CITY OF WHITTLESEA
STORMWATER QUALITY MONITORING PROGRAM
DATA REPORT

STEPHEN MARSHALL, DANIEL MACMAHON, DAVID SHARLEY

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Executive Summary

This document describes the results of a stormwater quality-monitoring program performed in partnership with the City of Whittlesea. This program consisted of two components: a regular stormwater survey and an ecological effects survey. The stormwater survey used sediment passive samplers (SPS) to monitor heavy metal and hydrocarbon contamination in the underground drainage network, while the ecological effects survey used laboratory bioassays to measure sediment toxicity in receiving waters before and after the education program. Passive samplers were deployed on a fortnightly basis by council staff and processed at CAPIM for contaminant analysis by a consulting laboratory. Initial survey results assisted in targeting the council environmental education program aimed at improving stormwater management practices in industrial areas. Stormwater survey results indicated significant reductions in oil and lead pollution after the education program, although the ecological effects survey found no reduction in toxicity between the start and end of the program. Although public reports of water pollution to EPA Victoria were low in number, they declined over the course of the program. In conclusion, catchments receiving the education program had lower concentrations of oil and lead, and public reports of water pollution reduced, suggesting modest behavioral changes may be able to substantially reduce stormwater pollution over relatively short timescales.

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Background

Urban runoff is highly variable in both flow and pollutant concentrations. Grab samples of urban runoff have pollutant concentrations with high variance in both space and time. This makes spatial and temporal comparisons challenging as many samples are often required to reliably distinguish differences between sites. Passive sampling offers an attractive approach to reducing this variance by integrating an average concentration over the sampling period (Namiesnik et al., 2005).

Passive sampling is becoming established as a useful tool for the monitoring and investigation of pollution in urban stormwater; however, the current generation of technology is primarily designed to target dissolved pollutants. This is a benefit for studies where bioavailable pollutants are of interest, but a liability when attempting to identify pollution sources since a significant fraction of pollutants in urban stormwater is not dissolved, but associated with fine particulates.

We developed an alternative stormwater monitoring approach based on passive sampling with polyurethane foam (PUF). PUF is well established as a tool for passive sampling air for both organic contaminants (Jaward et al., 2004) and metals (Moreno et al., 2004). It is an effective collector of fine particulate matter, which can then be removed and analysed for pollutants of interest using standard techniques. The approach is similar to solid phase passive sampling using activated carbon (DiGiano et al., 1988; Marshall et al., 2008), but with the advantage that the fine sediment can be separated from the sampler for analysis. This allows a much wider range of pollutants to be determined, and the extracted sediment can be further utilized in toxicity bioassays.

We applied this approach to measure the impact of a stormwater engagement program (SEP) run by local government environment officers. The SEP was targeted at improving communication with local small to medium enterprises (SEMs) to provide information on environmental best practice. The aim of the education program was to initiate and maintain a dialogue with potentially polluting businesses, with the aim of reducing waterway pollution by improving stormwater management practices. The aim of the monitoring program was to assess the effectiveness of the SEP. In this context, a successful SEP should reduce pollution levels from educated catchments.

Methods

Site Locations

Streams surrounding industrial area were surveyed at the start and end of the program. Major stormwater drains were surveyed fortnightly before and during the program. The stormwater monitoring program ran from 01/07/2014 to 01/07/2016. The ecological effects program first stage ran from 01/07/2014 to 30/11/2014, and second stage from 01/05/2016 to 30/06/2016.

Pollution Survey

Sediment was collected from streams by carefully removing the top layer of fine sediment using a clean shovel. Sediment was sieved on-site through a 63 um nylon mesh sock and allowed to settle overnight, and the overlying water decanted before preparation for analysis.

Sediment was collected from drains using sediment passive samplers constructed from strips of convoluted polyurethane foam contained in a woven polythene bag. Samplers were anchored in drains for two weeks and the foam removed for processing. Sediment was removed from the foam by squeezing through a clean wringer, allowed to settle overnight in clean plastic buckets, then the supernatant decanted before preparation for analysis. All equipment was washed in hot water and extran between sites.

Chemistry

Metals and hydrocarbons in sediment were determined by Australian Laboratory Services (ALS, 4 Westall Rd, Springvale, VIC, 3171) according to standard analytical methods (USEPA, 1983). Metals were determined by ICP-AES, and semi-volatile (C_{10} – C_{36}) aliphatic hydrocarbons determined by were summed to represent total petroleum hydrocarbons (TPH). Moisture content was determined by mass loss after 12 hours drying at 103^0C, and all concentrations reported as mg/kg dry weight. Quality control procedures included analysis of field and laboratory blanks, duplicate samples and determination of spike recoveries.

Rainfall Analysis

Daily rainfall data was downloaded from the Bureau of Meteorology for the Reservoir, Preston and Epping monitoring stations, covering the period 01/07/2014 to 01/07/2016. Site-specific rainfall was interpolated at each survey site using inverse distance weighting. To measure the importance of rainfall intensity and frequency on pollutant concentrations, we derived five summary variables. In the days immediately preceding passive sampler pickup, antecedent rainfall was the sum of total daily rainfall over 1, 3, 5, 7, and 14 days, while antecedent dry days was the number of consecutive days with less than 1 mm of rain. We measured the impact of rainfall on pollutant trends using multiple regression, with log-transformed pollutant concentrations as the response and rainfall summary variables as predictors. The influence of these variables as factors in the model was evaluated by comparing model AIC values.

