

Understand the role of small headwater streams in urbanising catchments for supporting waterway health



Healthy Waterways
Strategy 2018-2028
Port Phillip & Westernport, Victoria



Melbourne
Water



Strategic alignment

Regional Performance Objectives (RPOs):

- RPO16: Protection mechanisms are in place for headwaters to ensure that they are retained as features in the landscape for environmental, social, cultural and economic benefits.

Key Research Areas:

- Streamside vegetation and instream habitat: Improving our understanding of instream habitat conditions, threats and processes across the region to inform works planning
- Water Quality: Understanding the environmental impacts of pollutants, including contaminants of concern, to inform risk-based management of waterways across the region.

Summary

Headwater streams, where catchment runoff first accumulates sufficiently to create overland flow paths, are dominant and critical parts of catchments. Headwaters are primary sources of streamflow, important sources of organic matter and invertebrates to downstream waters, and act as 'hot spots' for retention and transformation of nutrients such as nitrogen and carbon. Their contribution to regional aquatic biodiversity is disproportionately large. For example, several studies have shown that headwater streams provide extensive habitat, with up to around one-third of aquatic invertebrate species being unique to these running waters. Headwater streams are also the first source of aquatic life in the transition from hillslopes to the river network and thus can be an important source of colonist to lower reaches.

While surface-flow can be highly variable (headwaters often cease to flow for periods of time), the upper layers of soil (also called the hyporheic zone, where shallow groundwater and surface water mix) of headwater streams commonly remain saturated during dry periods. This zone can harbour endemic species and contribute to important waterway functions such as nutrient processing and removal.

Small headwater streams are likely to be extremely important for maintaining downstream river and bay health (e.g. as natural 'stormwater treatment systems'), but they are particularly vulnerable to degradation or loss in rapidly urbanising cities such as Melbourne.

Despite this recognition, we still lack a clear understanding of:

- their ecological characteristics;
- hydrologic and water quality behaviour; and

- management opportunities (e.g. appropriately designed stormwater control measures (SCMs)) to protect them in the face of future urban growth and climate change.
- Their location and extent within the region.

This research sought to investigate and quantify the magnitude of the values and services provided by headwater streams across the Melbourne Water management region and ultimately facilitate their effective management and protection through a clear business case and appropriate policy and design guidelines.

Recommendations:

- Consistent with RPO 16 in the HWS, headwater streams should be protected from urban development. The new stream network layer from our research partnership, now includes headwater stream extents that can form the basis of planning decisions.
- 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.
- In cases where development occurs, appropriately designed Stormwater Control Measures (SCMs) must be

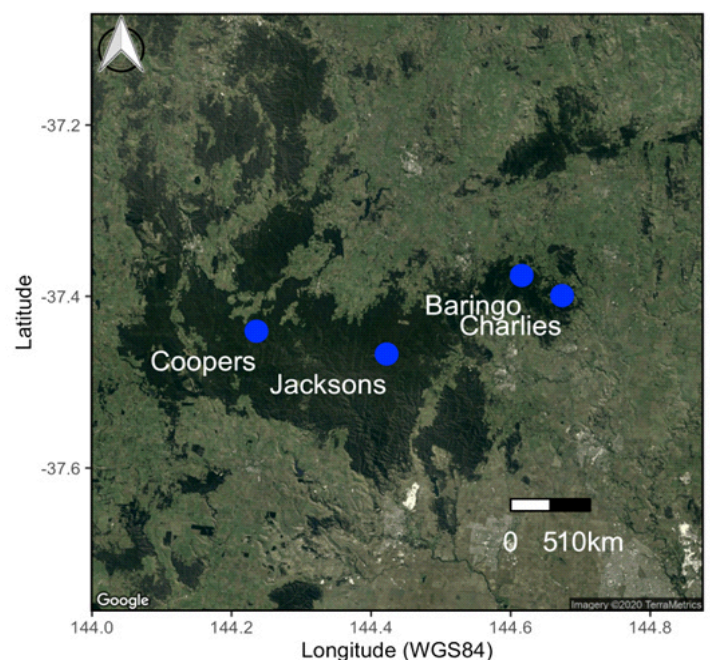


Figure 1: The four headwater streams monitored as part of this pilot study.

implemented. The SCMs must be designed in ways that mimic the natural flow and water quality regimes.

- Headwater streams are particularly vulnerable to any increases in flows, therefore, SCMs must drain all impervious surfaces in urban developments.
- 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.

What did we do?

