledge the valuable contribution citizen scientists make to waterway management.	
	S-10.4 Utilise data from the implementation of the new litter monitoring method to validate threat rating and identify litter prioritisation hotspot spatial analysis. Ensure high litter areas are reported either through the RPO or consider the addition of sub-catchment POs.	
Water for Environment	**S-11.1** Consider improved ways of assessing and reporting on the delivery of existing environmental entitlements and allocations on the strategy website to allow greater transparency and progress tracking.	
Water Quality	**S-12.1** Develop indicators and rubrics for construction runoff to ensure progress can be more quantitatively assessed for these POs.	
	S-12.2 Continuously improve the management options delivered by Melbourne Water's rural land program by integrating relevant monitoring data and research findings to inform the design and range of potential interventions, including updating the water quality metrics used to assess the likely benefits of particular interventions.	
	S-12.3 Review the location of performance objectives for managing run-off from industrial areas and associated water quality impacts and develop indicators, targets and/or quantitative metrics for assessing progress, including the required actions necessary to achieve sub-catchment and regional targets. Further develop spatial mapping of existing and future hotspot areas for industrial pollution. Consider the development of a 'toolkit' for structural and non-structural management options in industrial estates.	
	S-12.4 Combine the available knowledge and data on contaminants that accumulate in stormwater wetland sediments and consider using in existing maintenance prioritisation tool. Assess how contamination influences wetland performance, desilting frequency, waste disposal and maintenance costs, to help inform management protocols.	
	S-12.5 Advocate for changes in bifenthrin application for termite control in housing estates. Actions could include updating urban construction guidelines, education of construction companies and the pest control industry or chemical substitution.	
Stormwater	**S-13.1** Understand the barriers to the implementation of HWS stormwater POs e.g. lack of policy, guidance, capacity, funding, and/or sector willingness.	
	S-13.2 Update industry guidance for stormwater infiltration design (e.g. update constructed wetland guidelines to support design of effective infiltration)	
	S-13.3 Review guidance and procedures to prevent stormwater wetlands from being constructed within waterways.	

Value/ Condition	Near-term (i.e. for remainder of current HWS and to inform the development of the next strategy)	Long-term (on-going)
Wetlands, headwaters and floodplains	**S-14.1** Strengthen reporting on the need for protection of natural wetlands from the specific threat of urban development. Consider the addition or alteration of RPOs.	
	S-14.2 Develop and implement updated waterways spatial data for streams that are considered "designated waterways" in accordance with the Water Act 1989.	
	S-14.3 Ensure new regional priority wetlands identified since 2018 (that do not have POs) are managed to maintain existing values for example risk-based predator control. Include these in Annual Reporting.	
	S-14.4 Seek to update state wetland spatial data in the Port Phillip and Westernport region to reflect the best available information and alignment with the Healthy Waterways Strategy and the Regional Catchment Strategy.	
	S-14.5 Investigate options for changing policy instruments to support the protection of natural wetlands.	
	S-14.6 Explore further opportunities for improving wetland protection using the Catchment and Land Protections Act, 1994 and development referrals, particularly for those natural wetlands of most significance such as seasonal herbaceous wetlands.	
	S-14.7 Develop guidelines for the protection/restoration of natural wetlands and headwater streams in urbanising catchments, including setbacks that protect floodplain function and develop performance measures to track protection efforts.	**S-14.8** Further investigate opportunities to re-connect waterways with floodplains and billabongs, using lessons learnt from recent intervention monitoring projects such as Yellingbo.

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APPENDICES

Appendix 1: Waterway conditions

The conditions supporting environmental and social values for rivers, wetlands and estuaries are outlined below.

The conditions supporting **environmental** key values for **rivers** are:

- **Stormwater condition**: The impact of stormwater on waterways.
- P**hysical form:** Physical attributes such as shape, size and sediment characteristics.
- **Water for the environment**: Water that is managed to support waterway values.
- **Vegetation quality**: The quality of vegetation relative to Ecological Vegetation Classes (EVCs) 'benchmarks'.
- **Vegetation extent**: Extent of continuous indigenous vegetation cover within a defined width either side of the river.
- **Instream connectivity**: Ability of uninhibited fish passage.
- **Water quality - environmental**: Water quality indicators such as nutrients, water clarity, dissolved oxygen, salinity, pH and metals.

The conditions supporting **social** key values for **rivers** are:

- **Access:** Accessibility to and along waterways and corridors.
- **Recreational water quality:** The waterway water quality suitable for primary and secondary contact recreation.
- **Vegetation extent**: Extent of continuous indigenous vegetation cover within a defined width either side of the river.
- **Litter absence**: Litter detracts from people's enjoyment of waterways and can be detrimental to wildlife.
- **Participation**: Amount of participation in waterway stewardship activities.

The conditions supporting **environmental** key values for **wetlands** are:

- **Vegetation condition**: Refers to the extent that the 'natural' wetland vegetation are intact or displaced and modified.
- **Wetland buffer condition**: Wetland buffer is native vegetation above the maximum inundation extent.
- **Wetland water quality:** Considers changed water properties within the wetland including nutrients, salinity regime and disturbance of acid sulphate soils.
- **Water regime**: Considers changes to the wetland water regime, including those that impact the flow regime of the wetland water source, interfere with the natural connectivity of flow to the wetland, involve disposal of water into the wetland or extraction of water from the wetland and changed wetland depth.
- **Wetland habitat form:** Considers the extent that the wetland area has been reduced through levees, diversions, etc., and the extent that the wetland bed has been altered through excavation and land-forming activities.

The conditions supporting environmental key values for estuaries are:

- **Flow regime**: Changes from 'natural conditions' to the flow regime.
- **Tidal exchange**: The ability of sea water and fresh water to mix in the estuarine environment.
- **Longitudinal extent**: Considers the proportion of estuary affected by constructed barriers that interfere with the movement of water (in a typical year).
- **Water quality**: Water quality indicators such as nutrients, water clarity (turbidity), dissolved oxygen, pH and metals.
- **Estuarine vegetation**: The extent to which estuarine vegetation extent and condition is modified.
- **Estuarine wetland connectivity**: The proportion of the estuary that is connected to its fringing wetlands.

Appendix 2: Mid-Term Review Panel Group Charter

Healthy Waterways Mid-term Review Evaluation Panel

Extract from Group Charter

This charter sets out terms of reference and working arrangements for the Healthy Waterways Strategy mid-term review Evaluation Panel. Below we provide an extract that outlines the background, roles and responsibilities of the panel.

Background and focus for mid-term review

Background

Melbourne Water is the waterway manager in the Port Phillip and Westernport region and is periodically required to develop a Regional Waterway Strategy under the Water Act 1989. The Healthy Waterways Strategy (HWS) was developed in 2018 through a collaborative process led by Melbourne Water with participation by government agencies, stakeholders and the community. The HWS is a co-delivered strategy, led by Melbourne Water but contributed to by a range of other partner agencies and the community. It is overseen by a Region-wide Leadership Group (RLG) which includes key delivery partners.

The HWS website provides an overview of the HWS along with links to key documents, an annual report card to track progress and information on the science underpinning the HWS such as pages on each of the key values and condition. Healthy Waterways Strategy for Port Phillip and Westernport.

In collaboration with HWS delivery partners, Melbourne Water has developed a monitoring, evaluation, reporting and improvement (MERI) framework and monitoring and evaluation plans (MEP's) for rivers, wetlands and estuaries to enable evaluation and reporting on activities and progress towards targets and outcomes. The strategy is in place for 10 years (2018-2028) and the MERI outlines two opportunities for review; at mid-term (2022) and end-of-strategy review (2026).

There are two internal governance groups in Melbourne Water; the Internal Working Group (IWG) comprised of managers across relevant parts of the business and the Internal Steering Group (ISG) who are General Managers across waterways delivery and planning. Communication of the mid-term review process and key findings to these groups is critical for the review to be constructive and successful and to drive the progress of the strategy.

The RLG is a multi-agency group which is tasked with overseeing the implementation of the HWS. With respect to the mid-term evaluation the RLG will endorse the evaluation plan, champion involvement of members of their organisations and respond to evaluation by enabling implementation of evaluation recommendations.

Focus for mid-term review

Key focus areas for mid-term review will be:

- to use available data and analyses to determine (where possible) whether key values and conditions are on the target trajectory
- the extent to which collaboration and co-delivery contribute to strategy implementation, and
- how the latest data and research can help to inform decision making.

The outcomes of the mid-term review are anticipated to drive the improvement, efficiency and effectiveness of strategy implementation as well as increase preparedness for end of strategy evaluation.

As outlined in the mid-term review plan, which has been endorsed by the RLG, the focus on this evaluation is to:

1. Evaluate the effectiveness and appropriateness of implementation
2. Assess the potential for achieving targets at the end of strategy

3. Check that assumptions and external conditions that underpinned the strategy development have not changed, and
4. Identify remaining knowledge gaps.

To meet these objectives the evaluation will include a Science Inquiry Report, an Implementation Inquiry Report and a formal response.

The Science Panel, which was established when the HWS was being developed, has been reformed to support the mid-term evaluation. It will be referred to as the HWS Evaluation Panel. While the panel will focus largely on the Science Inquiry it will also contribute to the Implementation Inquiry. The mid-term review will be coordinated by the Waterways and Biodiversity Planning team at Melbourne Water. The HWS Evaluation Panel is not responsible for the conduct of the evaluation, however the panel has a review role and will provide advice to the evaluation coordinator/s, Melbourne Water governance groups and Regional Leadership Group on the evaluation process and findings including recommendations for operationalising findings and addressing knowledge gaps.

Role and responsibilities

Role

- Review evaluation plan and provide feedback.
- Critique science to ensure evidence is credible and explicit evaluative reasoning is applied.
- Prioritise and finalise recommendations for Science Inquiry and Implementation Inquiry.
- Endorse the Science Inquiry and implementation inquiry final reports.
- Communicate to RLG about findings from both enquiries.

The responsibilities of the HWS Evaluation Panel include:

- Provide critical, independent expertise to help distil the findings of the evaluation process into key priorities and recommendations
- Assess whether the evidence for the trajectory of a key value or condition is sufficient to inform a change in direction for HWS implementation
- Explore and recommend options to operationalise findings
- Check in on key strategy assumptions and the feasibility of integrating new insights
- Attend meetings as required and review associated briefing materials, papers and outputs including the Science Inquiry Report, and
- Enter into robust, constructive discussion with other panel members to collaboratively come to conclusions, drawing on group experience and knowledge with a view to informing and guiding the practical implementation of the strategy moving forward.

The HWS Evaluation Panel's role in developing the Science Inquiry Report is to:

- Contribute to and endorse the table of contents
- Discuss the findings presented to the Panel and provide recommendations to ensure the information has sound reasoning, the evidence used is credible and that any limitations or uncertainties associated with the analysis are explicit.
- Discuss what is important for the relevant HWS governance groups to consider for implementation. Review the draft report and recommendations and provide input to finalise the Science Inquiry report.
- Recommend priorities for further knowledge gathering to refine assumptions, fill knowledge gaps improve confidence and inform current and future evaluation, and
- Agree on how to communicate findings to relevant governance groups (i.e. RLG and IWG/ISG)

The Evaluation Panel's role in the Implementation Inquiry Report is:

- Ensure the findings of the Science Inquiry are considered in the Implementation Inquiry where relevant
- Provide feedback on the findings of the inquiry report particularly with respect to any matters relating to the Science Inquiry
- Review and endorse any recommendations for changes to performance objectives or catchment targets which stem from the mid-term evaluation, and
- Provide advice on specific findings of the Implementation Inquiry report as requested by Melbourne Water's Team Leader and Principal, Waterways

Additional responsibilities of Chairperson

The Chairperson will play a crucial leadership role in ensuring that the HWS Evaluation Panel operates effectively. The role will require the Chair to:

- Guide the conduct of all HWS Evaluation Panel Members
- Work closely with the Melbourne Water project team to ensure the HWS Evaluation Panel achieves the outcomes sought to inform the mid-term review process
- In conjunction with Melbourne Water project team, plan for each meeting/workshop and prepare an agenda, outlining topics and issues to be discussed, posing questions for members to consider prior to the workshop
- Effectively chair meetings and workshops in a timely manner, involve the views of all members and remain outcomes focused
- Keep discussion specific to the subject, drawing out real outcomes and suggestions.
- Facilitate effective communication between the panel members and the Melbourne Water project team
- Provide regular feedback to panel members on their performance in contributing to HWS Evaluation Panel objectives
- Actively engage panel members during and outside meetings to resolve any issues
- Present panel recommendations and priorities to IWG and RLG if required, and
- Lead a process with panel members to provide reflection on the mid-term evaluation process and how it can be improved for the end of strategy review.

Responsibilities of Melbourne Water

- Melbourne Water is ultimately accountable for decision making in relation to the HWS Science Portfolio and the mid-term review.
- Provide all administrative and secretariat support to the HWS Evaluation Panel, including organising meetings and circulation of associated documents in a timely manner.
- Undertake the analysis of data and evidence, clearly identify the associated limitation and uncertainties, present the findings as they relate to the KEQ's and developed rubrics.
- Draft the Science Inquiry Report and provide initial recommendations to the Panel for their discussion. Reflect the final recommendations of the HWS Evaluation Panel in the Science Inquiry Report.
- Report to the HWS Evaluation Panel on how its advice and decisions have shaped the Evaluation Response Report and the mid-term review more broadly.
- Communicate key concerns and findings from the Science Inquiry into the Implementation Inquiry and similarly ensure the key findings of the Implementation Inquiry are linked back to inform the finalisation of the Science Inquiry Report
- Melbourne Water's project team (and their research partners and contractors) may participate in meeting discussions to clarify and explore the feedback provided by the HWS Evaluation Panel.
- Melbourne Water's Principal, Waterways will provide the link between the HWS Evaluation Panel and the mid- term review.

HWS Evaluation Panel Operation, Governance and Decision Making

Evaluation Panel matters

The Evaluation Panel will consider and report on the following as part of its deliberations:

- The extent to which the evaluation design and data collection methods align with the purpose of the evaluation and the KEQs
- The extent to which analysis and findings are reliable, accurate with the limitations and uncertainties clearly described
- The extent to which evaluative reasoning has been applied to the analysis and findings, interpretations and judgements, and
- The implications of the findings, uncertainties, and limitations for the evaluation and HWS implementation.

The Panel will report on its deliberations and will advise on the extent to which the Panel supports the findings and judgements. The Panel will make recommendations to the evaluation coordinators and the HWS Governance Groups on improvements/adjustments to the HWS implementation and priority knowledge gaps to be addressed prior to the final evaluation.

Items out of scope for the Evaluation Panel include the evaluation focus and key evaluation requestions which have been previously defined through extensive stakeholder consultation. Decisions as to the selection of indicators and methods as well as the analysis of evidence and data and preparation of initial findings are the responsibility of the evaluation coordinator/s, however the Panel will require an understanding of the planning and design considerations to inform its advice and recommendations.