Trend Analysis

We measured the effect of the SEP on pollutant concentrations (Cu, Cr, Ni, Pb, Zn, Oils) using linear mixed-effect models, with pollutant concentration as the response variable, time and education as fixed effects, and site as a random effect. Time was set as an ordered factor, coded as before or after treatment, with the date of treatment set to June 1st, 2015. We tested the effect of including an autocorrelation term and rainfall, but these did not improve predictive performance (as measured by AIC) so were not included in the final models. Model performance was checked by plotting observed vs predicted and residual vs predicted values.

TOXICITY SURVEY

Sediment toxicity was determined by the effect on survival and growth of the amphipod *Austrochiltonia subtenuis* using a standard 21-day exposure. Differences between endpoints were evaluated using ANOVA, and compared to reference controls using Dunnetts post-hoc multiple comparisons. All response variables were arc-sin square root transformed before analysis.

POLLUTION REPORTS

Publically reported pollution reports supplied by EPA Victoria were restricted to reports directly related to water. The report date was taken to be the noted date where it was present, and the creation date where the noted date was absent. Reports were limited to dates between 01/07/2014 and 30/06/2016, and to locations in the study area and the surrounding suburbs. Pollution reports were summed by month and the temporal trend visualized using a moving average.

Results

Pollutant trends between catchments

Catchment pollution concentrations are summarized in graphical format and overlaid on a map of the survey area. Catchment maps are coloured by the median concentration of pollutant in sediment accumulated in SPS units, with the sampling point indicated by a white diamond. Boxplots provide a useful visual summary of the variability in concentrations between and within catchments over the sampling period to date: the horizontal line represents the median concentration, the box spans the interquartile range, and extreme values are represented as single points.

Arsenic

Arsenic was detected at the highest concentrations in catchment 243, with lower concentrations detected in neighboring catchments 235 and 211. This hotspot was likely associated with contaminated land on the abandoned industrial site at 6 Dunstans Ct. Arsenic was also elevated in catchment 232, although no obvious source was evident.

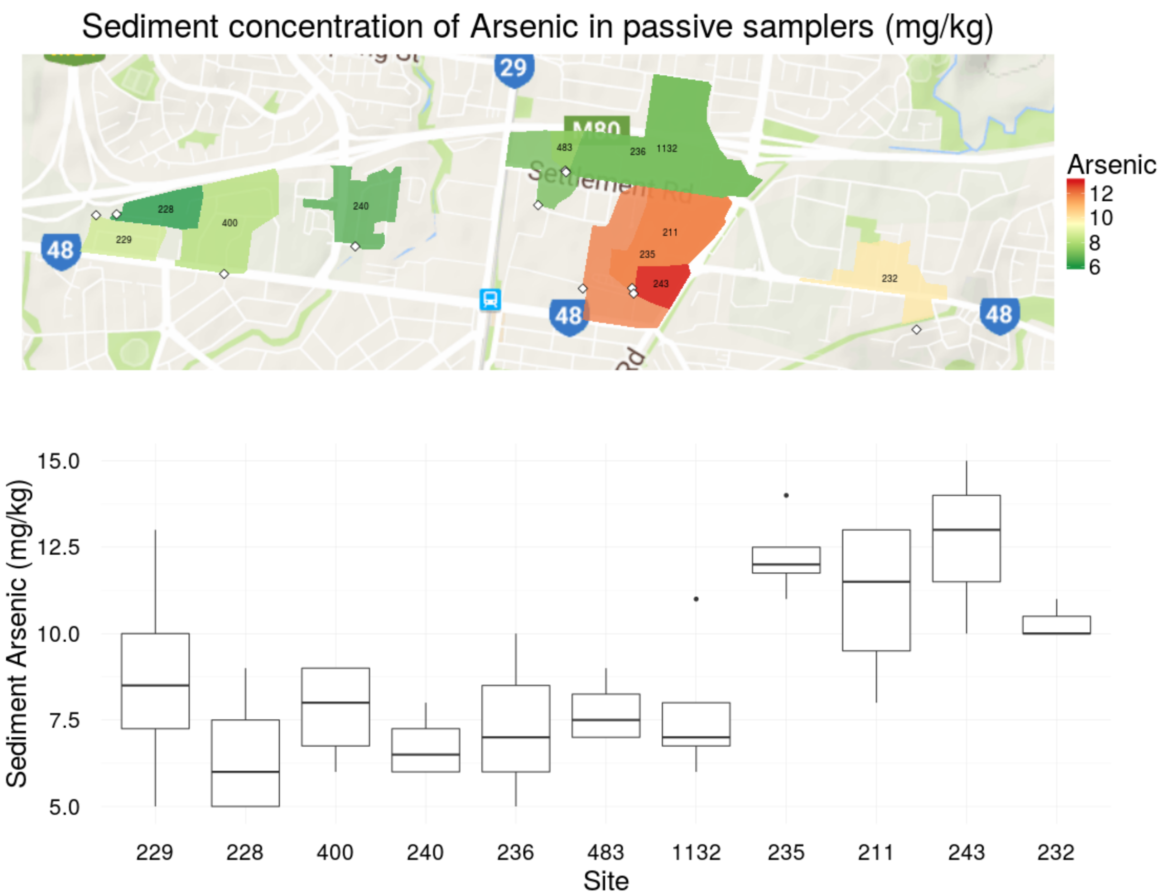

Figure 1. Spatial distribution of arsenic concentrations and variation between catchments.

