A multiple lines of evidence approach to assess the ecological condition of urban river catchments

Sharley, D. J.[1], Jeppe, K. J.[1] and Pettigrove, V.[1]

1. Centre for Aquatic Pollution Identification and Management, School of Bioscience, University of Melbourne, Grattan St, Parkville 3010. Email: dsharley@unimelb.edu.au

Key Points

- Multiple lines of evidence approach for assessment of urban catchments is critical
- Land uses and anthropogenic activities influence sediment pollution and the health of urban creeks
- Point source pollution can drive ecological degradation in urban areas
- Providing waterway managers with the likely reasons for increased ecological stress and prioritizing stakeholder investment is critical for improvement in catchment health.

Keywords
Sediment, pollution, multiple lines of evidence, ecotoxicology, landuse, bioassessment

Introduction
This technical note describes the assessment of an urban catchment using a multiple lines of evidence approach. A combination of sediment quality assessment, benthic communities, ecotoxicological testing of field sediments provided a multiple lines of evidence assessment of Merri Creek in Melbourne's north. Over 50% of the world's population now reside within cities, with significant increases expected over the next 50 years (Grimm et al., 2008). Aquatic ecosystems in urban areas provide important ecosystem services and it is challenging to protect and enhance them (Bolund and Hunhammar, 1999; Solecki et al., 2013). Increasing population and changes to landuse cause constant pressure, changing ecological features of aquatic ecosystems (Alberti et al., 2003). A common approach for evaluating the ecological impact of sediment-bound pollution has been the Sediment Quality Triad developed in the 1990s (Chapman, 1990). This study extends upon this approach to not only assess the health of Merri Creek but also to identify the main threats degrading the catchment, thus allowing water managers to prioritise waterway investments for improved waterway health and enhanced amenity.

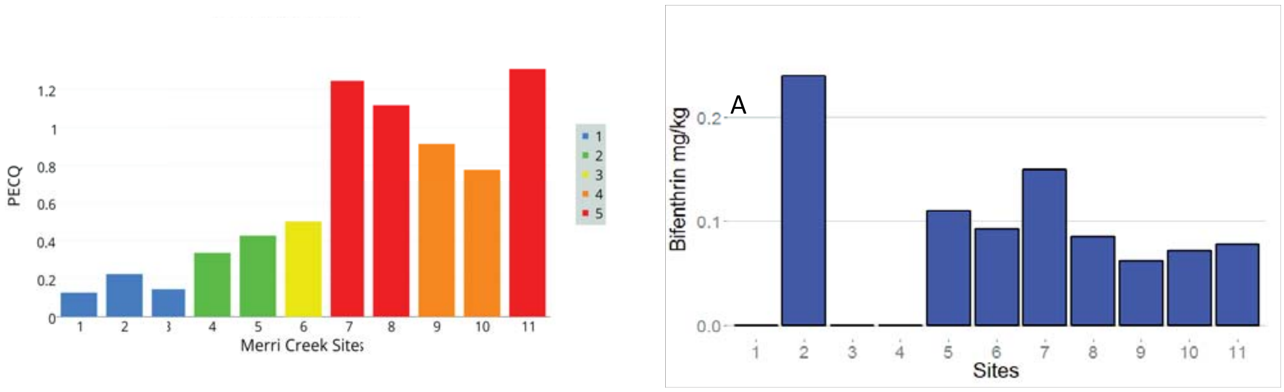
Methods
Fine (<63 µm) sediment and macroinvertebrates were collected from ten sites along Merri creek in Melbourne's north for ecotoxicological tests and chemical analysis by a NATA accredited laboratory (Figure 1). Chemistry included metals, hydrocarbons, organic pollutants and total organic carbon. Sediment bioassays were carried out on *Chironomus tepperi* a non-biting midge and *Austrochiltonia subtenuis*, a local amphipod using a range of biological endpoints including survival and total emergence (Sharley et al., In Prep). Macroinvertebrates were collected according to rapid bioassessment RBA (EPA, 1998) and common ecological indices such as SIGNAL2, number of families, the EPT index and Simpson's evenness measured.