Operation, governance and decision making

- Each meeting will involve discussion and debate involving both the panel members and relevant members of Melbourne Water project teams, secretariat and observers. The aim of distilling appropriate advice to guide the strategy direction should be the desired outcome.
- The panel will do this by leading by example; it will act in an intellectually open and critical way; it will embrace a diversity of views and seek to work together to gain new insights by the intersection of diverse perspectives to provide advice that is actionable and outcome focussed (i.e. don't get lost in the weeds).
- Melbourne Water is responsible for distributing relevant information prior to panel meetings. If material is lengthy or requires considerable time to review, then information will be provided at least one week prior to the meeting. Agendas will be circulated a week prior to panel sessions. Agendas will provide clarity about the focus of each meeting and the discussion topics for the panel.
- Draft minutes of each panel meeting shall be prepared by Melbourne Water within one week of the meeting for review by the Chairperson and subsequent circulation within two weeks of the meeting. These minutes will include Recommendations which summarise the key messages/outcomes, highlights, future issues and needed directions that have been decided by the panel.
- Melbourne Water will provide a written response to Recommendations back to the HWS Evaluation Panel prior to the following meeting. A log of recommendations and responses will be maintained and made available.

Procedures and decision making

Discussions within HWS Evaluation Panel meetings will be moderated by the Chair. A consensus process will provide for discussion of diverse opinion and used to develop recommendations. Where objections exist a simple majority will be used with provision to record objections in the meeting outcomes.

Appendix 3: Climate change plots

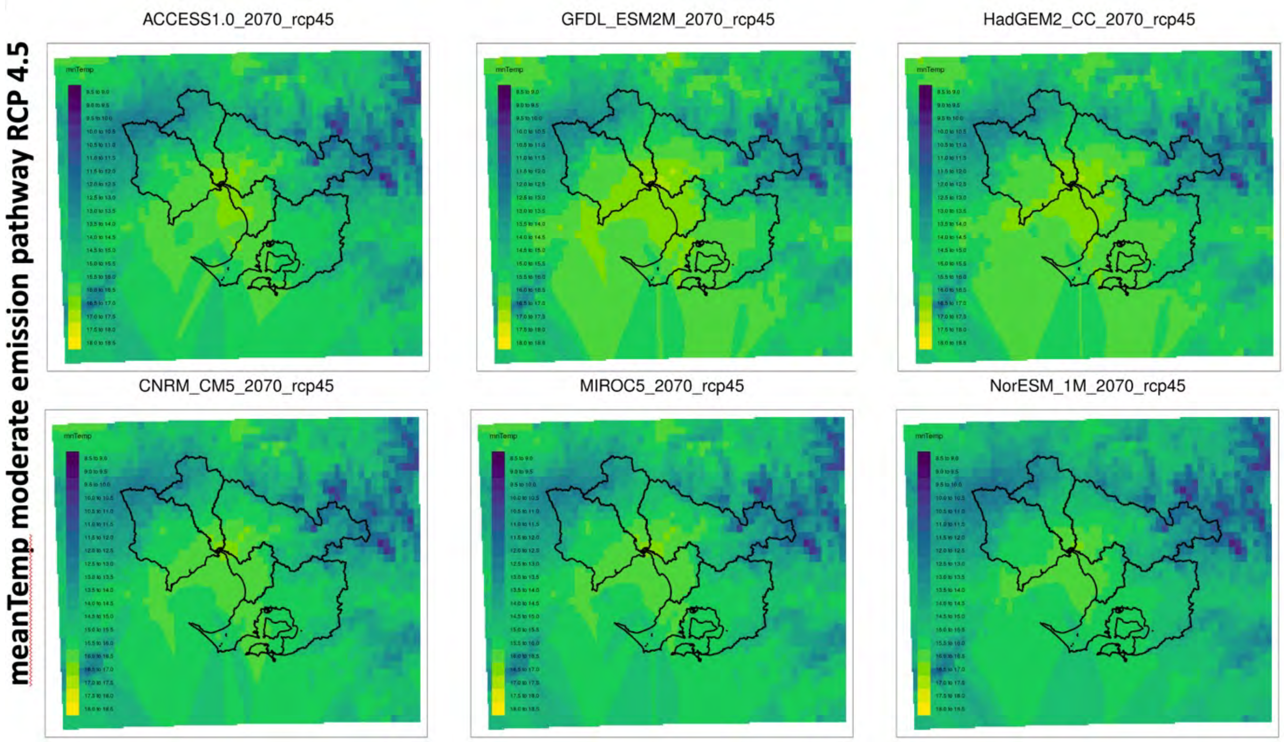

Figure 55. Gridded projections (5 km by 5km) of mean annual temperature across the PPWP region, for the six VCP19 models at 2070, given the moderate emission pathway scenario represented by RCP 4.5. Darker blues denote lower temperatures and lighter colours denote warmer temperatures.

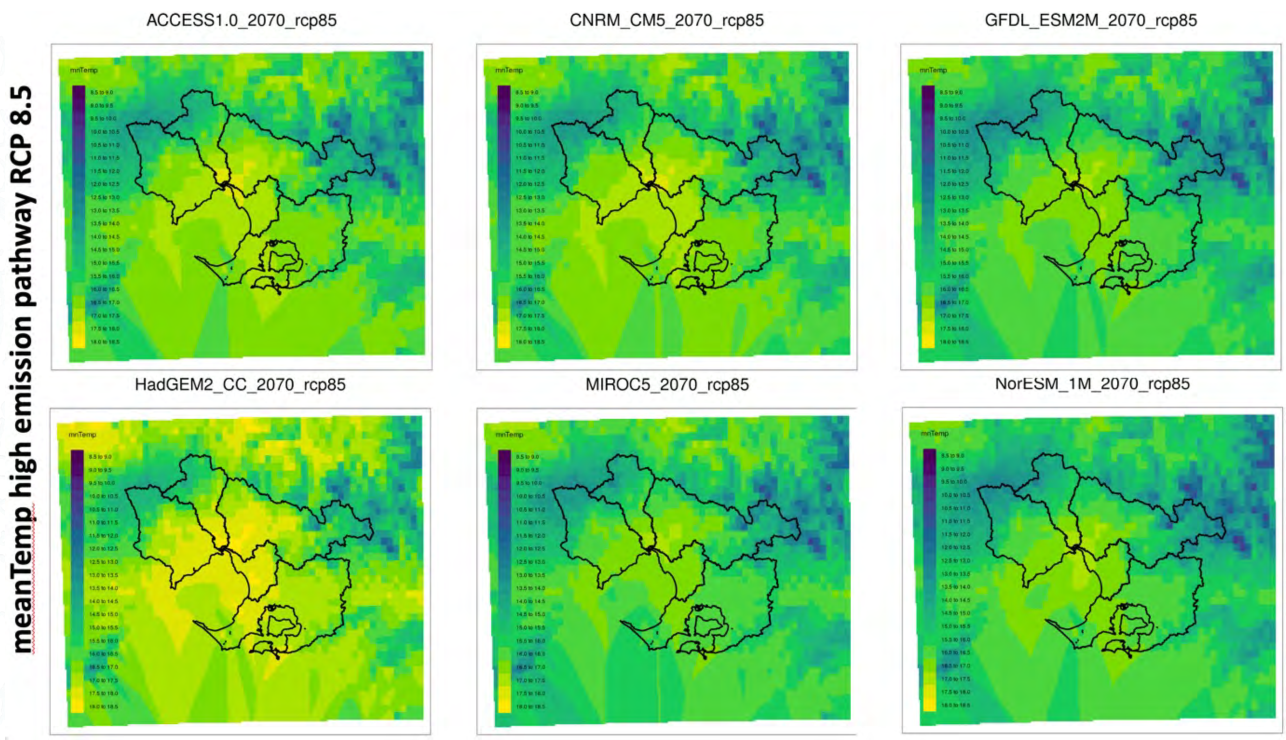

Figure 56. Gridded projections (5km by 5km) of mean annual temperature across the PPWP region, for the six VCP19 models at 2070, given the high emission pathway scenario represented by RCP 8.5. Darker blues denote lower temperatures and lighter colours denote warmer temperatures.

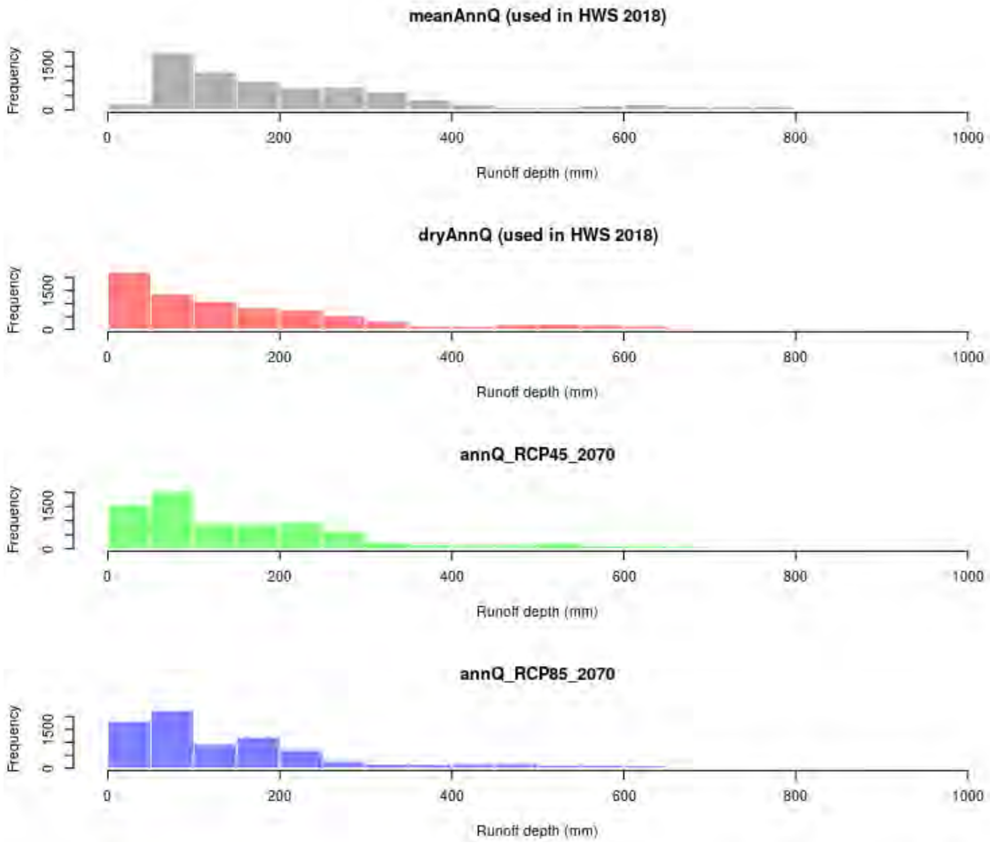

Figure 57. Histograms of the four mean annual runoff depth variables of interest. From top to bottom: 'meanAnnQ' (grey) – representing mean annual runoff for CURR (current, nominally ~2016) conditions; 'dryAnnQ' (red) – representing climate change-impacted drier BAUF (business-as-usual-future, circa 2070) conditions; 'annQ_RCP45_2070' (green) – mean annual runoff projection under moderate emission pathway RCP 4.5; 'annQ_RCP85_2070' (blue) – mean annual runoff projection under high emission pathway RCP 8.5.

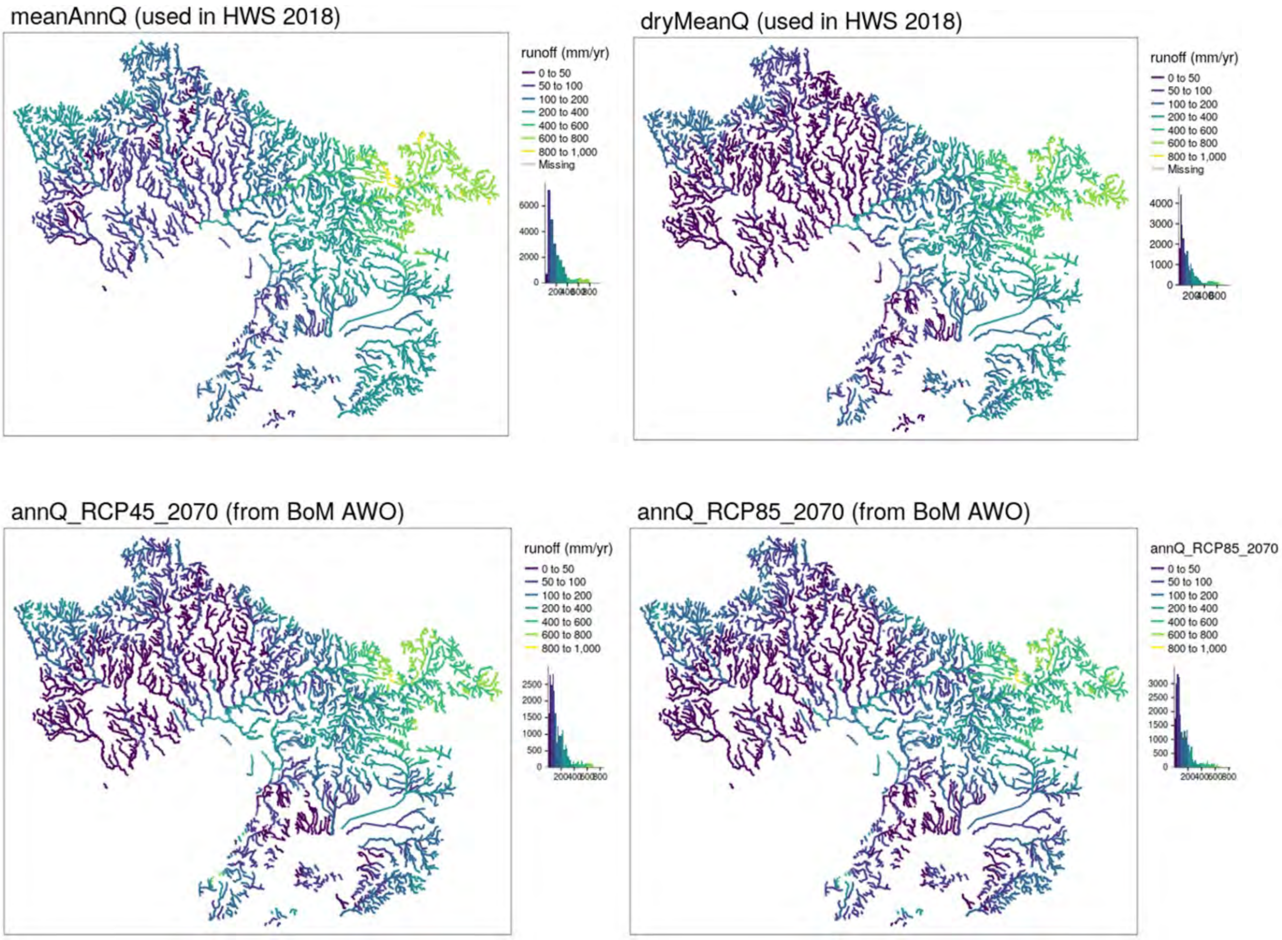

Figure 58. Mean annual runoff variables mapped for the PPWP region. 'meanAnnQ' was used to represent mean annual runoff for CURR (current, nominally ~2016) conditions in HWS 2018; 'dryAnnQ' was used to represent climate change-impacted drier BAUF (business-as-usual-future, circa 2070) conditions; 'annQ_RCP45_2070' is mean annual runoff projection under moderate emission pathway RCP 4.5; 'annQ_RCP85_2070' is mean annual runoff projection under high emission pathway RCP 8.5. Darker purples and blues represent lower runoff values and lighter greens and yellow represent higher runoff values.