Literature Review

We completed three literature reviews which culminated in the publication of Imberger *et al.* (2023). The first focused on understanding organic matter decomposition in headwater streams and made a strong argument for the further study of organic matter dynamics in headwater streams for three reasons: 1) in many headwater streams, food webs are driven by (dead) organic matter (or detritus), 2) as the first flow points in the catchment, such streams provide storage, processing and act

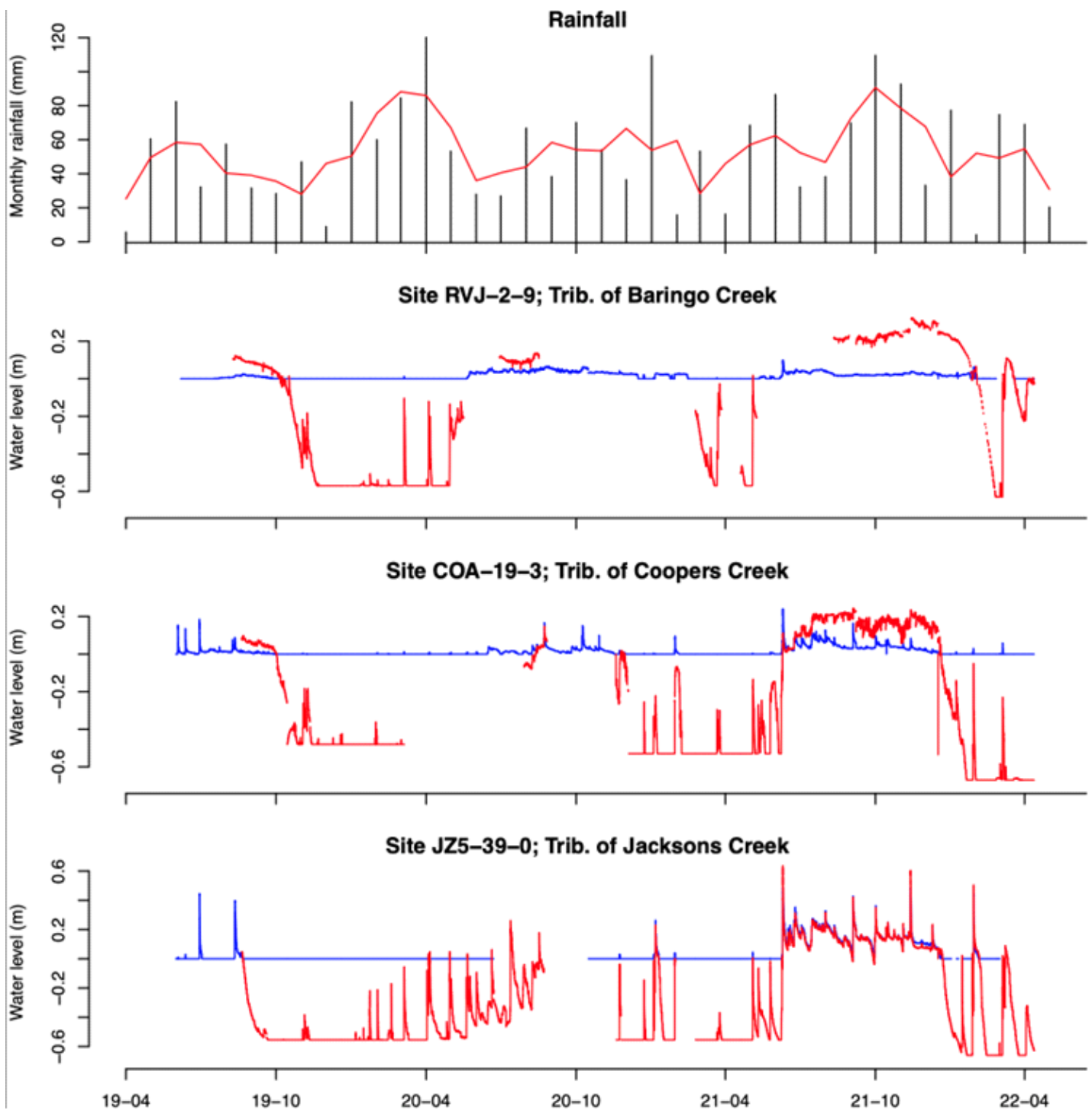


Figure 2: Continuous water level data for three of the four headwater sites (blue lines = surface water, red lines = groundwater). Data for the site in the Mount Charlie Flora Reserve (RSO-36) was not plotted because no water has been observed since records began.

as conduits of organic matter (leaves, bark, wood, dissolved organic compounds) downstream, and 3) due to their extent, their influence on the ecological integrity of downstream waters can be substantial. The second review revealed appropriate environmental monitoring methods for headwater streams that were subsequently implemented by this research project. The third review revisited the importance of headwater streams and identified critical knowledge gaps which are hampering efforts to assess and manage these unique systems.