CADMIUM

Cadmium was elevated in drains servicing only catchments 243, with associated contamination consistently present at sites 235 and 211. This hotspot was likely associated with contaminated land at 6 Dunstans Ct. Cadmium was also detected from catchment 232 at lower concentrations, although no obvious source was identified.

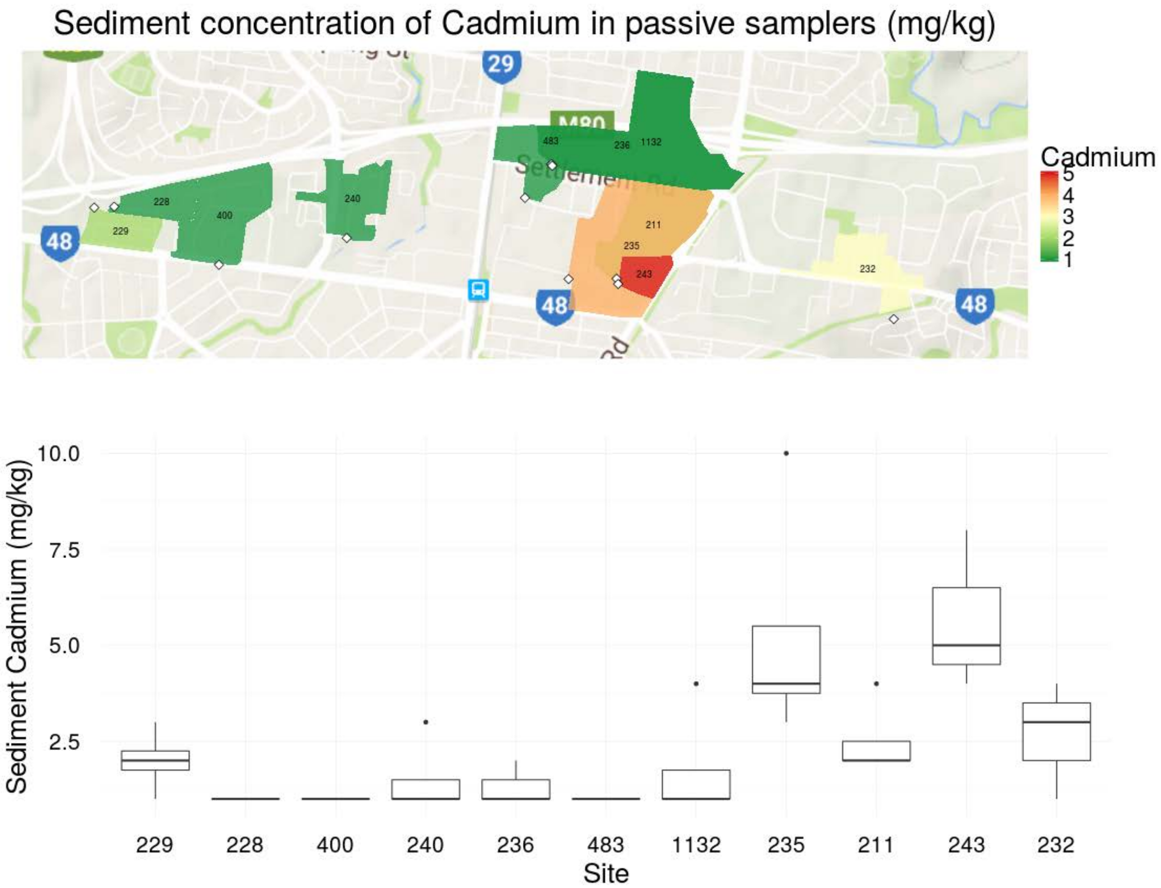

Figure 2. Spatial distribution of cadmium concentrations and variation between catchments.

CHROMIUM

Chromium was present at background concentrations throughout the catchment, but was consistently elevated at site 400. The median chromium concentration at site 400 was an order of magnitude higher than any other site. A consistent source of chromium is probably present in catchment 400, and should be investigated further.