Appendix 4: Values trajectories

Values trajectories for all 69 sub-catchments in the HWS.

Potentially declining	Stable	Declining	Gap	No target

* Indicates a threatened species is thought to be declining.

** Indicates two threatened species are thought to be declining.

Yarra

Sub-catchment	Rip. Birds	WL Birds	Frogs	Macroinv.	Fish (Rivers)	Fish (WLs)	Platypus	Rip. Veg.
Brushy Creek	Gap	No target	Stable	Stable	Stable	No target	Stable	Gap
Darebin Creek	Stable	No target	Declining *	Declining	Declining	No target	Stable	Gap
Diamond Creek (Rural)	Stable	No target	Potentially declining **	Declining	Gap	No target	Stable	Gap
Diamond Creek (Source)	Gap	No target	Potentially declining **	Stable	Stable	No target	Stable	Gap
Gardiners Creek	Declining	No target	Declining **	Stable	Gap	No target	Stable	Gap
Koonung Creek	Stable	No target	Potentially declining **	Stable	Gap	No target	Stable	Gap
Little Yarra River and Hoddles Creek	Gap	No target	Gap *	Stable	Stable	No target	Stable	Gap
Merri Creek Lower	Stable	Gap	Potentially declining *	Stable	Stable	No target	Stable	Gap
Merri Creek Upper	Stable	Gap	Potentially declining *	Declining	Stable	No target	Stable	Gap
Mullum Mullum Creek	Stable	Stable	Gap **	Stable	Gap	No target	Stable	Gap
Olinda Creek	Stable	Stable	Stable **	Stable	Stable	No target	Stable	Gap
Plenty River (Source)	Gap	No target	Potentially declining **	Stable	Stable	No target	Declining	Gap
Plenty River Lower	Stable	No target	Declining **	Stable	Gap	No target	Stable	Potentially declining
Plenty River Upper	Stable	No target	Potentially declining *	Stable	Stable	No target	Stable	Gap
Steels and Pauls Creek (Rural)	Gap	No target	Potentially declining **	Stable	Stable	No target	Declining	Gap
Steels and Pauls Creek (Source)	Gap	No target	Gap **	Stable	Stable	No target	Stable	Gap
Stringybark Creek	Gap	No target	Gap *	Stable	Declining	No target	Stable	Gap
Watsons Creek	Declining	No target	Stable *	Stable	Stable	No target	Stable	Gap
Watts River (Rural)	Stable	No target	Potentially declining **	Stable	Stable	No target	Stable	Gap
Watts River (Source)	Declining	No target	Gap *	Stable	Stable	No target	Stable	Gap
Woori Yallock Creek	Stable	No target	Stable **	Declining	Declining	No target	Stable	Potentially declining

Sub-catchment	Rip. Birds	WL Birds	Frogs	Macroinv.	Fish (Rivers)	Fish (WLs)	Platypus	Rip. Veg.
Yarra River Lower			*					
Yarra River Middle			**					
Yarra River Upper (Rural)			*					
Yarra River Upper (Source)								

Maribyrnong

Sub-catchment	Rip. Birds	WL Birds	Frogs	Macroinv.	Fish (Rivers)	Fish (WLs)	Platypus	Rip. Veg.
Boyd Creek			**					
Deep Creek Lower			*					
Deep Creek Upper			**					
Emu Creek			**					
Jacksons Creek			*					
Maribyrnong River			*					
Moonee Ponds Creek								
Steele Creek								
Stony Creek								
Taylors Creek			*					

Werribee

Sub-catchment	Rip. Birds	WL Birds	Frogs	Macroinv.	Fish (Rivers)	Fish (WLs)	Platypus	Rip. Veg.
Cherry Creek			*					
Kororoit Creek Lower								
Kororoit Creek Upper			*					
Laverton Creek			*					
Lerderderg River			*					
Little River Lower			*					
Little River Upper			*					
Lollypop Creek			*					
Parwan Creek								

Sub-catchment	Rip. Birds	WL Birds	Frogs	Macroinv.	Fish (Rivers)	Fish (WLs)	Platypus	Rip. Veg.
Skeleton Creek								
Toolern Creek			*					
Werribee River Lower								
Werribee River Middle								
Werribee River Upper								

Dandenong

Sub-catchment	Rip. Birds	WL Birds	Frogs	Macroinv.	Fish (Rivers)	Fish (WLs)	Platypus	Rip. Veg.
Bayside								
Blind Creek			**					
Corhanwarrabul, Monbulk and Ferny Creeks								
Dandenong Creek Lower			**					
Dandenong Creek Middle			*					
Dandenong Creek Upper			*					
Eumemmering Creek			*					
Kananook Creek			*					

Westernport

Sub-catchment	Rip. Birds	WL Birds	Frogs	Macroinv.	Fish (Rivers)	Fish (WLs)	Platypus	Rip. Veg.
Bass River			*					
Bunyip Lower			*					
Bunyip River Middle and Upper								
Cardinia, Toomuc, Deep and Ararat			*					
Dalmore Outfalls			*					
French and Phillip Islands			*					
King Parrot and Musk Creeks			*					

Sub-catchment	Rip. Birds	WL Birds	Frogs	Macroinv.	Fish (Rivers)	Fish (WLs)	Platypus	Rip. Veg.
Lang Lang River			**					
Mornington Peninsula North-Eastern Creeks								
Mornington Peninsula South-Eastern Creeks								
Mornington Peninsula Western Creeks								
Tarago River			*					

Appendix 5: MDVs – Multiple declining values

The sub-catchments identified as having Multiple Declining Values (MDVs) for each environmental value assessed. Sub-catchments are shown as those with moderate or greater underlying environmental conditions (Group A) and those with a high proportion of low or very low conditions (Group B). This provides information that may help prioritise effort based on findings of the Implementation Inquiry. Sub-catchments were also placed within the MDV category if there was a declining trend for macroinvertebrates in the main-stem of a river (e.g. Maribyrnong River) even if there was no evidence for other declining values – this is because macroinvertebrates are sensitive to changes in conditions, threats and management interventions, and thus declines in the main-stem likely reflects a broader deterioration in catchment conditions.

Potentially declining | Stable | Declining | Gap | No target

Catchment	Sub-catchment	Rip. Birds	WL Birds	Frogs	Macroinv.	Fish (Rivers)	Fish (WLs)	Platypus	Rip. Veg.	Group
Maribyrnong	Deep Creek Upper	Stable	No target	Gap	Declining	Declining	Gap	Declining	Gap	A
Maribyrnong	Emu Creek	Gap	No target	Gap	Declining	Stable	No target	Declining	Gap	A
Maribyrnong	Jacksons Creek	Stable	Gap	Declining	Declining	Declining	No target	Stable	Gap	A
Maribyrnong	Maribyrnong River	Stable	Gap	Stable	Declining	Stable	No target	Stable	Gap	A
Werribee	Werribee River Lower	Stable	Gap	Stable	Declining	Stable	No target	Stable	Gap	A
Werribee	Werribee River Middle	Stable	No target	Stable	Declining	Stable	No target	Stable	Gap	A
Westernport	Bunyip Lower	Gap	Gap	Stable	Declining	Declining	No target	Stable	Gap	B
Westernport	Cardinia, Toomuc, Deep and Ararat	Stable	Gap	Stable	Declining	Declining	Stable	Declining	Gap	A
Westernport	King Parrot and Musk Creeks	Gap	No target	Gap	Declining	Declining	No target	Stable	Gap	B
Westernport	Lang Lang River	Gap	Gap	Gap	Declining	Declining	Stable	Declining	Gap	A
Westernport	Mornington Peninsula South-Eastern Creeks	Declining	Gap	Stable	Declining	Stable	No target	No target	Gap	A
Westernport	Tarago River	Gap	No target	Gap	Declining	Declining	No target	Stable	Gap	A
Yarra	Darebin Creek	Stable	No target	Declining	Declining	Declining	No target	Stable	Gap	B
Yarra	Gardiners Creek	Declining	No target	Declining	Stable	Gap	No target	Stable	Gap	B
Yarra	Woori Yallock Creek	Stable	No target	Stable	Declining	Declining	No target	Stable	Potentially declining	A
Yarra	Yarra River Lower	Stable	No target	Stable	Declining	Stable	No target	Stable	Gap	A

Appendix 6: MSVs – Multiple stable values

The sub-catchments identified as having Multiple Stable Values (MSVs) for each environmental value assessed. Sub-catchments are shown as those with moderate or greater underlying environmental conditions (Group A) and those with a high proportion of low or very low conditions (Group B). This provides information that may help prioritise effort based on findings of the Implementation Inquiry.

Potentially declining | Stable | Declining | Gap | No target

Catchment	Sub-catchment	Rip. Birds	WL Birds	Frogs	Macroinv.	Fish (Rivers)	Fish (WLs)	Platypus	Rip. Veg.	Group
Dandenong	Blind Creek	Stable	No target	Stable	Stable	Gap	No target	Stable	Gap	B
Dandenong	Corhanwarrabul, Monbulk and Ferny Creeks	Stable	Gap	Stable	Stable	Stable	No target	Stable	Gap	A
Dandenong	Dandenong Creek Lower	Stable	Stable	Stable	Stable	Gap	No target	Stable	Gap	B
Dandenong	Dandenong Creek Middle	Stable	Stable	Stable	Stable	Gap	Stable	Stable	Gap	B
Dandenong	Dandenong Creek Upper	Stable	No target	Gap	Stable	Gap	No target	Stable	Gap	A
Maribyrnong	Boyd Creek	Gap	No target	Gap	Stable	Stable	No target	Stable	Gap	B
Maribyrnong	Moonee Ponds Creek	Stable	Gap	Stable	Stable	Stable	No target	Stable	Gap	B
Maribyrnong	Taylors Creek	Gap	No target	Gap	Stable	Stable	No target	Stable	Gap	B
Werribee	Kororoit Creek Upper	Gap	Gap	Gap	Stable	Stable	No target	No target	Gap	B
Werribee	Parwan Creek	Stable	Gap	Gap	Stable	Stable	No target	Stable	Gap	B
Werribee	Skeleton Creek	Stable	Gap	Stable	Stable	Stable	No target	No target	Gap	B
Westernport	Mornington Peninsula North-Eastern Creeks	Gap	No target	Stable	Stable	Gap	No target	No target	Gap	B
Westernport	Mornington Peninsula Western Creeks	Stable	Gap	Stable	Stable	Stable	No target	No target	Gap	B
Yarra	Little Yarra River and Hoddles Creek	Gap	No target	Gap	Stable	Stable	No target	Stable	Gap	A
Yarra	Mullum Mullum Creek	Stable	Stable	Gap	Stable	Gap	No target	Stable	Gap	B
Yarra	Olinda Creek	Stable	Stable	Stable	Stable	Stable	No target	Stable	Gap	A
Yarra	Steels and Pauls Creek (Source)	Gap	No target	Gap	Stable	Stable	No target	Stable	Gap	A
Yarra	Yarra River Middle	Stable	Gap	Stable	Stable	Stable	No target	Stable	Gap	A

Appendix 7: CCV and CCS sub-catchments

The sub-catchments identified as Climate Change Vulnerable (CCV) for each environmental value assessed. Sub-catchments are shown as those with moderate or greater underlying environmental conditions (Group A) and those with a high proportion of low or very low conditions (Group B). This provides information that may help prioritise effort based on findings of the Implementation Inquiry.

Potentially declining | Stable | Declining | Gap | No target

Catchment	Sub-catchment	Rip. Birds	WL Birds	Frogs	Macroinv.	Fish (Rivers)	Fish (WLs)	Platypus	Rip. Veg.	Group
Maribyrnong	Boyd Creek	Gap	No target	Gap	Stable	Stable	No target	Stable	Gap	B
Maribyrnong	Deep Creek Upper	Stable	No target	Gap	Declining	Declining	No target	Declining	Gap	A
Werribee	Lerderderg River	Gap	No target	Potentially declining	Declining	Stable	No target	Stable	Potentially declining	A
Werribee	Werribee River Middle	Stable	No target	Stable	Declining	Stable	No target	Stable	Gap	A
Werribee	Werribee River Upper	Gap	No target	Gap	Stable	Stable	No target	Stable	Potentially declining	A
Westernport	Bass River	Gap	No target	Potentially declining	Stable	Stable	No target	Stable	Gap	A
Westernport	Bunyip River Middle and Upper	Declining	No target	Stable	Stable	Stable	No target	Stable	Gap	A
Westernport	King Parrot and Musk Creeks	Gap	No target	Gap	Declining	Declining	No target	Stable	Gap	B
Westernport	Lang Lang River	Gap	Gap	Gap	Declining	Declining	Stable	Declining	Gap	A
Yarra	Diamond Creek (Source)	Gap	No target	Potentially declining	Stable	Stable	No target	Stable	Gap	A
Yarra	Plenty River (Source)	Gap	No target	Potentially declining	Stable	Stable	No target	Declining	Gap	A
Yarra	Plenty River Upper	Stable	Gap	Potentially declining	Stable	Stable	No target	Stable	Gap	A
Yarra	Steels and Pauls Creek (Source)	Gap	No target	Gap	Stable	Stable	No target	Stable	Gap	A
Yarra	Watts River (Rural)	Stable	No target	Potentially declining	Stable	Stable	No target	Stable	Gap	A
Yarra	Watts River (Source)	Declining	No target	Gap	Stable	Stable	No target	Stable	Gap	A
Yarra	Woori Yallock Creek	Stable	No target	Stable	Declining	Declining	No target	Stable	Potentially declining	A
Yarra	Yarra River Upper (Rural)	Stable	Gap	Potentially declining	Stable	Stable	No target	Stable	Potentially declining	A
Yarra	Yarra River Upper (Source)	Gap	No target	Potentially declining	Stable	Stable	No target	Stable	Gap	A

The sub-catchments identified as Climate Change Stronghold (CCS) for each environmental value assessed. Sub-catchments are shown as those with moderate or greater underlying environmental conditions (Group A) and those with a high proportion of low or very low conditions (Group B). This provides information that may help prioritise effort based on findings of the Implementation Inquiry.