Mapping of headwater streams

Data from this project was used to help map headwater streams in the region (see MWRPP Report 22.5: A new dataset for designating headwater streams in the Port Phillip and Westernport region). The new mapping provides an accurate representation of the extent of streams throughout the MW region and is incorporated in the 2022 Melbourne Water Stream Network Layer.

Empirical monitoring

The monitoring of four headwater streams in the west of Melbourne commenced in 2019 and continues (Figure 1). These streams drain 100% forested catchments in 1) Mount Macedon, 2) Wombat State Forest, 3) Lerderderg State Park, and 4) Mount Charlie Reserve. The sites have been instrumented with surface- and sub-surface monitoring wells and have been sampled for nutrients and stable isotopes. Stable isotopes have been sampled to help understand the sources of surface water,

whether it is dominated by recent rainfall or groundwater.

Studies on stream decomposition

An initial pilot study on organic matter dynamics in headwater streams deployed cotton strips (that provide standardised estimates of organic matter decomposition rates) in four sites in Melbourne's west. Building on this pilot study, we undertook a much broader study on decomposition, targeting ~40 headwater streams around the Melbourne Region. For each site we deployed cotton strips, along with temperature and surface-water level loggers. Data was collected for ~28 days and has been prepared for publication (see Future Direction and

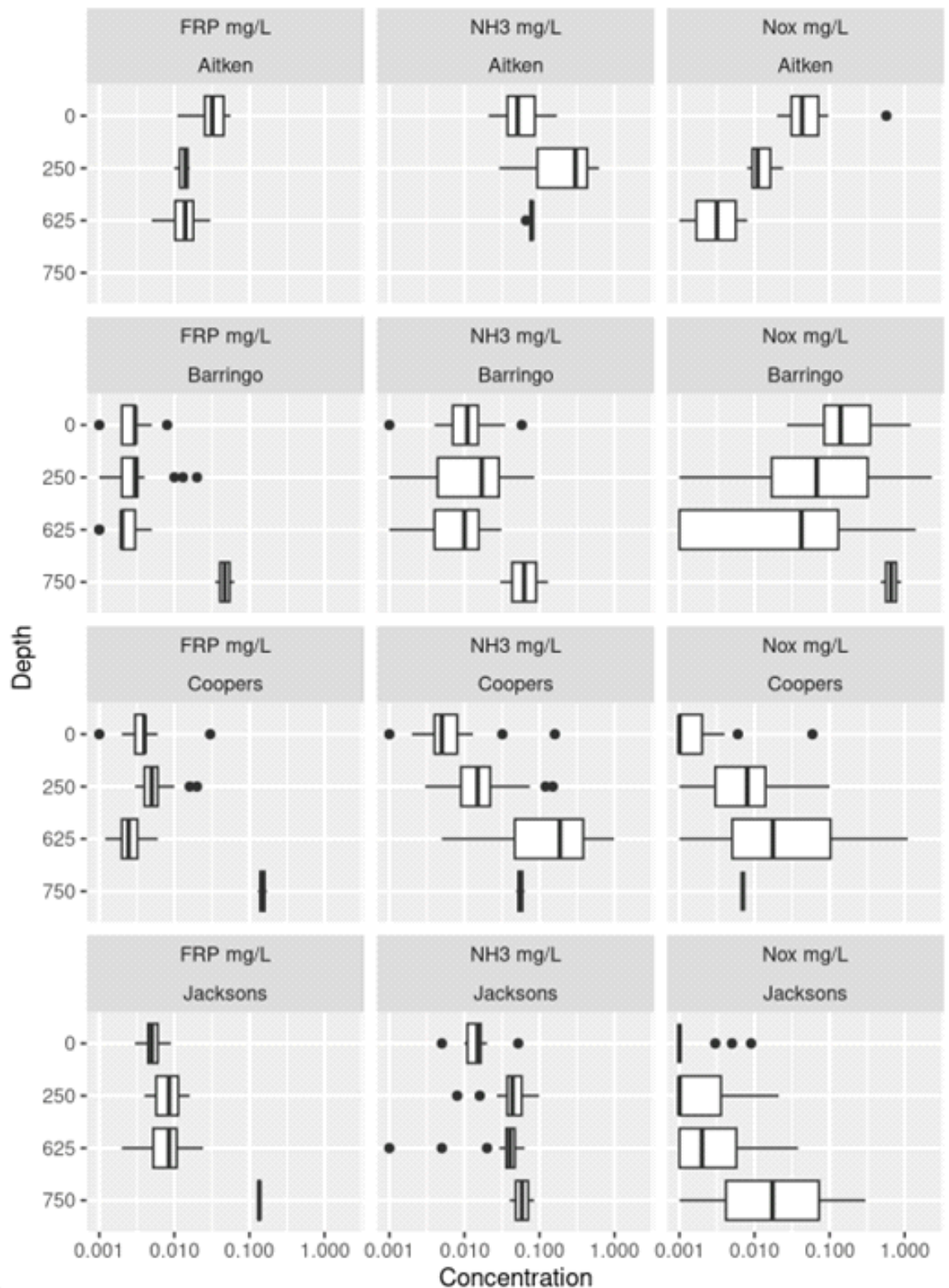


Figure 3: Filterable reactive phosphorus (FRP) concentrations for water quality samples collected at the headwater sites. Samples were collected from surface waters (depth = 0), groundwater (depth = 750) as well as from the substrate at two different depths (depths = 250 and 625).

Knowledge gaps).

Aitken Creek Case Study

This headwater site is immediately downstream of a future development area. It forms part of another Melbourne Waterway Research-Practice Partnership project ('Project A3') which is investigating the role and function of floodplains in newly urbanised areas. We have instrumented this site with surface and sub-surface water level loggers in order to obtain some pre-development hydrologic data. There is a plan also to collect water quality samples (for nutrients, suspended solids, dissolved oxygen, electrical conductivity, pH and redox potential). The data collected at this site will inform a local case study of possible stormwater management options for the protection of headwater streams.