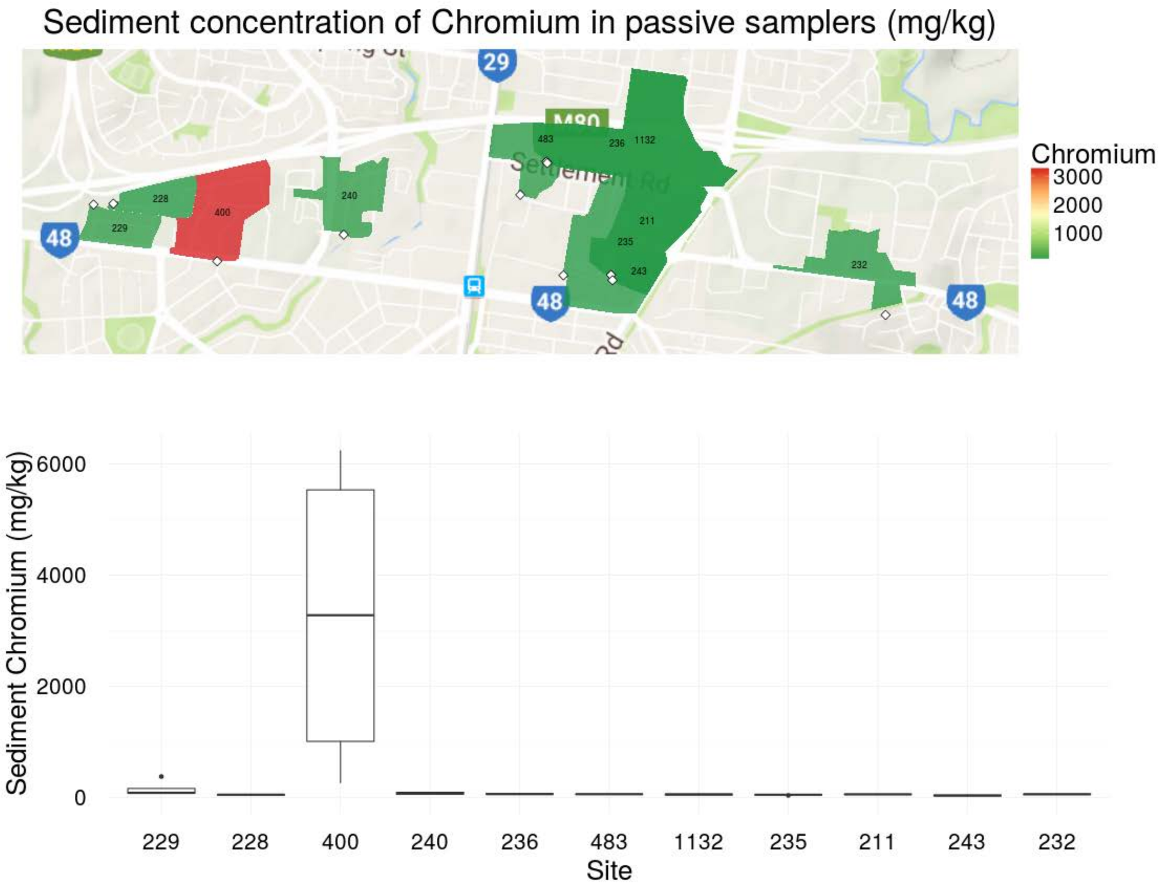

Figure 3. Spatial distribution of chromium concentrations and variation between catchments.

COPPER

Copper concentrations were consistently elevated in catchments 235, 211 and 243, most likely associated with contaminated land at 6 Dunstans Ct. Copper was also elevated at site 400, although median concentrations were approximately half those at site 235. The source of copper in catchment 400 may be associated with the chromium source identified above, and should be investigated further.