Potentially declining | Stable | Declining | Gap | No target

Catchment	Sub-catchment	Rip. Birds	WL Birds	Frogs	Macroinv.	Fish (Rivers)	Fish (WLs)	Platypus	Rip. Veg.	Group
Dandenong	Corhanwarrabul, Monbulk and Ferny Creeks	Stable	Gap	Stable	Stable	Stable	No target	Stable	Gap	A
Dandenong	Dandenong Creek Upper	Stable	No target	Gap	Stable	Gap	No target	Stable	Gap	A
Werribee	Lerderderg River	Gap	No target	Potentially declining	Declining	Stable	No target	Stable	Potentially declining	A
Werribee	Werribee River Upper	Gap	No target	Gap	Stable	Stable	No target	Stable	Potentially declining	A
Westernport	Bunyip River Middle and Upper	Declining	No target	Stable	Stable	Stable	No target	Stable	Gap	A
Westernport	Tarago River	Gap	No target	Gap	Declining	Declining	No target	Stable	Gap	A
Yarra	Plenty River (Source)	Gap	No target	Potentially declining	Stable	Stable	No target	Declining	Gap	A
Yarra	Watsons Creek	Declining	No target	Stable	Stable	Stable	No target	Stable	Gap	A
Yarra	Watts River (Rural)	Stable	No target	Potentially declining	Stable	Stable	No target	Stable	Gap	A
Yarra	Watts River (Source)	Declining	No target	Gap	Stable	Stable	No target	Stable	Gap	A
Yarra	Woori Yallock Creek	Stable	No target	Stable	Declining	Declining	No target	Stable	Potentially declining	A
Yarra	Yarra River Middle	Stable	Gap	Stable	Stable	Stable	No target	Stable	Gap	A
Yarra	Yarra River Upper (Rural)	Stable	Gap	Potentially declining	Stable	Stable	No target	Stable	Potentially declining	A
Yarra	Yarra River Upper (Source)	Gap	No target	Potentially declining	Stable	Stable	No target	Stable	Gap	A

Appendix 8: In-stream barriers

List of 10-year planned fishways to overcome instream barriers to fish movement within PPWP waterways. Rows shaded in light blue are the fishways that have been completed in work-to-date (WTD).

ID	Severity	Type	Catchment	Sub-catchment	Subc
747	Full	Drop structure	Yarra	Darebin Creek	YARR7044
344	Partial	Gauging weir	Werribee	Werribee River Middle	WERR1578
347	Partial	Crossing	Werribee	Toolern Creek	WERR1397
354	Partial	Crossing	Werribee	Werribee River Lower	WERR1654
706	Partial	Weir	Maribyrnong	Maribyrnong River	MARI1820
707	Partial	Weir	Maribyrnong	Taylors Creek	MARI1782
760	Partial	Pipe	Yarra	Darebin Creek	YARR6120
808	Partial	Drop structure	Westernport	Lang Lang River	LANG160
881	Partial	Crossing	Werribee	Werribee River Lower	WERR1753
891	Partial	Crossing	Werribee	Little River Lower	LITT366
893	Partial	Crossing	Werribee	Little River Lower	LITT368
2	Full	Dam	Yarra	Yarra River Upper (Source)	YARR5274
44	Full	Weir	Yarra	Watts River (Rural)	YARR5288
352	Full	Weir	Werribee	Werribee River Lower	WERR1684
358	Full	Weir	Yarra	Yarra River Upper (Source)	YARR6649
361	Full	Weir	Yarra	Watts River (Rural)	YARR5964
716	Full	Gauging weir	Westernport	Lang Lang River	LANG95
882	Partial	Natural rock	Werribee	Werribee River Lower	WERR1721
883	Partial	Weir	Werribee	Werribee River Lower	WERR1718
884	Partial	Weir	Werribee	Werribee River Lower	WERR1718
885	Partial	Weir	Werribee	Werribee River Lower	WERR1718
886	Partial	Natural rock	Werribee	Werribee River Lower	WERR1714
887	Partial	Natural rock	Werribee	Werribee River Lower	WERR1699
888	Partial	Natural rock	Werribee	Werribee River Lower	WERR1684
889	Partial	Natural rock	Werribee	Werribee River Lower	WERR1684
892	Partial	Crossing	Werribee	Little River Lower	LITT366
894	Partial	Weir	Werribee	Little River Lower	LITT361
895	Partial	Gauging weir	Werribee	Little River Lower	LITT361

Appendix 9: Results from intervention evaluation

Table 45. Interventions that could benefit from improvements to design, implementation or maintenance.

Intervention	Rationale
Vegetation establishment and management	
Tubestock planting	Tubestock planting tends to be the default method for revegetation in the Melbourne region. Lessons from several intervention monitoring projects in the region and across Victoria indicate that the use of complementary interventions such as weed control, tree guards and stock exclusion fencing increase effectiveness. The density of overstorey species planting could be reduced by carefully considering upfront the implications of the overstorey species outcompeting understorey and ground cover species (which has been observed after 10 years). Planning for revegetation to occur over a number of years, rather than planting all species at once, would help to mitigate this and emulate natural succession resulting in a more natural vegetation community structure. Work is already underway in the region to modify species selection for climate resilience, however the mechanisms and processes to support the sourcing of climate adjusted seed mixes will become increasingly important over the next five years.
Weed control	
Chemical weed control	Chemical control tends to be the default method and is used as part of capital establishment and maintenance revegetation works. Herbicides produce the most effective and reliable weed control outcomes when used for the target species, but environmental and human health risks vary depending on the product used. An integrated strategy that combines physical, chemical, biological and alternate chemical methods may be required in the future in order to manage environmental and public health risks.
Instream barrier management	
Fishways	Fishways have been installed across the region, however some designs are in early adoption (e.g. cone fishway) compared to others (e.g. rock ramp). Lessons from the Dights Fall Weir upgrade and Pillars Road fishway highlight the importance of undertaking fish surveys to monitor the effectiveness of fishway operation and inform upgrades or rectification works to maximise the effectiveness for a range of species over time.
Channel modification	
Daylighting / naturalisation	Daylighting and naturalisation has been applied in five locations through the Reimagining your creek program since 2018. While there are assertions that this program helps to improve environmental and amenity values, no monitoring results from the program are current available to support this. A proportion of investment in applying this intervention could include monitoring and evaluation of environmental and social conditions as part of an adaptive management and learning based process.
Stormwater infiltrate & harvest	
Infiltration wetlands	Stormwater wetlands have been designed primarily to treat stormwater through infiltration and nutrient removal via vegetation. There is a need to improve the standard designs to maximise infiltration rates and harvesting opportunities to reduce the volume of stormwater entering waterways to help meet the HWS stormwater targets as well as meet best practice for nutrient removal. Harvesting is critical as research has shown that infiltration systems alone cannot improve stream health. However harvesting stormwater from existing stormwater wetlands built for primarily removing nutrients and toxicants does have a number of issues related to the potential level of toxicants. Recent toxicant surveys of wetlands in the region should be used to inform stormwater reuse and recycling schemes.
Raingardens	Raingardens have had moderate application in the region, particularly by councils. Designs typically focus on encouraging nutrient uptake by plants. There is potential to improve designs in future applications to maximise infiltration as well as removing toxicants and nutrients.

Intervention	Rationale
Passively watered street trees	Passively watered street trees are an intervention that has been increasingly applied by councils in the past 10 years. Research has shown that to maximise the stormwater treatment or runoff reduction, the tree pit area needs to be sized according to the exfiltration rate of the native soil. Access to stormwater can double the growth of street trees compared to traditional planting techniques, but if not carefully managed, passive irrigation may lead to reduced tree growth or even death due to waterlogging.
Industrial pollution management	
Property containment measures	While property containment measures can be effective, many businesses, particularly small to medium ones fail to install these. These measures should be incorporated when designing new industrial estates.
Rural land management	
Riparian buffer/ swales	Riparian buffers and swales are used regularly across the region to improve water quality. Recent research indicates that setbacks should be wider in areas where higher or more concentrated flows are expected. Maintaining dense vegetation at the ground surface reduces erodibility and improves flow interception Re-planting with shade-tolerant species can be considered to improve density. In high relief landscapes, with narrow buffers, pollutants from groundwater are unlikely to be significantly mitigated by buffers. In these circumstances, at source methods of control including fertiliser application management should be the focus.
Gully erosion control	Gully erosion control involves stabilising erosion and managing surface flow from the catchment. The intervention has been applied in the Melbourne region but recent research has identified improvements to design. Installing fencing along gullies can provide water quality benefits regardless of the width by excluding cattle from the stream bed and adjacent banks. Where stock exclusion is not possible rotational grazing (managing grazing pressure) can improve sediment, nutrient and microbial water quality. Lessons regarding width and design for riparian buffers also have application for this intervention.
Access management	
Signage	The use of QR codes on signs is gaining momentum in natural resource management as a way to provide more information to interested members of the community, encourage action to be taken (e.g. download Frog census app to monitor frogs) and to track engagement.

Table 46. Interventions that have been tested through research or pilot programs but not applied widely.

Intervention	Rationale
Vegetation establishment and management	
Direct seeding	Direct seeding has had limited application in the region as it can be difficult to use in riparian areas. Direct seeding is effective for establishing overstory on large, flat, and accessible sites, but its success can be limited by weed competition. There is potential to use direct seeding more broadly where the settings are appropriate and if the primary objective is the establishment of overstorey. Supplementary planting shade tolerant understorey species using tube stock could be considered after establishment.
Reprofiling (saltmarsh)	Reprofiling has had limited application in the Melbourne region. The method can be effective if it provides the right level of inundation and water regime. Reprofiling and shaping of the western lagoon at the Western Treatment Plant has helped facilitate natural recolonisation of saltmarsh through the creation of hydraulic conditions beneficial for the community. Monitoring of Western Lagoon has demonstrated that the technique is very successful and is progressing towards a functioning ecosystem comparable to adjoining areas of remnant saltmarsh.

Intervention	Rationale
Weed control	
Alternative chemical weed control	Alternative chemical treatment is used by a few councils in suburban or high public use areas. It involves the use of biodegradable products such as acetic acid, pelargonic acid and manuka oil to kill weeds. A review of literature indicates they are most effective on small annuals and broadleaf species but are less effective for the control of large established perennial species or grasses. There is opportunity to incorporate alternative treatments in combination with other weed control techniques as part of an integrated program.
Pest animal control	
Lethal control (deer) Exclusion fencing (deer / rabbits)	Both lethal control and exclusion fencing have been applied in the Melbourne region to control deer in specific locations and circumstances. A recent review of literature found that non-lethal strategies are only effective over the short-term (weeks) and those that are effective, generally reduce impacts but do not mitigate them entirely. Exclusion fencing remains the most effective non-lethal method to prevent impacts by deer provided they are constructed appropriately and are regularly check and maintained. However, the technique is costly and thus usually limited to small and medium-sized projects. Lethal control through ground-shooting can effectively reduce deer densities and impacts but requires sufficient resources over a long period of time.
Channel modifications	
LWD / Fish hotels	LWD reintroduction has only been used at a small number of locations in the Melbourne region, and most were undertaken over 10 years ago. Evaluating the effectiveness of existing structures and reviewing contemporary approaches used in other regions would assist with providing new information to inform future LWD reintroductions.
Instream barrier management	
Barrier operation change	Barrier operation change has not been applied widely in the region but could be used more in the future during periods of high flows. Lessons from the Starvation Creek Weir change of operations indicate that modification to standard operating procedures can be made to enable sediment and coarse particulate organic matter (CPOM) to move through a system. While there are risks associated with potential deoxygenation, research from xx indicates that this can be minimised through timing with high flows. Intervention monitoring could be used to understand how to minimise the risks and the potential benefits to environmental values and maintenance costs.
Floodplain/wetland flow management	
Structural flow intervention	Structural flow interventions (diversion weirs, pipes and pumps) have only been trialled as part of research and pilot programs for wetlands and floodplains on the Yarra River. The mixed results indicates potential to be applied in other projects however, they do require detailed understanding and monitoring of the local environment, along with a regular maintenance regime to be effective. In particular, the approach of trialling the intervention before investing in an engineered permanent structure is recommended to enable adaptive management for complex systems.
Industrial pollution management	
Precinct toxicant traps	Precinct toxicant traps in industrial estates are still in the trial phase. They are designed to trap sediment and pollutants and prevent them from entering the stormwater system. They are most effective when used at the start of a treatment train and easy access to the removal of waste products has been factored in.
Swales and raingardens (industrial areas)	There has been limited uptake of lot and streetscape swales and raingardens in industrial areas. They tend to be more suitable for 'light' industrial areas, as the contaminate loading from sites will be too high for these vegetated systems. These treatments can be integrated at low cost within an industrial site.
Stormwater infiltrate and harvest	
Leaky tanks	Leaky tanks have only been installed in a small number of sub-catchments as part of research and trial programs. Lessons from the Dobsons Creek pilot indicate that controls such as leaky tanks and rain tanks positively influenced the stormflow hydrology of small to moderate storm events (2-8mm), however they diminished for large storm events (>20mm). They are best incorporated with other storm control measures and the potential for a 'maintenance lag' needs to be factored in.

Intervention	Rationale
Smart tanks	Smart tanks can be remotely controlled to release water and are being tested as part of the Monbulk Creek smart water network research project. This project is in early stages of implementation but a recent ARC grant provides a unique opportunity to build on this to explore the potential of a market-driven smart-grid of stormwater storages, providing consumers with nonpotable water supply, while financially rewarding them for contributions to flood mitigation and environmental flows to waterways.
Green roof	Green roof interventions have had limited application in the Melbourne region to date, despite great potential to reduce stormwater runoff. Research and monitoring of green roofs in Australia has provided important lessons in adapting designs for the climate and vegetation species. The maintenance requirements for green roofs is complex but recent publication of Australian maintenance guidelines will help to improve understanding of maintenance to ensure to ensure they continue to deliver aesthetic and environmental outcomes.
Litter management	
Litter vacuum	Litter Vacuum is a device used to suck litter from hard to reach areas such as along river banks or reed beds or road verges. A trial application has been completed in the Lower Yarra. The technique is effective at removing litter that is difficult to extract via traditional methods in hard to access areas. There is potential to use this technique more frequently along major waterways that have a wide margin of reeds that trap litter that is difficult and time consuming to remove.
Rural land management	
Farm dam management	Farm dam management has had variable application in the region and involves managing stock access and control of erosion around the dam (i.e. from cattle or the inflow point) as well as planting vegetation and installing floating islands or partly submerged logs for biodiversity outcomes. Research from North East Victoria has shown management through fencing and planting helps to lower levels of nitrogen, turbidity and e-coli counts and increase macroinvertebrate diversity as well as improving farm productivity and weight gain in stock.

Table 47. Interventions that have limited effectiveness or appropriateness.

Intervention	Rationale
Sediment control	
Online treatment wetlands [tertiary treatment]	Research indicates online wetlands consistently fail to meet minimum performance objectives for water quality treatment, with higher water levels, frequent bypassing of stormwater flows and lower vegetation cover than required.
Pest animal control	
Ripping near waterways	Ripping is not a suitable intervention along riverbanks and steep slopes due to the risk of soil erosion or bank instability. May be suitable in other contexts e.g. when used in paddocks or open spaces away from waterways.