In partnership with Water Sensitive Cities Australia, we ran two co-design workshops to develop ideas for practical and innovative design solutions for the protection of headwater streams in a Melbourne-based development case study, using Aitken Creek as the case study.

What did we find?

Empirical monitoring

Hydrology: Flow behaviour at the headwater sites is strongly seasonal, with surface flow only occurring during the wetter months (Figure 2). For three of the four study sites, they remain dry during summer except for times following very large rain events. No surface or sub-surface water has been observed at the site within the Mount Charlie Flora Reserve. Groundwater

behaviour appears complex. Surface and sub-surface waters appear to be very well connected only once the catchment is sufficiently wet (e.g. tributary of Jacksons Creek during Spring-2021). A surprising finding was to see sub-surface waters higher than surface water, for example the tributary of Coopers Creek during mid-2021. This finding was confirmed by field observations and could be related to increasing water pressures below ground. Further investigations are required to understand the cause of this.

Water quality: We have found that surface water from the headwater sites is very clean compared to small streams in nearby agricultural catchments (Figure 3). For example, water drained from the headwaters is very low in Filterable Reactive Phosphorus (FRP, <0.01 mg/L) compared to the more polluted waters of streams in the Sunbury region where FRP is generally greater than 0.1 mg/L.

Stream decomposition

Leaf breakdown rates (an indicator of stream decomposition) were found to be generally lower in the headwater sites compared to nearby agricultural streams (Figure 4). These slow rates are generally indicative of healthy ecosystem function in predominantly natural systems, with slow material turnover and high retention.

We also found that organic matter decomposition is much faster beneath the surface than at the streambed (e.g. Figure 5), which highlights the high nutrient and carbon processing potential of the hyporheic zone (the upper layers of soil) and their role for filtering water. It also highlights that changes in the frequency of wetting and drying are going to alter decomposition rates and