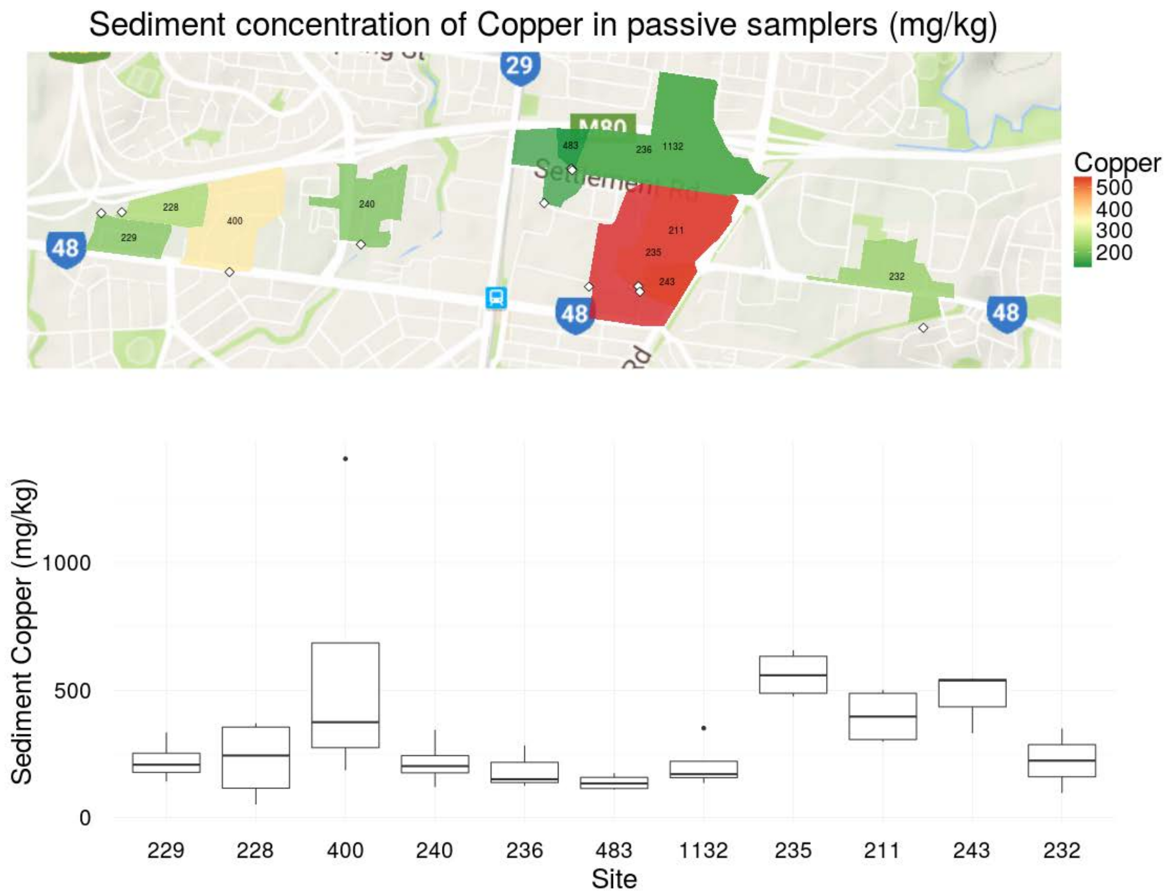

Figure 4. Spatial distribution of copper concentrations and variation between catchments.

LEAD

Lead concentrations were consistently elevated in catchments 243, likely associated with the contaminated land at 6 Dunstans Ct. Site 232 and 229 also had elevated median lead concentrations, indicating possible sources of lead within these catchments.

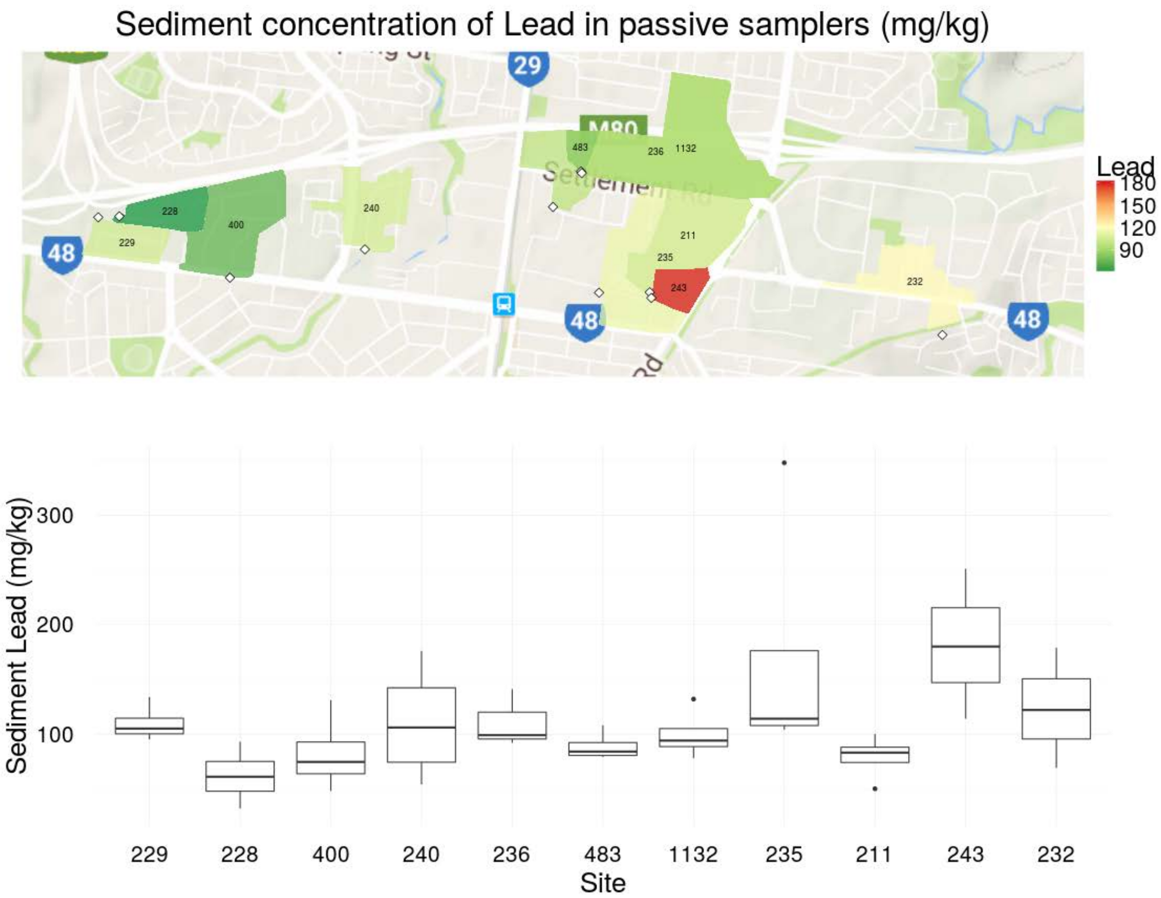

Figure 5. Spatial distribution of lead concentrations and variation between catchments.