Appendix 10: HWS Key Research Areas 2018

Liveability, community engagement, and social research	Stormwater management and flooding	Water Quality	Hydrology and Environmental Flows
Refining our conceptual models and developing tools to support investment in waterway works for recreation and amenity Defining public health and wellbeing benefits of waterway, stormwater and urban cooling programs to support investment decisions Understanding the compatibility between social and environmental values and whether management actions are required to balance potentially competing objectives Understanding demographics, preferences, values and water awareness of our customers to inform waterway works planning and delivery Understanding, involving and supporting volunteers in waterway management to facilitate shared waterway objectives Increasing community awareness and connection to waterways so we have informed, engaged partners Understanding aboriginal cultural values of waterways and establish a framework to better integrate these values in waterway management decision-making	Improve our understanding how system design to prevent flooding needs to alter to accommodate impacts of climate change Improving the stormwater treatment performance and determine the optimal maintenance of WSUD systems Understanding the costs and benefits of various stormwater management interventions for biodiversity, amenity and recreational outcomes Develop improved technologies and systems to support stormwater harvesting and re-use Identifying and addressing institutional and structural barriers to implementation of Integrated Water Management Develop decision support tools to inform the most effective stormwater treatment systems and locations to protect waterway biodiversity, amenity and recreation	Understanding the environmental impacts of pollutants, including contaminants of concern, to inform risk-based management of waterways across the region Quantifying ecosystem services in waterways for improving water quality to better account for the benefits of healthy waterways Develop improved water quality indicators and monitoring methods to better understand the impacts of pollutants on waterway health Developing tools and approaches to assist in strategic planning of pollution management to protect biodiversity, amenity and recreation in waterways across the region Understanding and managing public health risks from recreation along waterways in the region Understanding the impact of climate change on water quality and management implications for the protection of aquatic biodiversity, amenity and recreation along waterways	Developing improved approaches to flow data collection and data management to support flow management decisions Understanding and mitigating climate change effects on the hydrology of waterways, estuaries and wetlands Improving our understanding of the responses of key environmental values to flow regimes to refine our environmental flow objectives Developing tools and frameworks to assist improved decision-making in the management of flows to meet environmental flow objectives Investigate opportunities for managing stream flows in urban catchments to protect and improve aquatic biodiversity, amenity, recreation and reduce flooding Improved understanding of the hydrology of floodplains, wetlands and estuaries, including groundwater-surface water interactions to protect and improve aquatic biodiversity Improved understanding of the flow requirements of estuaries to develop and refine environmental flow objectives Explore opportunities to integrate methods for determining ecological flows objectives in urban and rural streams to improve approaches to objective setting across both stream types

Riparian Vegetation and Instream Habitat	Wetlands and Estuaries	Other Aquatic Biodiversity	Port Phillip and Western Port
Understand the potential impacts of climate change on riparian vegetation communities and opportunities to effectively build resilience or transition vegetation communities Understand the impact and effective management of pest plants and animals on riparian vegetation Develop decision support tools to support improved investment in riparian and instream habitat activities and locations Identify critical constraints to revegetation success and opportunities to improve vegetation outcomes Improved understanding of instream habitat conditions, threats and processes across the region to inform works planning	Developing strategic decision-making tools and frameworks for the prioritisation of management interventions for wetlands and estuaries Improving our understanding of management techniques that are most effective for protecting and improving the ecological health of wetlands and estuaries Developing improved monitoring, assessment and reporting methods to understand environmental conditions and values of wetlands and estuaries	Improving our understanding of critical ecological processes and ecology of key species to improve our conceptual and quantitative models Understanding the unintended consequences of our management activities on aquatic biodiversity to inform works planning and programming to reduce impacts on environmental values Understanding areas of high biodiversity significance (e.g. Melbourne Water's Sites of Biodiversity Significance, Ramsar) and appropriate management responses to manage key threats to environmental values	Undertake priority research projects identified in the Port Phillip Environmental Management Plan Undertake priority research projects identified in the Western Port Environment Science Review and synthesis report Undertake priority research projects identified in the Ramsar management plans for the Port Phillip and Westernport region

Appendix 11: Waterways and Wetlands Research Projects 2018-2023

Table 48. Mapping of Waterways and Wetlands Research Projects 2018-2023 Healthy Waterways Strategy Key Research Areas.

Riparian Vegetation and Instream Habitat	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
Impacts of climate change on riparian vegetation communities			■									■																																							
Impact and effective management of pest plants and animals on riparian vegetation			■						■																																										
Decision support tools to support investment in riparian and instream habitat	■												■			■																																	■		
Constraints to revegetation success and opportunities to improve outcomes			■							■																								■							■					■	■				■	
Instream habitat conditions, threats and processes across the region					■			■																																				■						■	
Stormwater management and flooding																																																			
System design to prevent flooding and accommodate climate change																		■																															■		
Improving the stormwater treatment performance and maintenance of WSUD															■		■			■				■																											
Costs and benefits of various stormwater management interventions	■						■						■				■	■							■																								■		
Technologies and systems to support stormwater harvesting and re-use															■		■	■																															■		
Institutional and structural barriers to implementation of IWM																				■																													■		
Develop decision support tools to inform stormwater treatment systems and locations	■													■										■																											
Water Quality																																																			
Environmental impacts of pollutants, including contaminants of concern																										■	■	■			■										■	■	■								
Quantifying ecosystem services in waterways for improving water quality								■								■																																			
Improved water quality indicators and monitoring methods													■	■												■				■		■				■			■				■								
Tools and approaches to assist in strategic planning of pollution management																■							■	■	■	■						■	■						■					■							
Managing public health risks from recreation along waterways																																	■																		
Impact of climate change on water quality and management implications																																			■									■							
Hydrology and Environmental Flows																																																			
Data collection and data management to support flow management																																																			
Mitigating climate change effects on the hydrology of waterways, estuaries and wetlands																																			■												■				
Responses of key environmental values to flow regimes				■							■																																				■				
Tools and frameworks to assist the management of environmental flows	■																	■																																	
Managing stream flows in urban catchments	■						■						■		■																																				
Hydrology of floodplains, wetlands and estuaries, including groundwater-surface water				■		■																																													
Flow requirements of estuaries to develop and refine environmental flow objectives																																															■				
Methods for determining ecological flows objectives in urban and rural streams							■																																												
Liveability, community engagement, and social research																																																			
Conceptual models and tools to support investment in works for recreation and amenity																																																			
Public health and wellbeing benefits of waterway, stormwater, urban cooling programs																						■																											■		
Compatibility between social and environmental values and management implications																																																			
Demographics, preferences, values and water awareness of our customers																				■		■																													
Understanding, involving and supporting volunteers in waterway management																			■																																
Community awareness and connection to waterways																																																			
Aboriginal cultural values of waterways to inform waterway management decision-making				■																	■																														■
Wetlands and Estuaries																																																			
Decision-making tools and frameworks for the prioritisation of management interventions	■																																																		
Most effective management techniques for ecological health of wetlands and estuaries	■			■							■																													■					■	■					
Improved conditions monitoring, assessment and reporting methods																																				■	■														
Other Aquatic Biodiversity																																																			
Critical ecological processes and ecology of key species	■	■			■								■																								■	■									■				
Unintended consequences of our management activities on aquatic biodiversity																															■																				
Areas of high biodiversity significance and appropriate management responses																													■							■		■													
Port Phillip and Western Port																																																			
Research projects identified in the Port Phillip Environmental Management Plan																																																■			
Research projects identified in the Western Port Environment Science Review/synthesis														■																						■				■	■	■	■	■			■				
Research projects identified in the Ramsar management plans for the region																																																			

Appendix 12: Prioritisation approach for knowledge gaps

Prioritisation approach for monitoring and investigations knowledge gaps

Following the integration of the monitoring and investigations knowledge gaps identified during the mid-term evaluation of the Healthy Waterways Strategy into the Science Inquiry, the next key steps will be to (see figure below):

- Develop a monitoring and investigations plan to address the new knowledge gaps, including the prioritisation of knowledge gaps (see below)
- Include the outcomes of the monitoring and investigation plan into the Healthy Waterways Strategy mid-term evaluation Response Report.
- Update (and report on) the MERI Framework and MEPs based on the monitoring and investigations plan

To assist in the development of the monitoring and investigation plan, it is proposed that knowledge gaps be assigned as Priority 1–3 based on the number of the following criteria that apply:

Importance - for example:

- Required for delivering the current Healthy Waterways Strategy (near-term)
- Required for developing the next strategy (near-term) or future strategies (long-term)
- relates to a mid-term evaluation major threat or substantial value decline
- provides benefits to multiple strategies e.g. IWM, flooding, Regional Catchment Strategy

Feasibility - for example:

- there is an existing Melbourne Water team with a clear responsibility for addressing the knowledge gap
- there is an existing budget to address the knowledge gap
- there are established protocols and methods to address the knowledge gap

Cost - for example:

- low cost relative to benefit
- can be efficiently addressed by leveraging an existing monitoring or investigation program
- substantial leverage of funds is likely or known to be possible

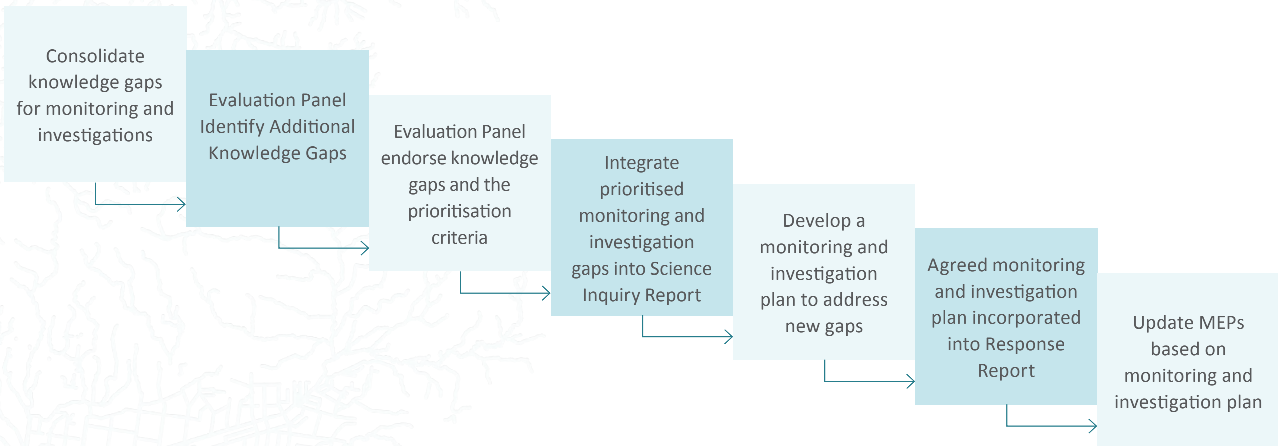

Figure 59. Steps to Consolidate, Review, Plan and Deliver Monitoring and Investigations Knowledge Gaps Identified during the mid-term review of the Healthy Waterways Strategy.

Prioritisation approach for the research knowledge gaps

Following the integration of the research knowledge gaps identified during the mid-term review of the Healthy Waterways Strategy into the Science Inquiry, the next key steps will be to (see figure below):

- Similar to research planning workshops conducted in 2018, undertake research planning workshops in June 2023 for the two major waterways and wetlands research Partnerships (MWRPP and A3P) to prioritise research knowledge gaps under Key Research Areas. These workshops will be attended by both relevant Melbourne Water teams and research partners – with Melbourne Water staff determining knowledge gap priorities and researchers helping to facilitate discussions. Once priorities are determined, the research Partnerships will co-develop research proposals with Melbourne Water for further prioritisation where necessary, to ultimately set the five-year program. The direction and proposed outputs of each project will be reviewed annually as part of a prospectus document for Melbourne Water.
- Once the new research projects have been identified, the previous and new research projects will be mapped against the revised Key Research Areas and incorporated into the Healthy Waterways Strategy mid-term review formal response.

Research priorities are principally directed towards management activities that have a high level of investment, but a low-level of knowledge of the most effective way to undertake the activity. Similarly, research may be directed towards high-investment activities for which the range of potential outcomes is not fully understood. Research knowledge gaps identified during the mid-term evaluation of the Healthy Waterways Strategy will be prioritised during the planning workshops with the following criteria in mind:

Research has been adequately addressed (i.e. knowledge sharing or a literature review may be sufficient).

Importance - for example:

- an area of high investment by the HWS but low confidence in management outcomes
- for delivering the current Healthy Waterways Strategy
- for developing the next strategy
- relates to a mid-term evaluation major threat or substantial value decline
- provides benefits to multiple strategies (e.g. IWM, flooding, Regional Catchment Strategy)

Feasibility - for example:

- research can be delivered within the life of the Strategy
- could be delivered by one of the existing Partnerships (either with the current expertise, or through a collaboration with known researcher from another institution)

Cost - for example:

- low cost relative to benefit
- substantial leverage of funds is likely or known to be possible
- synergies or dependencies with other projects can reduce costs

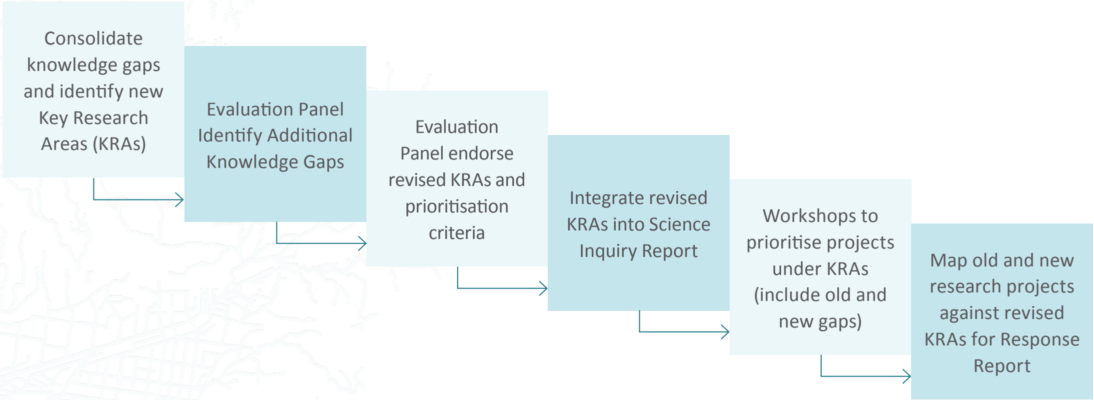

Figure 60. Steps to Consolidate, Review, Plan and Deliver Research Knowledge Gaps Identified during the Mid-term evaluation of the Healthy Waterways Strategy.

Appendix 13: Monitoring and Investigations Knowledge Gaps

Table 49. Monitoring and Investigations Knowledge Gaps Identified During the Mid-term evaluation of the Healthy Waterways Strategy.