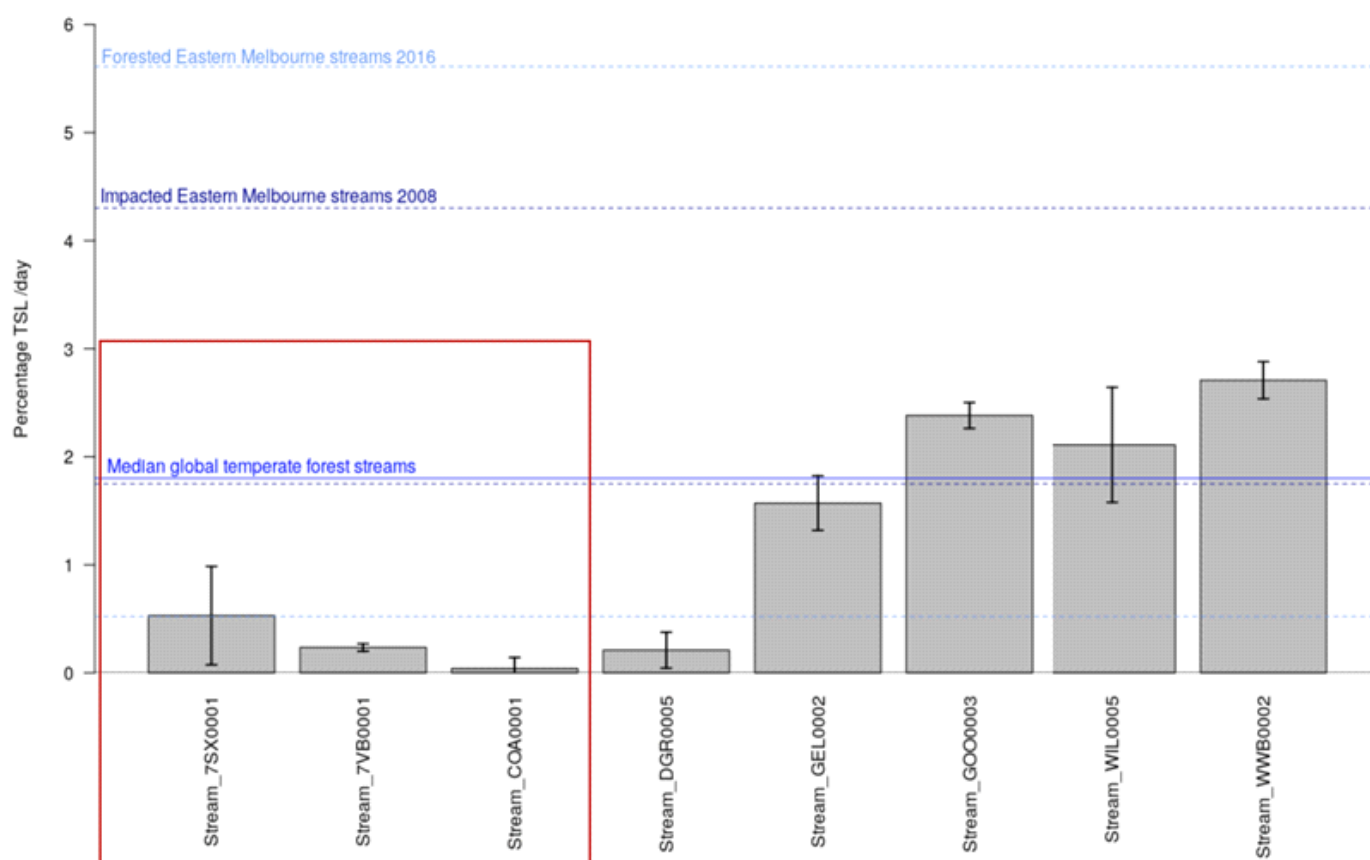


Figure 4: Leaf breakdown rates for 8 sites to the west of Melbourne. The three sites bounded by the red box are our monitored headwaters, with the other sites nearby agricultural streams.

the ongoing availability of organic matter to support the aquatic food web.

Future direction and Knowledge gaps

Thermal camera work

We trialled the use of a novel thermal camera to detect groundwater inputs to the stream. We had issues with the first prototype tested in that it failed to trigger when water level increased in the stream. Further development work is required.

Broad-scale study on decomposition—data analysis and publication

The data collected from the ~40 sites will be used to investigate variation in organic matter decomposition rates in both surface and hyporheic zones as well as the physical (e.g. hydrology, water temperature), chemical (e.g. nutrient concentrations), and biological (e.g. microbial diversity and activity) factors driving any variation. A particularly novel aspect of this work will be to characterise microbial community composition using DNA analysis or community level physiological profiling.

Data summary

We are currently preparing a technical report which describes the hydrologic, water quality and ecological data collected thus far as part of this project. It will also outline our plan for future analyses and outputs associated with this project.

How are we sharing findings?