Figure 1. Map of study sites

Results and Discussion

Sediment contaminants

Sediment chemistry varied throughout the catchment, although an urban trend was evident with increasing zinc and hydrocarbon concentrations correlating with increasing residential and commercial activities. Numerous contaminants were elevated at both sites 7 and 8, linking primarily with storm water outlets draining industrial areas (Figure 2a). While a range of pesticides were detected throughout the catchment, the prevalence of Bifenthrin, a synthetic pyrethroid was surprising (Figure 2b). In particular, the high concentrations detected at site 2, which we contribute to a new housing development upstream and the extensive use of synthetic pyrethroids in infrastructure protection.



B

Figure 2. Sediment quality results from the 11 sites (A) heavy metal Probable effects quotient 1-5 in order of ascending pollution (MacDonald et al., 2000) and (B) Bifenthrin concentrations (mg/kg)

The macroinvertebrate community varied throughout the catchment, although based upon SIGNAL 2 index, the entire creek was classified as being in poor condition with a mean SIGNAL score of 4.4 (± 0.55) (for edge and 4.2 (±0.69)for riffle habitats, which were all below the State Environmental Protection guidelines for urban catchments (5.5). Between sites 1 (upstream reference) and site 2 (downstream of housing development), the number of families collected reduced nearly 50%, with moderate recovery at sites 3 and 6, then reduced again at sites 7-9, with further recovery downstream of the industrial areas. Both the EPT index and Simpson's evenness (a measure of biodiversity) were low throughout the catchment, indicating again that the catchment as a whole was in poor condition.

Laboratory Assay

Chironomus tepperi

The emergence and larval dry weight of *C. tepperi* after exposure to Merri Creek sediments was significantly different between sites when analysed using ANOVA ($F_{11,37} = 13.28$, $P < 0.001$, $F_{10,37} = 7.413$, $P < 0.001$, respectively). Post-Hoc tests showed that emergence was significantly reduced at sites 7 (10%) and 8 (0%), with marginal reductions at sites 2 (70%) and 3 (60%). The significant reductions at sites 7 and 8 are likely due to the presence of highly toxic sediments (Figure 3a). For larval dry weight, Post-Hoc testing indicated that larval dry weight was reduced in sediments from sites 2, 3, 4, 5, 7 and 8 relative to the top site 1, although only 3, 5, 7 and 8 were different compared to the reference (Figure 3a).

Austrochiltonia subtenuis

The survival of *A. subtenuis* after 3 weeks exposed to Merri Creek sediments differed significantly between sites (adults: $F_{11,36} = 4.0$, $P = 0.001$ and juveniles: $F_{11,36} = 18.15$, $P < 0.001$). Post-Hoc tests indicated that survival was significantly reduced by exposure to sediment from sites 2 and 8 when compared to reference sediment and sediments from site 1, while juvenile survival was significantly affected at numerous sites throughout the catchment, including sites 2 and 8 (Figure 3b). It is clear from the results that bifenthrin concentrations at both these sites are causing amphipod adult mortality, while for juveniles; a mixture of toxicants (including bifenthrin) is likely having an effect. Furthermore the absence of Amphipoda in benthic community collections at site 2 gives further weight that high concentrations of bifenthrin is likely affecting the benthic community more than any other factor.