Knowledge gap ID	Description	Research/ Investigation/ Monitoring	Discussion Paper/ Factsheet
1	Quantifying the effects of our revegetation, relative to the natural variation caused by rainfall fluctuations.	Investigation	Riparian Birds Technical Paper
4	Understanding the likely causes of declines and increases in Riparian Bird Index (RBI) scores in selected sub-catchments	Investigation	Riparian Birds Technical Paper
7	Effectiveness of community-based bird surveys relative to professional counts	Investigation	Riparian Birds Technical Paper
8	A base level of fish monitoring be prioritised to support fish occupancy models to all major catchments as well as confidence in the model estimates	Monitoring	Fish Technical Paper
9	Investigate how conditions and threats explain the observed patterns from the fish occupancy models	Investigation	Fish Technical Paper
11	Investigate opportunities for a more pro-active approach to fish habitat restoration and if new performance objectives in priority locations should be considered.	Investigation	Fish Technical Paper
12	Investigate sites where there have been substantial decreases or increases in aquatic macroinvertebrate condition scores in order to better understand causal factors (prioritising declining sites)	Investigation	Macroinvertebrates Technical Paper
13	Ensure annual data collection for monitoring sites where trends are uncertain and review trends by 2025. If confidence in the trends increases add to the list of sites to investigate causal factors	Monitoring	Macroinvertebrates Technical Paper
14	Acquire impervious surface spatial mapping data across the region, including historical data, in order to track urban development in new and existing (infill) urban areas	Monitoring	Macroinvertebrates Technical Paper
15	Conduct live-trapping surveys in the Lang Lang and Cardinia systems, and at all other locations as described in the Rivers MEP, and re-assess trajectory when sufficient data is available	Monitoring	Platypus Technical Paper
16	Continue eDNA monitoring in sub-catchments where platypus are considered to be effectively extinct (Plenty River (Source) and Deep Creek Upper). There may be a need to review performance objectives and communicate this information	Monitoring	Platypus Technical Paper
17	Investigate the sustainable diversion limits in unregulated sub-catchments that support platypus (e.g. Deep Creek Upper) and identify what more can be done to protect platypus in unregulated waterways	Investigation	Platypus Technical Paper
18	Undertake eDNA surveys in lower Emu Creek where platypus are known to occur	Monitoring	Platypus Technical Paper

Knowledge gap ID	Description	Research/ Investigation/ Monitoring	Discussion Paper/ Factsheet
19	Investigate the relationship between in-stream habitat condition and platypus condition	Investigation	Platypus Technical Paper
21	Understand the potential effect of practitioner changes and sampling effort variability on platypus captures in the long-term datasets	Investigation	Platypus Technical Paper
22	Investigate alternative metrics to CPUE for representing platypus community and population abundance	Investigation	Platypus Technical Paper
25	Evaluating the success of reintroductions/translocations, particularly for genetic management of populations	Investigation	Platypus Technical Paper
26	Investigate the feasibility of re-introducing platypus to Toorourrong Reservoir	Investigation	Platypus Technical Paper
27	Undertaking additional surveys to 'fill the data gaps' at targeted sub-catchment locations (e.g. on-site intercept surveys or collaborating with and interviewing local groups about their experiences)	Monitoring	Social Values Technical Paper
28	Investigate further the use of visitation (GIS) data and continue to collect every year to provide multiple timeframes to compare and analyse	Monitoring	Social Values Technical Paper
29	Understand Traditional Owner values through separate perceptions surveys or conducting targeted and collaborative engagements with individual Traditional Owner groups relevant to waterway catchments	Investigation	Social Values Technical Paper
30	Investigate opportunities to refine social values conceptual models for wetlands	Investigation	Social Values Technical Paper
31	Assess priority wetlands (i.e. Typology 3 - amenity/ recreation primary purpose wetlands) against desired levels of service (for that wetland type) using the social values of wetlands conceptual model to inform investment and management needs	Monitoring	Social Values Technical Paper
32	Complete a Cost Benefit Analysis (CBA) to assess the economic, social, and environmental impact of social value interventions for wetlands in Melbourne Water catchment areas	Investigation	Social Values Technical Paper
34	Undertake further investigations and additional surveys to understand the key factors leading to Kananook Creeks decline in social values	Investigation	Social Values Technical Paper
35	Explore why amenity is lagging in the Werribee Catchment and identify the conditions that could lead to priority interventions and improvements	Investigation	Social Values Technical Paper
36	Understand why Maribyrnong River Lower satisfaction scores are all following a declining trajectory, in particular why Moonee Ponds Creek sub-catchment has a substantially low community connection satisfaction score (in 2022)	Investigation	Social Values Technical Paper
37	Further sub-catchments in Westernport and Peninsula need to be measured to ensure a better representation of this catchment in the dataset	Monitoring	Social Values Technical Paper

Knowledge gap ID	Description	Research/ Investigation/ Monitoring	Discussion Paper/ Factsheet
38	Following implementation of the Lower Dandenong Litter Collaboration, monitor and compare litter satisfaction ratings within the Dandenong Creek Catchment against other catchments for the end of strategy review	Monitoring	Social Values Technical Paper
39	Further investigations and improvements to the social values framework, including methods for how social values are measured should consider how the availability of on-ground assets, facilities and activities can support or build on qualitative data on community satisfaction	Investigation	Social Values Technical Paper
40	Understanding how we better measure the social values of waterways to expand beyond just the Community Perceptions Survey, tapping into other data sources (e.g. digital data, human movement data) or building in targeted surveys that dive-deeper into specific social values topics	Monitoring	Social Values Technical Paper
41	Adopt the new A3P litter monitoring framework method across the region	Monitoring	Social Values Technical Paper
44	Better understand community connections to cultural activities	Investigation	Social Values Technical Paper
45	Actively recruit under-represented groups in social surveys	Monitoring	Social Values Technical Paper
46	Further investigations are required to understand the relationships between access and facilities (i.e. pathways) and delve into factors that could better measure access performance in 'wilderness' catchment typologies (e.g. visitation data versus community perceptions analysis)	Investigation	Social Values Technical Paper
48	Determine the extent and connectivity of the area of new high value vegetation reaches that should be included in the HWS Protection areas	Investigation	Vegetation Technical Paper
49	Understand the apparent decline in vegetation condition in some priority areas, and if confirmed, understand what may be causing the decline	Investigation	Vegetation Technical Paper
50	Better understand the extent of low regeneration of vegetation at some sites	Investigation	Vegetation Technical Paper
52	Assess the current vegetation data (and where appropriate other associated data for revegetation and fauna) and develop a database that is able to adequately collect this information	Investigation	Vegetation Technical Paper
53	Investigate the 2 sites which showed low connectivity but high-quality vegetation condition scores to confirm there are no methodological issues	Investigation	Vegetation Technical Paper
54	Continue to improve data and give further consideration of available spatial data, quantum/costs of management action, expert opinion, and economic analysis to increase the power of the wetland prioritisation decision tool	Investigation	Wetlands Technical Paper
55	Investigate why Paradise Road Ponds at the WTP and Truganina Swamp that are 'off-track' (i.e. two or more categories below the 2018 benchmark) – i.e. 'High chance that long-term targets will not be met'	Investigation	Wetlands Technical Paper

Knowledge gap ID	Description	Research/ Investigation/ Monitoring	Discussion Paper/ Factsheet
58	Melbourne Water continues to develop the Wetland Bird Index using Summed Reporting Rate for the Basic Score as a useful means of tracking the condition of wetland bird communities over time using bird data	Monitoring	Wetlands Technical Paper
59	Where possible/available, the data used in analyses for the Wetland Bird Index should include sites surveyed at least 40 times	Monitoring	Wetlands Technical Paper
60	For the Wetland Bird Index, consider a weighting system for identifying 'listed' species, such that species listed as threatened under the Commonwealth EPBC Act 1999 and the Victorian FFG Act 1988, are provided more weight than species listed only under the Migratory Schedules (i.e. not threatened) under EPBC Act	Monitoring	Wetlands Technical Paper
61	For the Listed Species sub-index, Melbourne Water considers, for completeness and because it is a dynamic document and often a precursor to a threatened species being listed under the EPBC Act 1999, incorporating the Conservation Statuses of threatened wetland bird species provided in the National Action Plan for Australian Birds (Garnett et al. 2020)	Monitoring	Wetlands Technical Paper
62	Understand drivers behind wetland bird community change at the site level (and subsequent wetland bird index score changes) by incorporating site-based management data (e.g. water levels, salinity, vegetation works, nutrient levels)	Investigation	Wetlands Technical Paper
64	Review our wetlands to focus monitoring on – our high value, "priority" or regionally significant wetlands. At the very least, certain wetlands need to be removed since we now know they have been altered and/or lost the values for which they were noted.	Monitoring	Wetlands Technical Paper
65	Remove constructed wetlands and waterbodies, (e.g. urban lakes from the IWC assessments as these are monitored via Melbourne Water's asset management framework which focuses on system performance). These wetlands will not be part of the end of strategy HWS condition assessments	Monitoring	Wetlands Technical Paper
66	All wetland assessments undertaken for other reasons (e.g. planning for growth should include a standard IWC assessment, and these data should be made available to the monitoring team as early as possible)	Monitoring	Wetlands Technical Paper
67	Regularly update and maintain the waterbodies spatial inventory to ensure ongoing utility and reliability for management and research applications	Monitoring	Wetlands Technical Paper
69	Undertake additional surveys in the south-east area of the Port Phillip and Western Port region where a number of the frog HSMs suggest high habitat suitability but where there are relatively few surveys	Monitoring	Wetlands Technical Paper
78	To improve HSMs we need to improve predictions of future development including development densities for shorter time periods (e.g. 10 years in addition to full development)	Investigation	Threats Paper
79	Reporting of stormwater treatment outside of priority areas	Investigation	Threats Paper

Knowledge gap ID	Description	Research/ Investigation/ Monitoring	Discussion Paper/ Factsheet
82	As part of the review of the Emu Creek performance objective we will conduct an analysis to determine where new industrial areas are proposed in greenfield areas and whether appropriate performance objectives exist to address this new emerging threat have been included in relevant sub-catchment	Investigation	Threats Paper
94	Monitoring data on flow extractions in unregulated systems	Monitoring	Threats Paper
95	Understanding management levers and policy options for managing flows in unregulated systems	Investigation	Threats Paper
96	The ability to provide "manufactured" water to irrigation areas and potentially reduce flow stress from extraction is dependent on government direction which is still unclear	Investigation	Threats Paper
104	Improved mapping of barriers across the region	Investigation	Threats Paper
106	Better characterisation of partial versus full barriers in our barrier mapping	Investigation	Threats Paper
108	Data on recreational access to waterways across the region	Monitoring	Threats Paper
110	ROMP intervention monitoring to better understand the threat from deer and benefits of interventions	Monitoring	Threats Paper
114	Tracking loss of vegetation through time by aerial/satellite imaging	Monitoring	Threats Paper
117	Monitor Capital Works sites to assess the outcomes of management interventions to provide information on how restored areas develop over time and the factors likely to impact restoration outcomes	Monitoring	A2 sub. Monitoring, Evaluation, Reporting and Improvement (MERI) for Riparian Revegetation
118	Develop monitoring of faunal species (especially birds and macroinvertebrates) at nominated vegetation condition and revegetation sites	Monitoring	A2 sub. Monitoring, Evaluation, Reporting and Improvement (MERI) for Riparian Revegetation
119	Understanding the impacts of weeds, pest animals such as deer, stock and rabbits, and climate change on restored and remnant habitats.	Monitoring	A2 sub. Monitoring, Evaluation, Reporting and Improvement (MERI) for Riparian Revegetation
122	Better align Vegetation Visions detailed monitoring with ROMP methods	Monitoring	A2 sub. Monitoring, Evaluation, Reporting and Improvement (MERI) for Riparian Revegetation
124	Incorporate the inclusion of instream vegetation cover into 'regular' geomorphic and biological monitoring programs	Monitoring	B1 Urban flow ecology: Investigating relationships between flow, channel form, instream vegetation and ecosystem function
130	Ecohydrological investigation of potential instream structures	Investigation	D4 Yellingbo hydrology works MERI program

Knowledge gap ID	Description	Research/ Investigation/ Monitoring	Discussion Paper/ Factsheet
133	Test spatial analysis of statistical and mechanistic models by planting species in predicted refugia and monitoring establishment success and survivorship over time	Monitoring	D5 Modelling the risk of climate change to key revegetation species
140	Hydraulic assessment of wetland assets to confirm the frequency of bypass	Investigation	B3 Optimising constructed wetland design, management and performance prediction
141	Vegetation cover data be collected annually and integrated into the WAVE tool	Monitoring	B3 Optimising constructed wetland design, management and performance prediction
143	Develop a low-cost water level monitoring network to identify affected wetlands	Monitoring	B3 Optimising constructed wetland design, management and performance prediction
145	Investigate alternative wetland configurations which can de-water the macrophyte zone even when receiving water levels are high	Investigation	B3 Optimising constructed wetland design, management and performance prediction
146	Undertake source-tracking investigations in catchments, before investing in water quality improvement works	Investigation	C2 Effectiveness of rural land interventions to improve stream flows and water quality
147	Review the metrics in the Rural Land Management Program spreadsheet to take into account recent research	Investigation	C2 Effectiveness of rural land interventions to improve stream flows and water quality
150	Understanding how might we support and evaluate the range and depth of value that participants offer citizen science programs and the management of waterways (i.e. beyond the rate of participation and the number of biodiversity records submitted)	Investigation	E1 The impacts of 'next generation' citizen science programs
151	Understanding how might we support and evaluate the outreach performed by program participants through to non-participants (e.g. education and awareness)?	Investigation	E1 The impacts of 'next generation' citizen science programs
152	Understanding how might we support citizen scientists in using data from these programs as evidence in advocating for their local waterways and wetlands?	Investigation	E1 The impacts of 'next generation' citizen science programs
157	Combine knowledge of what contaminants accumulate in wetland sediments and how they influence desilting, waste disposal and maintenance costs to help inform management protocols	Investigation	A1.2 Develop efficient and effective indicators and approaches to monitor the performance of stormwater wetlands
160	Use knowledge of toxicant concentrations in water to inform stormwater reuse and recycling schemes	Investigation	A1.2 Develop efficient and effective indicators and approaches to monitor the performance of stormwater wetlands

Knowledge gap ID	Description	Research/ Investigation/ Monitoring	Discussion Paper/ Factsheet
164	Identify the major sources of pollutants from high-risk industrial estates	Investigation	A1.5 Identification of cost-effective opportunities for addressing pollutants from industrial catchments
167	The annual use of passive samplers in routine monitoring programs is recommended as this can be used to gather information on a suite of serious pollutants that are currently not screened in the current water quality monitoring programs	Monitoring	B1.1 Identifying and managing emerging contaminants of concern
168	Annual survey of sediment quality (heavy metals, pesticides, personal care products, petroleum hydrocarbons) at all water quality monitoring sites	Monitoring	B1.1 Identifying and managing emerging contaminants of concern
169	Understand the levels of contaminants in waters and sediments of Port Phillip to determine whether they pose a threat to the Bay ecosystems.	Monitoring	B1.1 Identifying and managing emerging contaminants of concern
177	Provide recommendations about potential new metrics for water quality targets and reporting	Investigation	C3.3 Developing methods to increase the efficiency and effectiveness of waterway health assessment within streams, wetlands and estuaries
178	Trial the development of an integrated vegetation management plan for Melbourne Water's business which incorporates current research findings on alternative vegetation management approaches	Investigation	E2.4 What are the effects of chemicals frequently used by Melbourne Water on or near waterways on aquatic ecosystems and public health?
184	Streamline the QMRA methodology for broader application beyond the Yarra River	Investigation	Lower Yarra recreational water quality
185	Develop site-specific objectives for the Yarra River that better represent health risk, as an alternative to the state-wide objectives in the Environment Reference Standard.	Investigation	Lower Yarra recreational water quality
186	Use of pathogen concentrations, rather than faecal indicators for future monitoring of recreational water quality	Monitoring	Lower Yarra recreational water quality
194	Install long-term flow gauges in upper catchment reaches (perennial and non-perennial) to better understand impacts of climate change on flow regimes, including monitoring of water quality changes	Monitoring	Macroinvertebrates Discussion Paper

Appendix 14: Research Knowledge Gaps Identified

Table 50. Research Knowledge Gaps Identified During the Mid-Term Evaluation of the Healthy Waterways Strategy.