MERCURY

Mercury was less commonly detected than most other contaminants, but was consistently elevated in catchment 243, 235 and 211. This hotspot is likely associated with the contaminated land at 6 Dunstans Ct. Moderate mercury concentrations were also found in catchments 236 and 232, although no obvious sources were identified.

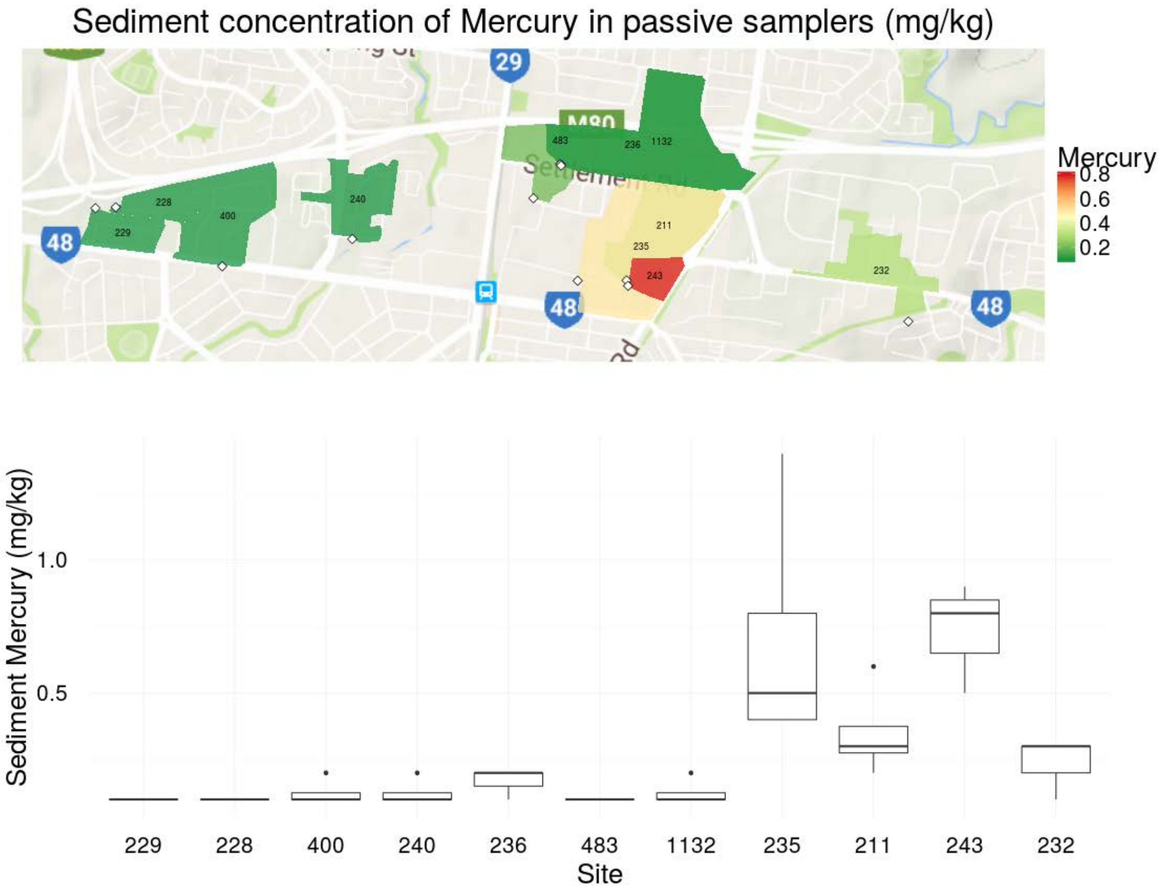

Figure 6. Spatial distribution of mercury concentrations and variation between catchments.

NICKEL

Nickel concentrations were generally low at all sites, with only one hotspot detected at site 400. A consistent source of nickel is suspected in catchment 400, possibly associated with copper and chromium.