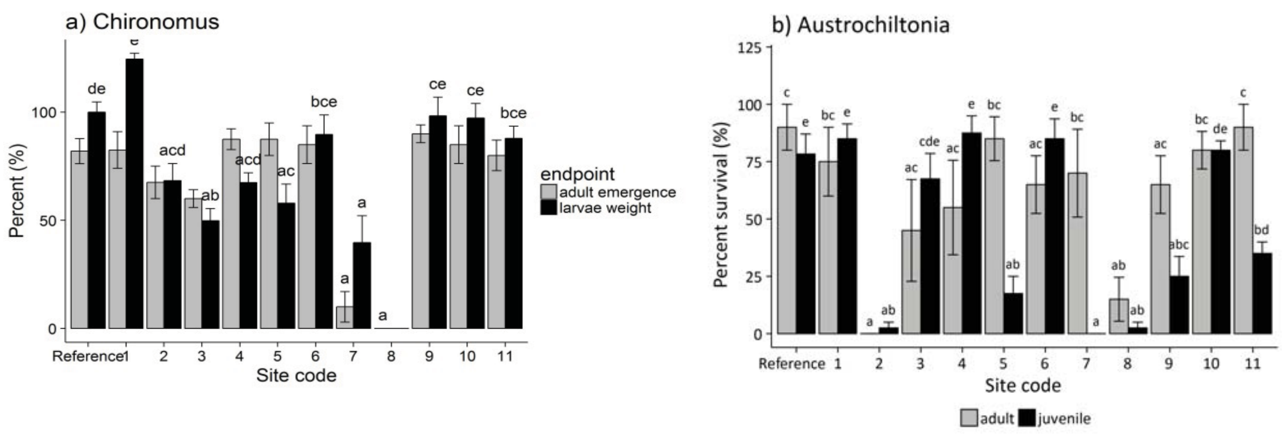


Figure 3. Graphs depicting laboratory assay results for a) *Chironomus tepperi* and b) *Austrochiltonia subtenuis* with both adult emergence and larvae weight.

General discussion

It is clear from the results that although the catchment as a whole is in poor condition as indicated by numerous benthic indices such as SIGNAL 2 and diversity, subtle site differences in ecological condition are not as predictable using these metrics. The addition of laboratory-based assays on field sediments however was able to delineate sites that would require further attention by resource management agencies. The use of both *C. tepperi* and *A. subtenuis* was important in this study. While previous testing suggests that *C. tepperi* is more tolerant and robust to pollution than *A. subtenuis*, the results at site 7, and 8 in particular where both species were severely affected, provide good evidence of point source pollution originating from industrial activities, which if managed would considerably improve the health of the creek. Additionally, the causal links between high concentrations of bifenthrin at site 2 and significant reductions in amphipod survival and the absence of field amphipods provides clear indication that infrastructure protection measures (termite control) within the new housing development precinct is likely driving ecological stress. Results from this investigation recently featured in a pilot study that investigated an outcome based approach to catchment pollution management, aligning stakeholder investments with outcomes that would benefit the community and the environment (MWH, 2016).

Conclusions

The aims of this study were to use a multiple lines of evidence approach for the ecological assessment of a large urban catchment. Results from the study show that a multiple lines of evidence approach is important when planning catchment assessments. Reliance on traditional benthic community assessments in absentia of other indicators is unlikely to delineate the main reasons for any deterioration of catchment health. Providing waterway and catchment managers with the likely reasons for increased ecological stress and prioritizing stakeholder investments is critical for improvement in catchment health.

Acknowledgments

We wish to thank Melbourne Water for funding this work. CAPIM and Melbourne University for infrastructure support, we also thank. We also thank Dan MacMahon for assistance in the field, Cameron Amos for fieldwork and macroinvertebrate identification and Rebecca Reid for laboratory assistance.

References

Alberti, M., Marzluff, J.M., Shulenberger, E., Bradley, G., Ryan, C., Zumbrunnen, C., 2003. Integrating Humans into Ecology: Opportunities and Challenges for Studying Urban Ecosystems. BioScience 53, 1169-1179.

Bolund, P., Hunhammar, S., 1999. Ecosystem services in urban areas. Ecological Economics 29, 293-301.

Chapman, P.M., 1990. Fate and Effects of Toxic Chemicals in Large Rivers and Their Estuaries The sediment quality triad approach to determining pollution-induced degradation. Science of The Total Environment 97, 815-825.

EPA, 1998. Rapid bioassessment of Victorian streams. State Government of Victoria, Melbourne.

Grimm, N.B., Faeth, S.H., Golubiewski, N.E., Redman, C.L., Wu, J., Bai, X., Briggs, J.M., 2008. Global Change and the Ecology of Cities. Science 319, 756-760.

MacDonald, D.D., Ingersoll, C.G., Berger, T.A., 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology 39, 20-31.

MWH, 2016. Waterway Investment Prioritisation: Merri Creek Catchment Pilot Study. MWH, Melbourne.

Sharley, D.J., Jeppe, K., Pettigrove, V., In Prep. Using a multiple lines of evidence approach to assess the ecological condition of urban watersheds.

Solecki, W., Seto, K.C., Marcotullio, P.J., 2013. It's Time for an Urbanization Science. Environment: Science and Policy for Sustainable Development 55, 12-17.