Knowledge gap ID	Description	Discussion Paper/ Factsheet	Research Theme	Key Research Area
2	The nature and extent of the threat posed to insectivorous birds by pesticides in the environment, particularly newer persistent compounds	Riparian Birds Discussion Paper	Water quality	Understanding the environmental impacts of pollutants, including contaminants of concern, to inform risk-based management of waterways across the region
3	The nature and extent of the threat posed to riparian bird communities by increased human visitation to waterways (a key HWS objective)	Riparian Birds Discussion Paper	Liveability, community engagement and social research	Understanding the compatibility between social and environmental values and whether management actions are required to balance potentially competing objectives
5	Understanding of the relationship between water quality and hydrology, and riparian birds	Riparian Birds Discussion Paper	Other Biodiversity	Improving our understanding of critical ecological processes and ecology of key species to improve our conceptual and quantitative models
6	Investigating the effectiveness of streamside management, as practised by Melbourne Water, and riparian bird responses	Riparian Birds Discussion Paper	Other Biodiversity	Improving our understanding of critical ecological processes and ecology of key species to improve our conceptual and quantitative models
10	Gain an understanding of the benefits to environmental flow plans when interactions among multiple species (meta-community perspective) are accounted for. Reword: Understand the benefits when multi-species interactions (meta-community perspective) are accounted for in environmental flow plans	Fish Discussion Paper	Hydrology and Environmental Flows	Improving our understanding of the responses of key environmental values to flow regimes to refine our environmental flow objectives
20	Investigate the relationship between macroinvertebrate condition (abundance and diversity), water quality and platypus	Platypus Discussion Paper	Other Biodiversity	Improving our understanding of critical ecological processes and ecology of key species to improve our conceptual and quantitative models
23	Investigate the relationship between platypus populations and macroinvertebrate communities	Platypus Discussion Paper	Other Biodiversity	Improving our understanding of critical ecological processes and ecology of key species to improve our conceptual and quantitative models
24	Understand the carrying capacity and minimum habitat patch size required to support a self-sustaining population.	Platypus Discussion Paper	Other Biodiversity	Improving our understanding of critical ecological processes and ecology of key species to improve our conceptual and quantitative models

Knowledge gap ID	Description	Discussion Paper/ Factsheet	Research Theme	Key Research Area
33	Better understand the relationship between human wellbeing and wetland health to inform the potential adoption of wellbeing as a social value in the HWS	Social Values Discussion Paper	Liveability, community engagement and social research	Defining public health and wellbeing benefits of waterway, stormwater and urban cooling programs to support investment decisions
42	Undertake further investigations to better understand these causal links between conditions (e.g. litter and access) and how that impacts social values (perceptions and realities)	Social Values Discussion Paper	Liveability, community engagement and social research	Refining our conceptual models and developing tools to support investment in waterway works for recreation and amenity
43	A new approach needs to be tested which combines the qualitative insights captured from community perception surveys with known, tangible conditions such as built assets	Social Values Discussion Paper	Liveability, community engagement and social research	Understanding demographics, preferences, values and water awareness of our customers to inform waterway works planning and delivery
47	Continue to invest in data, technology and research that allows vegetation value (condition and extent) to be evaluated frequently over large scales and over time (including back casting)	Vegetation Discussion Paper	Streamside vegetation and instream habitat	Develop remote sensing monitoring methods to better understand changes in vegetation condition and extent across the entire region
51	Better understand how instream vegetation is influenced by stream order, flow and terrestrial vegetation	Vegetation Discussion Paper	Streamside vegetation and instream habitat	Improved understanding of instream habitat conditions, threats and processes across the region to inform works planning
56	Understand the risk of contaminants in several WTP habitat ponds and also Edithvale Wetlands and Banyan Waterhole to waterbirds in our Ramsar sites	Wetlands Discussion Paper	Other Biodiversity	Understanding areas of high biodiversity significance (e.g. Melbourne Water's Sites of Biodiversity Significance, Ramsar) and appropriate management responses to manage key threats to environmental values
63	Develop remote sensing to collect data for the wetland extent metric and ensure data for other metrics (e.g. IWC vegetation condition) and threatened species is ready for final strategy evaluation	Wetlands Discussion Paper	Wetlands and estuaries	Developing improved monitoring, assessment and reporting methods to understand environmental conditions and values of wetlands and estuaries
68	Finalise HSM for frogs, birds and fish, and develop decision support tools like zonation to aid in management scenarios for wetlands	Wetlands Discussion Paper	Wetlands and estuaries	Developing strategic decision-making tools and frameworks for the prioritisation of management interventions for wetlands and estuaries

Knowledge gap ID	Description	Discussion Paper/ Factsheet	Research Theme	Key Research Area
70	Further develop the environmental data library to include HSM predictors we expect to be influential, such as measures of impervious cover within the catchment areas of waterbodies. As well as predictors we would like to use to explore future scenarios of interest such as those associated with aspects of climate change impact	Wetlands Discussion Paper	Wetlands and estuaries	Developing strategic decision-making tools and frameworks for the prioritisation of management interventions for wetlands and estuaries
71	Validate the HSMs using averaged model predictions from specific time periods, rather than averages of the predictor variables over a time	Wetlands Discussion Paper	Wetlands and estuaries	Developing strategic decision-making tools and frameworks for the prioritisation of management interventions for wetlands and estuaries
72	Consider other approaches to assessing climate change impacts as the HSMs will only provide partial ability to explore potential climate change impacts and mitigating actions (e.g. they will not provide the capability to model the impacts of extreme events such as fire, heatwaves, 'rain bombs', floods, and storm surges).	Wetlands Discussion Paper	Wetlands and estuaries	Understanding the potential impacts of climate change on wetland health and mitigation options
73	Once the HSMs are finalised further analysis of representativeness across the region with respect to species should be carried out	Wetlands Discussion Paper	Wetlands and estuaries	Developing strategic decision-making tools and frameworks for the prioritisation of management interventions for wetlands and estuaries
74	Future analyses, incorporating the results of HSMs, could investigate the potential for waterbodies or regions to be refuge areas for particular species during dry conditions	Wetlands Discussion Paper	Wetlands and estuaries	Developing strategic decision-making tools and frameworks for the prioritisation of management interventions for wetlands and estuaries
75	Further develop the change detection methodology to determine its accuracy and applicability to flag wetlands where substantial changes in open water may have occurred and could be subject to follow up investigations	Wetlands Discussion Paper	Wetlands and estuaries	Develop remote sensing monitoring methods to better understand changes in wetland condition across the region

Knowledge gap ID	Description	Discussion Paper/ Factsheet	Research Theme	Key Research Area
76	Undertake research to better understand the impacts of urbanisation and to define appropriate buffer distances and the measures required to maintain and improve values of differing sensitivity to human and vehicle movement, noise, lighting, introduced predators etc. In absence of this information, design responses in urban developments may miss the mark.	Wetlands Discussion Paper	Stormwater management and flooding	Understanding and managing the threat of urbanisation to floodplain function, wetlands and headwater streams
77	Future research is needed to understand how the effectiveness of different intervention techniques could potentially be impacted by climate change.	Interventions Paper	All	Understanding the impact of climate change and management implications for the protection of aquatic biodiversity, amenity and recreation along waterways
80	Better understand how flow changes associated with climate change will influence the threat of urban stormwater (e.g. increased storm intensity) and how interventions can mitigate these compounding threats (e.g. smart tanks).	Threats Paper	Stormwater management and flooding	Improve our understanding how system design to prevent flooding needs to alter to accommodate impacts of climate change
81	Understanding the barriers to the implementation of HWS stormwater Performance Objectives (e.g. policy, guidance, capacity and funding, sector willingness).	Threats Paper	Stormwater management and flooding	Identifying and addressing institutional and structural barriers to implementation of Integrated Water Management
83	Potential impacts to water quality from residential use of recycled water.	Threats Paper	Water quality	Understanding and managing the impacts of treated and untreated wastewater on waterway health
84	Improve understanding of climate change implications with respect to contaminants	Threats Paper	Water quality	Understanding the impact of climate change on water quality and management implications for the protection of aquatic biodiversity, amenity and recreation along waterways
85	Validate relevant chemical indicators of sewage pollution.	Threats Paper	Water quality	Understanding and managing the impacts of treated and untreated wastewater on waterway health
86	Refine passive sampling methods - move from semi-quantitative (presence/absence) to quantitative assessments (to report data as a concentration).	Threats Paper	Water quality	Develop improved water quality indicators and monitoring methods to better understand the impacts of pollutants on waterway health
87	Quantify risks to key environmental values associated with chemicals associated with wastewater	Threats Paper	Water quality	Understanding and managing the impacts of treated and untreated wastewater on waterway health

Knowledge gap ID	Description	Discussion Paper/ Factsheet	Research Theme	Key Research Area
88	Understanding the risks of treated and untreated wastewater into waterway under a changing climate. Including wet and dry weather risks.	Threats Paper	Water quality	Understanding the impact of climate change on water quality and management implications for the protection of aquatic biodiversity, amenity and recreation along waterways
89	Understand risk to waterways from increased use of recycled water for environmental flow purposes and use in residential and agricultural areas.	Threats Paper	Water quality	Understanding and managing the impacts of treated and untreated wastewater on waterway health
90	Quantification sewage overflows from ERSs from both MW and water retailer assets to assess with the threat quantification.	Threats Paper	Water quality	Understanding and managing the impacts of treated and untreated wastewater on waterway health
91	Development of site-specific waterway setbacks that protect floodplain functioning	Threats Paper	Stormwater management and flooding	Understanding and managing the threat of urbanisation to floodplain function, wetlands and headwater streams
92	Understanding implementation barriers for headwater stream and wetland protection	Threats Paper	Stormwater management and flooding	Improved understanding of instream habitat conditions, threats and processes across the region to inform works planning
93	Case studies for 'how to protect' streams from urbanisation. (e.g. Aitken Creek).	Threats Paper	Stormwater management and flooding	Improved understanding of instream habitat conditions, threats and processes across the region to inform works planning
97	Though conceptually sound, the effectiveness of site scale agricultural interventions to reduce sediment and nutrient run-off and protect waterway health is very difficult to measure	Threats Paper	Water quality	Developing tools and approaches to assist in strategic planning of pollution management to protect biodiversity, amenity and recreation in waterways across the region
98	The current rural land metric calculator used in the MW Rural Land Program to estimate sediment and nutrient improvements from projects does not currently estimate benefits in pesticide reduction. Improvements in the metric calculator to include more region-specific information as well as estimated benefits from pesticide reduction would be helpful.	Threats Paper	Water quality	Developing tools and approaches to assist in strategic planning of pollution management to protect biodiversity, amenity and recreation in waterways across the region

Knowledge gap ID	Description	Discussion Paper/ Factsheet	Research Theme	Key Research Area
99	Whilst ambient water quality data is available, little data on threats from pesticides, sediment contaminants and ecotoxicology is available for waterways where high values (e.g. macroinvertebrates, platypus) intersect with rural land use.	Threats Paper	Water quality	Develop improved water quality indicators and monitoring methods to better understand the impacts of pollutants on waterway health
100	Understanding the risk of Antimicrobial Resistance (AMR) to waterway health from agricultural sources	Threats Paper	Other Biodiversity	Understanding the environmental impacts of pollutants, including contaminants of concern, to inform risk-based management of waterways across the region
101	Better understanding of the risk of entrapment for other values (e.g. birds and fish) beyond platypus	Threats Paper	Water quality	Understanding the environmental impacts of pollutants, including contaminants of concern, to inform risk-based management of waterways across the region
102	Understanding how climate change could impact the function of fishways	Threats Paper	Streamside vegetation and instream habitat	Improved understanding of instream habitat conditions, threats and processes across the region to inform works planning
103	Understanding of other barriers such as roads to other values e.g. frogs, birds.	Threats Paper	Other Biodiversity	Understanding the impacts of barriers to dispersal across the landscape on key values
105	Better understanding of fragmentation and population health due to barriers, particularly under climate change scenarios.	Threats Paper	Other Biodiversity	Understanding the impacts of barriers to dispersal across the landscape on key values
107	Genetic studies could help understand population fragmentation and help improve business cases for barrier removal.	Threats Paper	Other Biodiversity	Understanding the impacts of barriers to dispersal across the landscape on key values
109	Better understanding of the threat of recreational access to waterways on key environmental values	Threats Paper	Liveability, community engagement and social research	Understanding the compatibility between social and environmental values and whether management actions are required to balance potentially competing objectives
111	Identifying opportunities for managing invasive fish (e.g. Mosquito Fish).	Threats Paper	Streamside vegetation and instream habitat	Understand the impact and effective management of pest plants and animals on riparian vegetation

Knowledge gap ID	Description	Discussion Paper/ Factsheet	Research Theme	Key Research Area
112	Understanding the likely changes to weed distributions from climate change.	Threats Paper	Streamside vegetation and instream habitat	Understand the potential impacts of climate change on riparian vegetation communities and opportunities to effectively build resilience or transition vegetation communities
113	Understanding the extent and likely impacts of vegetation clearing.	Threats Paper	Streamside vegetation and instream habitat	Develop remote sensing monitoring methods to better understand changes in vegetation condition and extent across the entire region
115	TBC	A1. Spatial prioritisation of management actions for biodiversity outcomes in streams & wetlands		
116	NA	A2. Testing critical assumptions of interventions and outcomes, and designing effective, efficient biodiversity monitoring to support strategy implementation		
120	Understand the ability to use new technologies (LiDAR, high resolution satellite imagery) to monitor the quality and extent of restored habitats over time.	A2 sub. Monitoring, Evaluation, Reporting and Improvement (MERI) for Riparian Revegetation	Streamside Vegetation and Instream Habitat	Develop remote sensing monitoring methods to better understand changes in vegetation condition and extent across the entire region
121	Better forecast and mitigate climate change impacts on remnant and areas of revegetation investment.	A2 sub. Monitoring, Evaluation, Reporting and Improvement (MERI) for Riparian Revegetation	Streamside Vegetation and Instream Habitat	Understand the potential impacts of climate change on riparian vegetation communities and opportunities to effectively build resilience or transition vegetation communities
123	Further investigate past (e.g. analysis of sediment cores to understand historical wetting and drying cycles, vegetation communities and fire regimes) and enhance future Wurundjeri-led management of Birrarung's billabongs.	A2-sub Birrarung's billabongs: vegetation response to environmental watering	Hydrology and Environmental Flows, Liveability, community engagement, and social research	Improving our understanding of the responses of key environmental values to flow regimes to refine our environmental flow objectives, understanding aboriginal cultural values of waterways and establish a framework to better integrate these values in waterway management decision-making
125	Investigate opportunities for real-time monitoring and control of WSUD systems to protect and improve the health of GDEs	B4 Groundwater: understanding the interactions between groundwater, surface water and Groundwater Dependent Ecosystems (GDEs)	Stormwater Management and Flooding	Develop improved technologies and systems to support stormwater harvesting and re-use