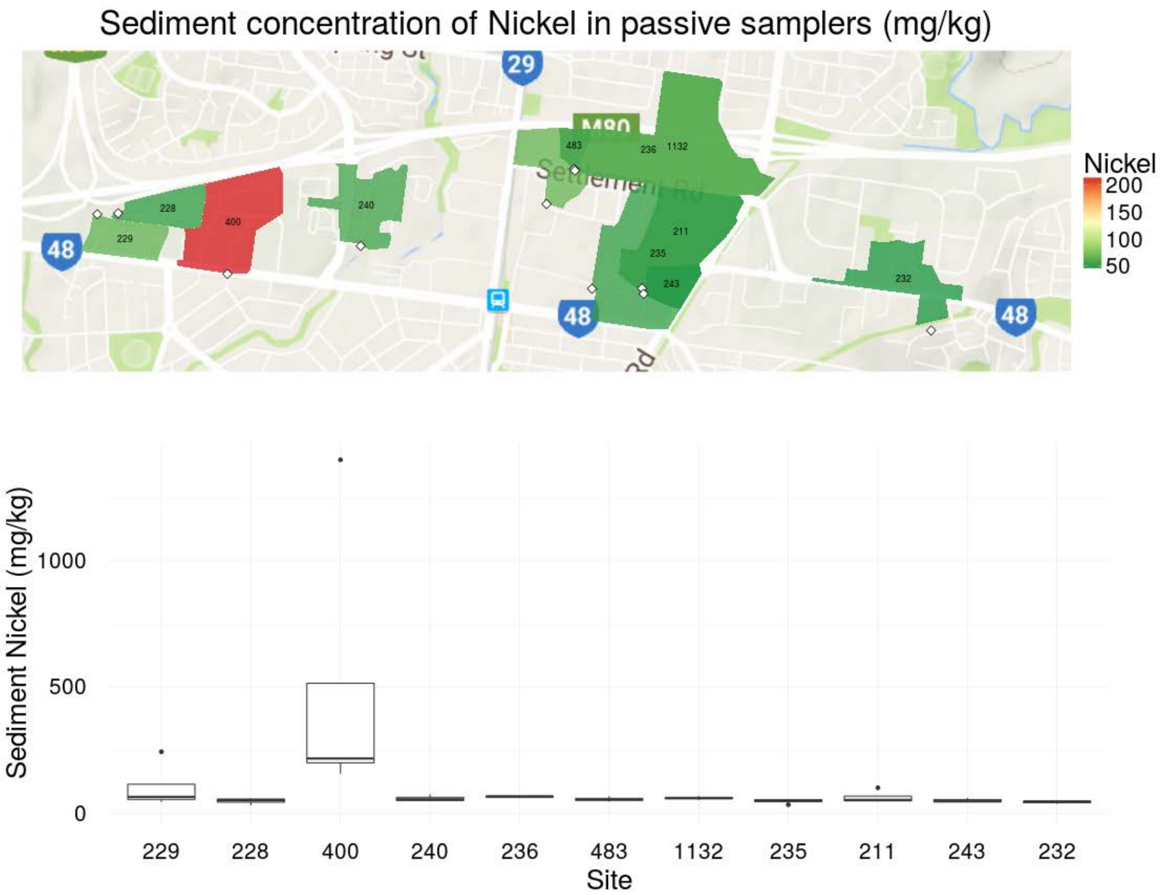

Figure 7. Spatial distribution of nickel concentrations and variation between catchments.

SILVER

Silver can be a highly toxic pollutant but is rarely found stormwater. Previous studies have found persistently high silver concentrations in Edgars Creek sediment downstream of Keon Park Main Drain, and localized the source to catchment 243. This is likely associated with the contaminated land at 6 Dunstans Ct and remains the dominant source of silver pollution to Edgars Creek.