- Imberger, M., Hatt, B., Brown, S., Burns, M. J., Burrows, R. M., & Walsh, C. J. (2023). Headwater streams in an urbanising world.
- Technical Report No. 22.5: A new dataset for designating headwater streams in the Port Phillip and Westernport region. (2022) Walsh, C.J., Burns, M.J., Hehir, G., Poelsma, P., Hatt, B.E., Kunapo, J., Burrows, R., Imberger, M., Brown, S., Chee, Y. E., Smith, L., and Lovell, B.

For more details on the research outcomes of this project, or other projects of the MWRPP, please contact:

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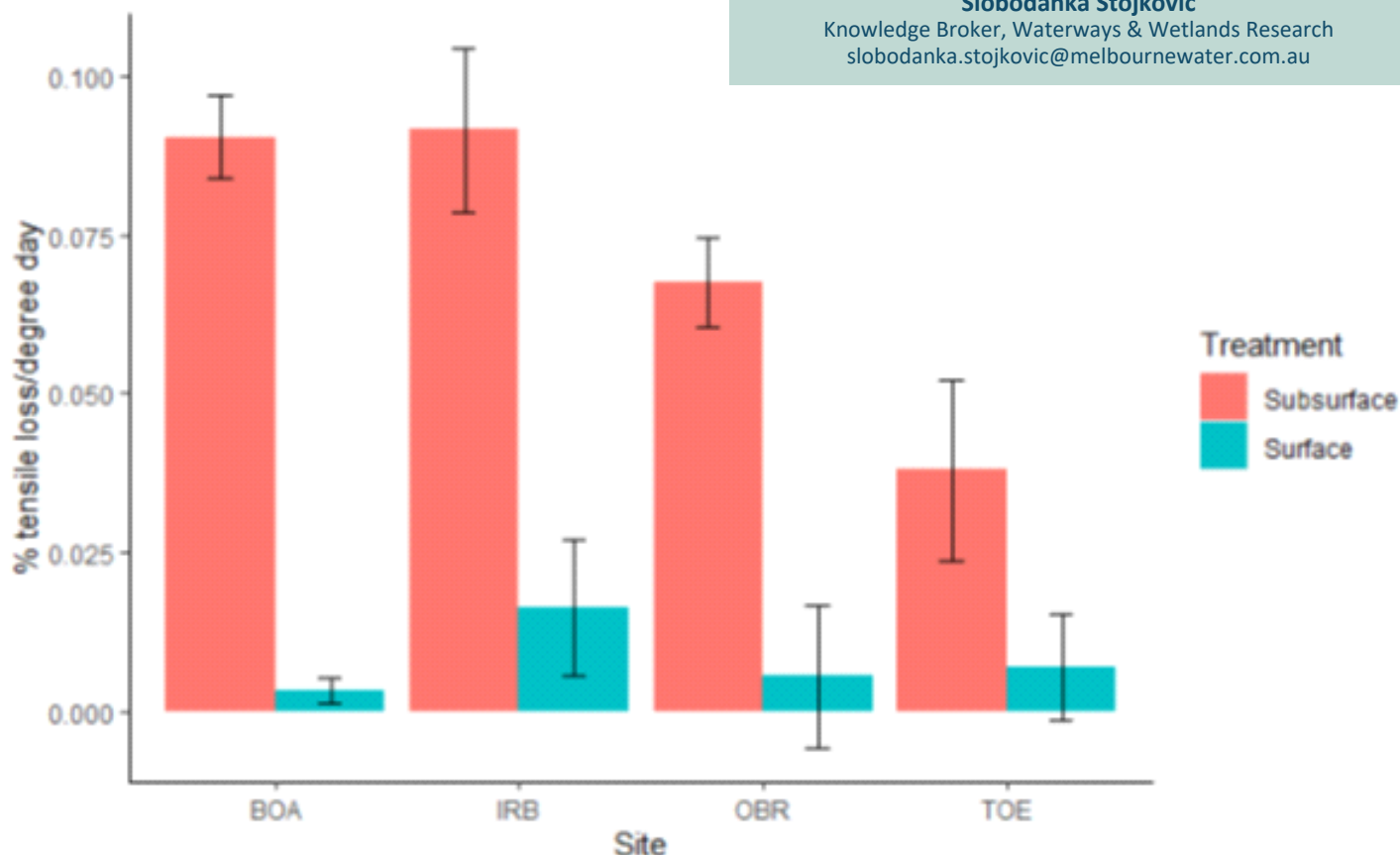


Figure 5: Percent tensile strength loss per degree day (mean +/- 1 SD) of cotton strips for four pilot study sites in Melbourne's west.

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