Knowledge gap ID	Description	Discussion Paper/ Factsheet	Research Theme	Key Research Area
126	Adoption of benthic algal biomass as an additional measure of ecosystem structure and health through time	C1 How can retention, use and treatment of urban stormwater protect or provide natural flow regimes for waterway health?	Other Aquatic Biodiversity	Developing methods, metrics and strategic management frameworks for waterway function as a key environmental value
127	Extend the analysis of existing and future microbial DNA data to assess the functional role of microbial communities in rates of nutrient processing.	C1 How can retention, use and treatment of urban stormwater protect or provide natural flow regimes for waterway health?	Other Aquatic Biodiversity	Developing methods, metrics and strategic management frameworks for waterway function as a key environmental value
128	Quantify the loss of headwater streams to date and estimate the length of headwater streams that are vulnerable to urban development. In doing so, determine the implications for regional flow, water quality and biodiversity targets.	D1 Understand the role of small headwater streams in urbanizing catchments for supporting waterway health	Streamside Vegetation and Instream Habitat	Improved understanding of instream habitat conditions, threats and processes across the region to inform works planning
129	Develop guidelines for the protection or restoration of headwater streams in urban developments based on project outcomes along with data and knowledge from other related studies.	D1 Understand the role of small headwater streams in urbanizing catchments for supporting waterway health	Streamside Vegetation and Instream Habitat	Develop decision support tools to support improved investment in riparian and instream habitat activities and locations
131	Develop a new management framework that integrates and uses statistical and mechanistic species modelling, climate-matching, species traits and genetic data to build resilience and adaptation to projected future climatic conditions	D5 Modelling the risk of climate change to key revegetation species	Streamside Vegetation and Instream Habitat	Understand the potential impacts of climate change on riparian vegetation communities and opportunities to effectively build resilience or transition vegetation communities
132	Expand mechanistic modelling to all species of interest for revegetation including provenances and species from warmer and drier climates. This requires conducting studies on germination ecology and ecophysiological responses to drought.	D5 Modelling the risk of climate change to key revegetation species	Streamside Vegetation and Instream Habitat	Understand the potential impacts of climate change on riparian vegetation communities and opportunities to effectively build resilience or transition vegetation communities
134	Test the underlying assumption of the climate-matching approach	D5 Modelling the risk of climate change to key revegetation species	Streamside Vegetation and Instream Habitat	Understand the potential impacts of climate change on riparian vegetation communities and opportunities to effectively build resilience or transition vegetation communities
135	Experimentally test different admixture proportions to better understand the short- and long-term implications of implementing climate-adjusted seed-sourcing.	D5 Modelling the risk of climate change to key revegetation species	Streamside Vegetation and Instream Habitat	Understand the potential impacts of climate change on riparian vegetation communities and opportunities to effectively build resilience or transition vegetation communities

Knowledge gap ID	Description	Discussion Paper/ Factsheet	Research Theme	Key Research Area
136	NA	A4 Improving stream management using ecological modelling and DNA barcodes		
137	Development of low-cost monitoring systems to increase the coverage and resolution of data and to provide tools to further assist with adaptive management (e.g. construction sediment control, compliance monitoring, sediment pond maintenance).	B2 Major sources and fate of sediments in streams, wetlands, estuaries and bays to inform management opportunities	Water Quality	Develop improved water quality indicators and monitoring methods to better understand the impacts of pollutants on waterway health
138	Resolve the contributions of different construction phases and activities with long-term monitoring and application of new monitoring systems at finer scales.	B2 Major sources and fate of sediments in streams, wetlands, estuaries and bays to inform management opportunities	Water Quality	Develop improved water quality indicators and monitoring methods to better understand the impacts of pollutants on waterway health
139	Validation of key parameters and processes in the Westernport sediment budget model to contribute to development of plans to meet the SEPP sediment target.	B2 Major sources and fate of sediments in streams, wetlands, estuaries and bays to inform management opportunities	Water Quality	Developing tools and approaches to assist in strategic planning of pollution management to protect biodiversity, amenity and recreation in waterways across the region
142	Investigate real-time control of wetland hydraulic structures to i) restrict inflow when outflow is not possible and ii) harvest treated water from wetlands to rapidly lower water levels and prevent vegetation loss.	B3 Optimising constructed wetland design, management and performance prediction	Stormwater Management and Flooding	Develop improved technologies and systems to support stormwater harvesting and re-use
144	Investigate the impact of removing extended detention zones on treatment performance	B3 Optimising constructed wetland design, management and performance prediction	Stormwater Management and Flooding	Improving the stormwater treatment performance and determine the optimal maintenance of WSUD systems
148	Demonstrate the stormwater capture and infiltration potential of a fully functional ‘leaky’ streetscape with street trees	C5. Re-designing streetscapes for managing stormwater and increasing tree canopy cover	Stormwater Management and Flooding	Develop improved technologies and systems to support stormwater harvesting and re-use
149	NA	C6 Optimised real-time monitoring and control of networked stormwater harvesting systems to augment household water supply, reduce nuisance flooding and provide environmental flows to streams		
153	NA	E3 Long-term effectiveness of WSUD assets on private land		

Knowledge gap ID	Description	Discussion Paper/ Factsheet	Research Theme	Key Research Area
154	NA	E4 Indigenous perspectives and practices in the management of Melbourne's waterways		
155	NA	E5 Community engagement with Melbourne's blue spaces before, during and after the COVID-19 pandemic.		
156	TBC	A1. 1 Synopsis of the sources and impacts of pollutants		
158	Understanding effect of toxicants on wetland performance e.g. biofilms, sediment bacterial communities	A1.2 Develop efficient and effective indicators and approaches to monitor the performance of stormwater wetlands	Stormwater Management and Flooding	Improving the stormwater treatment performance and determine the optimal maintenance of WSUD systems
159	Expand sampling to include receiving waters downstream of stormwater wetlands investigating what is currently not being treated	A1.2 Develop efficient and effective indicators and approaches to monitor the performance of stormwater wetlands	Stormwater Management and Flooding	Improving the stormwater treatment performance and determine the optimal maintenance of WSUD systems
161	Undertake a more thorough sampling protocol/ regime to characterise particle size variation across and within wetlands to further understand the relationship between particle size and toxicants	A1.2 Develop efficient and effective indicators and approaches to monitor the performance of stormwater wetlands	Stormwater Management and Flooding	Improving the stormwater treatment performance and determine the optimal maintenance of WSUD systems
162	Optimisation of in-field online treatments to understand maintenance schedule and costs, reuse and recycling options for online treatment facilities	A1.5 Identification of cost-effective opportunities for addressing pollutants from industrial catchments	Stormwater Management and Flooding	Improving the stormwater treatment performance and determine the optimal maintenance of WSUD systems
163	Understand the benefits of non-structural strategies (education and enforcement) to manage pollution from industrial areas	A1.5 Identification of cost effective opportunities for addressing pollutants from industrial catchments	Water Quality	Developing tools and approaches to assist in strategic planning of pollution management to protect biodiversity, amenity and recreation in waterways across the region
165	Better understand the effects of Bifenthrin on aquatic organisms	A2.4 Impacts of sediments from urban and rural stormwater on stream health/B2. 6 Understanding the risk of contaminants in environmentally sensitive areas	Water Quality	Understanding the environmental impacts of pollutants, including contaminants of concern, to inform risk-based management of waterways across the region

Knowledge gap ID	Description	Discussion Paper/ Factsheet	Research Theme	Key Research Area
166	Develop a risk assessment framework to include the information provided in the A3P program to better protect ecological values.	B1.1 Identifying and managing emerging contaminants of concern	Water Quality	Developing tools and approaches to assist in strategic planning of pollution management to protect biodiversity, amenity and recreation in waterways across the region
170	Continue targeted field sampling at sites likely to be impacted by sewage pollution to determine the presence of priority chemicals identified in the literature review and to validate their use as chemical indicators of sewage pollution.	B1.2 Understanding the ecological impacts of treated and untreated sewage inputs in waterways	Water Quality	Develop improved water quality indicators and monitoring methods to better understand the impacts of pollutants on waterway health
171	Refine passive sampling methods - move from semi-quantitative (presence/absence) to quantitative assessments (to report data as a concentration)	B1.2 Understanding the ecological impacts of treated and untreated sewage inputs in waterways	Water Quality	Develop improved water quality indicators and monitoring methods to better understand the impacts of pollutants on waterway health
172	Understand the relative ecological risk of chemicals in wastewater discharges to waterways	B1.2 Understanding the ecological impacts of treated and untreated sewage inputs in waterways	Water Quality	Developing tools and approaches to assist in strategic planning of pollution management to protect biodiversity, amenity and recreation in waterways across the region
173	Continue to undertake a systematic approach for management of SoBS and sites of interest, incorporating multiple lines of evidence, to ensure all contaminant risks are considered and assessed and consequently, management actions can be put forward to sustain and improve the condition of these sites.	B2. 6 Understanding the risk of contaminants in environmentally sensitive areas	Water Quality	Developing tools and approaches to assist in strategic planning of pollution management to protect biodiversity, amenity and recreation in waterways across the region
174	Continue developing molecular tools such as eDNA and metabolomics and evaluate the feasibility to incorporate into biomonitoring programs	C3.3 Developing methods to increase the efficiency and effectiveness of waterway health assessment within streams, wetlands and estuaries	Water Quality	Develop improved water quality indicators and monitoring methods to better understand the impacts of pollutants on waterway health
175	Continue to develop non-destructive sampling tools to help understand the impacts of pollutants on waterway health	C3.3 Developing methods to increase the efficiency and effectiveness of waterway health assessment within streams, wetlands and estuaries	Water Quality	Develop improved water quality indicators and monitoring methods to better understand the impacts of pollutants on waterway health

Knowledge gap ID	Description	Discussion Paper/ Factsheet	Research Theme	Key Research Area
176	Apply the multiple lines of evidence framework to understand major stressors in sub-catchments where key environmental values are declining (e.g. Lang Lang River aquatic macroinvertebrates, River Blackfish in the Plenty River)	C3.3 Developing methods to increase the efficiency and effectiveness of waterway health assessment within streams, wetlands and estuaries	Water Quality	Developing tools and approaches to assist in strategic planning of pollution management to protect biodiversity, amenity and recreation in waterways across the region
179	Trial approaches to maximise the efficacy of an integrated management regime through combined treatments	E2.4 What are the effects of chemicals frequently used by Melbourne Water on or near waterways on aquatic ecosystems and public health?	Streamside Vegetation and Instream Habitat	Understand the impact and effective management of pest plants and animals on riparian vegetation
180	Review and refine chemicals accepted for use in washdown and pathogen control procedures to reduce impacts to the aquatic environment and human health	E2.4 What are the effects of chemicals frequently used by Melbourne Water on or near waterways on aquatic ecosystems and public health?	Water Quality	Understanding the environmental impacts of pollutants, including contaminants of concern, to inform risk-based management of waterways across the region
181	Investigate the ecological impacts of herbicides where they are sprayed directly into drains and water bodies to better understand how to mitigate impacts	E2.4 What are the effects of chemicals frequently used by Melbourne Water on or near waterways on aquatic ecosystems and public health?	Water Quality	Understanding the environmental impacts of pollutants, including contaminants of concern, to inform risk-based management of waterways across the region
182	Continue assessments of toxicity of current and alternative herbicides to waterway values, particularly frogs, to understand risks of herbicide spraying activities on key Healthy Waterway Strategy values	E2.4 What are the effects of chemicals frequently used by Melbourne Water on or near waterways on aquatic ecosystems and public health?	Water Quality	Understanding the environmental impacts of pollutants, including contaminants of concern, to inform risk-based management of waterways across the region
183	Develop a Litter Prioritisation Framework	F5.1 Understand the impact of litter, including microplastics, on the social and ecological values of waterways and bays	Water Quality	Developing tools and approaches to assist in strategic planning of pollution management to protect biodiversity, amenity and recreation in waterways across the region
187	NA	Propagation of native plants for riparian restoration		
188	TBC	Developing and applying eDNA methods for aquatic biodiversity monitoring e.g. MERI program, threatened species, invasive species, wetlands, billabong plants		

Knowledge gap ID	Description	Discussion Paper/ Factsheet	Research Theme	Key Research Area
189	TBC	Review of freshwater biodiversity (mudfish, crayfish, mussels, blackfish)		
190	Increase our understanding of the distribution of threatened aquatic macroinvertebrates, including clarifying taxonomic uncertainty	Threatened invertebrate assessment	Other Aquatic Biodiversity	Improving our understanding of critical ecological processes and ecology of key species to improve our conceptual and quantitative models
191	Identify important source and sink populations for propagule dispersal	Seagrass restoration	Port Phillip and Western Port	Undertake priority research projects identified in the Western Port Environment Science Review and synthesis report
192	Identifying approaches and opportunities to mainstreaming IWM	CRC for Water Sensitive Cities	Stormwater Management and Flooding	Identifying and addressing institutional and structural barriers to implementation of Integrated Water Management
193	NA	Functional links between revegetation and instream habitat	NA	

Appendix 15: Focus sub-catchments

Catchment	Sub-catchment	MDVs	MSVs	CCV	CCS	Group
Yarra	Diamond Creek (Source)			×		A
Yarra	Little Yarra River and Hoddles Creek		×			A
Yarra	Olinda Creek		×			A
Yarra	Plenty River (Source)			×	×	A
Yarra	Plenty River Upper			×		A
Yarra	Steels and Pauls Creek (Source)		×	×		A
Yarra	Watsons Creek				×	A
Yarra	Watts River (Rural)			×	×	A
Yarra	Watts River (Source)			×	×	A
Yarra	Woori Yallock Creek	×		×	×	A
Yarra	Yarra River Lower	×*				A
Yarra	Yarra River Middle		×		×	A
Yarra	Yarra River Upper (Rural)			×	×	A
Yarra	Yarra River Upper (Source)			×	×	A
Yarra	Darebin Creek	×				B
Yarra	Gardiners Creek	×				B
Yarra	Mullum Mullum Creek		×			B
Werribee	Lerderderg River			×	×	A
Werribee	Werribee River Lower	×*				A
Werribee	Werribee River Middle	×*		×		A
Werribee	Werribee River Upper			×	×	A
Werribee	Kororoit Creek Upper		×			B
Werribee	Parwan Creek		×			B
Werribee	Skeleton Creek		×			B
Maribyrnong	Deep Creek Upper	×		×		A
Maribyrnong	Emu Creek	×				A
Maribyrnong	Jacksons Creek	×				A

Catchment	Sub-catchment	MDVs	MSVs	CCV	CCS	Group
Maribyrnong	Maribyrnong River	×*				A
Maribyrnong	Moonee Ponds Creek		×			B
Maribyrnong	Taylors Creek		×			B
Maribyrnong	Boyd Creek		×	×		B
Dandenong	Corhanwarrabul, Monbulk and Ferny Creeks		×		×	A
Dandenong	Dandenong Creek Upper		×		×	A
Dandenong	Blind Creek		×			B
Dandenong	Dandenong Creek Lower		×			B
Dandenong	Dandenong Creek Middle		×			B
Westernport	Bunyip River Middle and Upper			×	×	A
Westernport	Cardinia, Toomuc, Deep and Ararat	×				A
Westernport	Lang Lang River	×		×		A
Westernport	Mornington Peninsula South-Eastern Creeks	×				A
Westernport	Tarago River	×			×	A
Westernport	Bass River			×		B
Westernport	Bunyip Lower	×				B
Westernport	King Parrot and Musk Creeks	×		×		B
Westernport	Mornington Peninsula North-Eastern Creeks		×			B
Westernport	Mornington Peninsula Western Creeks		×			B

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More Information

Healthy Waterways Strategy
Access the Mid-term Review Summary Report >>
Access the Implementation Inquiry Report >>
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