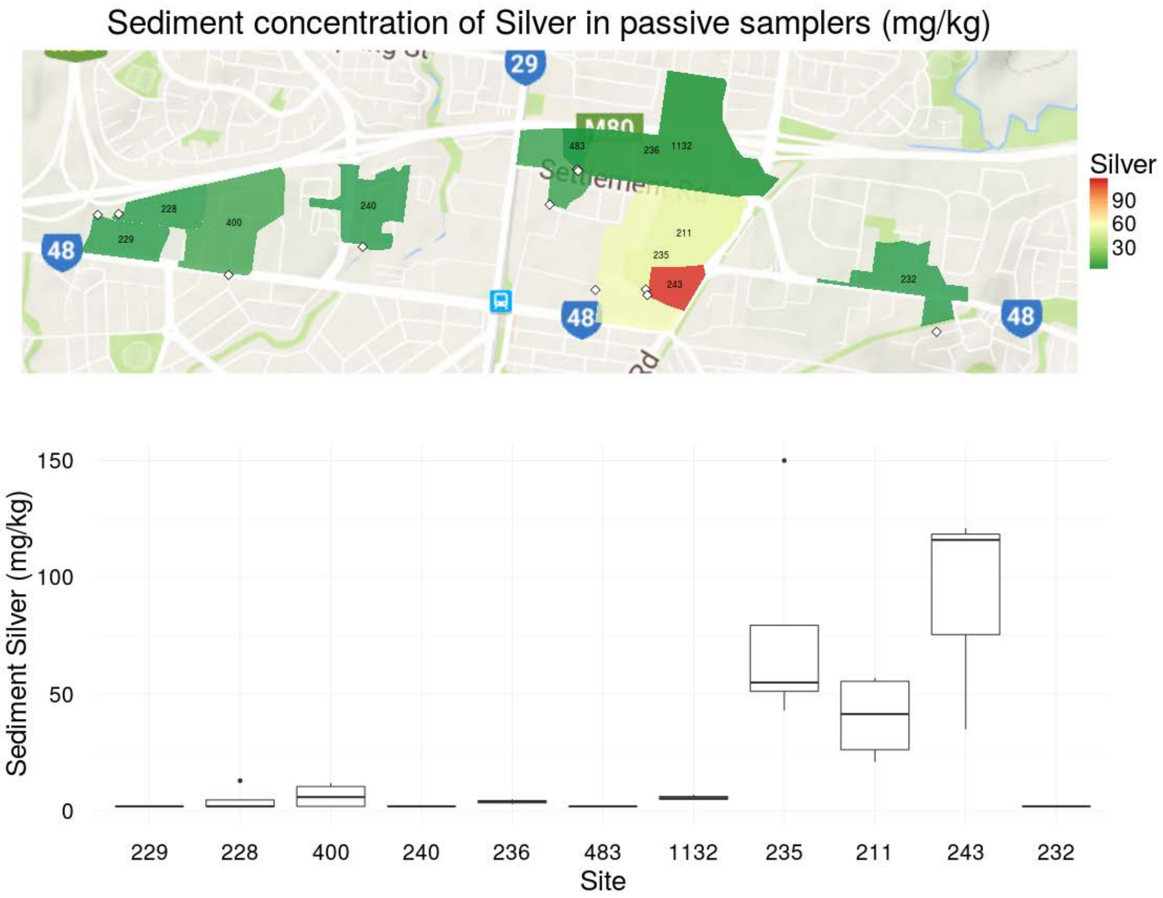

Figure 8. Spatial distribution of silver concentrations and variation between catchments.

ZINC

Zinc concentrations were elevated in most catchments to some extent, but were particularly high at catchments 229 and 232. There appears to be a consistent source of zinc located in catchments 232 and 229, which should be further investigated.

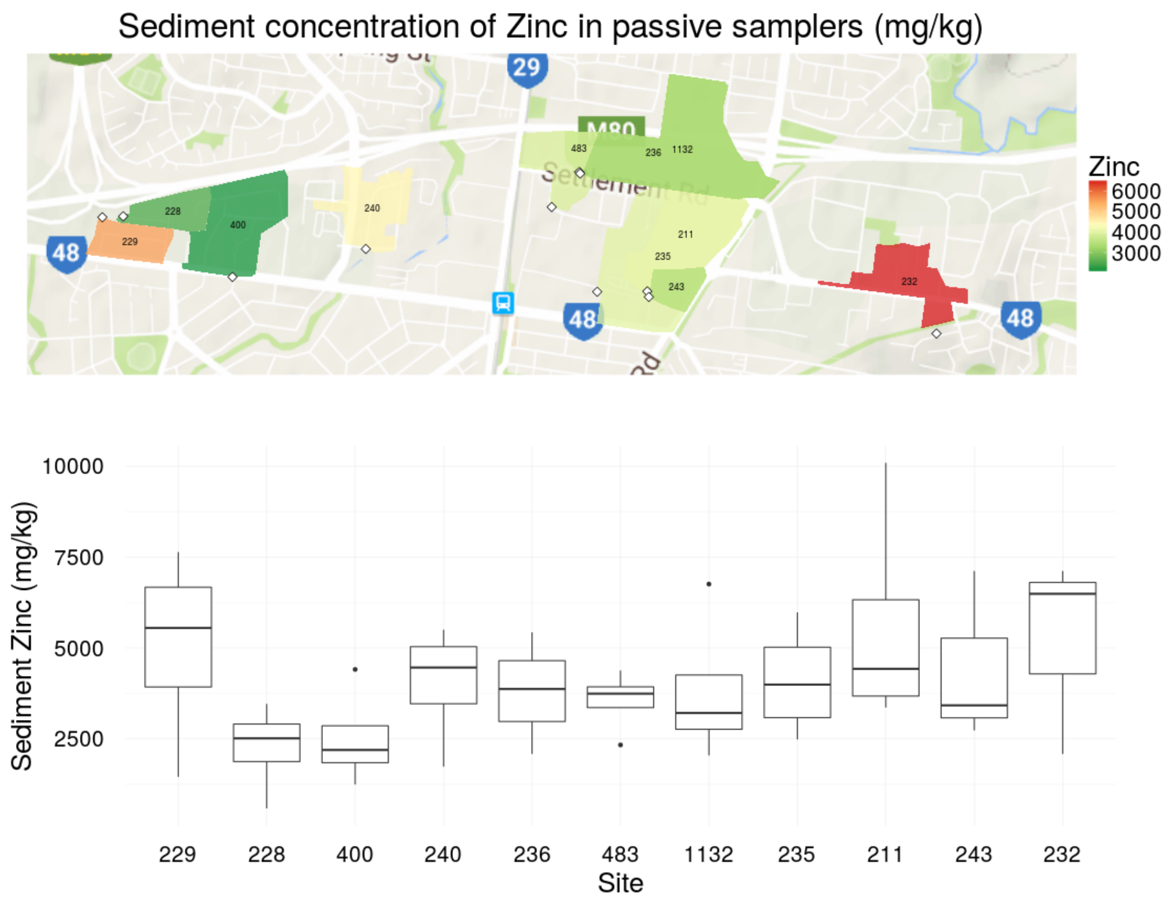

Figure 9. Spatial distribution of zinc concentrations and variation between catchments.

OILS (SEMI-VOLATILE HYDROCARBONS)

Oil pollution was consistently observed at sites 240 and 232. Catchment 240 contains several vehicle recycling businesses which may be a potential source. No obvious sources were observed in catchment 232. The persistent sources of oil pollution from these catchments should be further investigated.

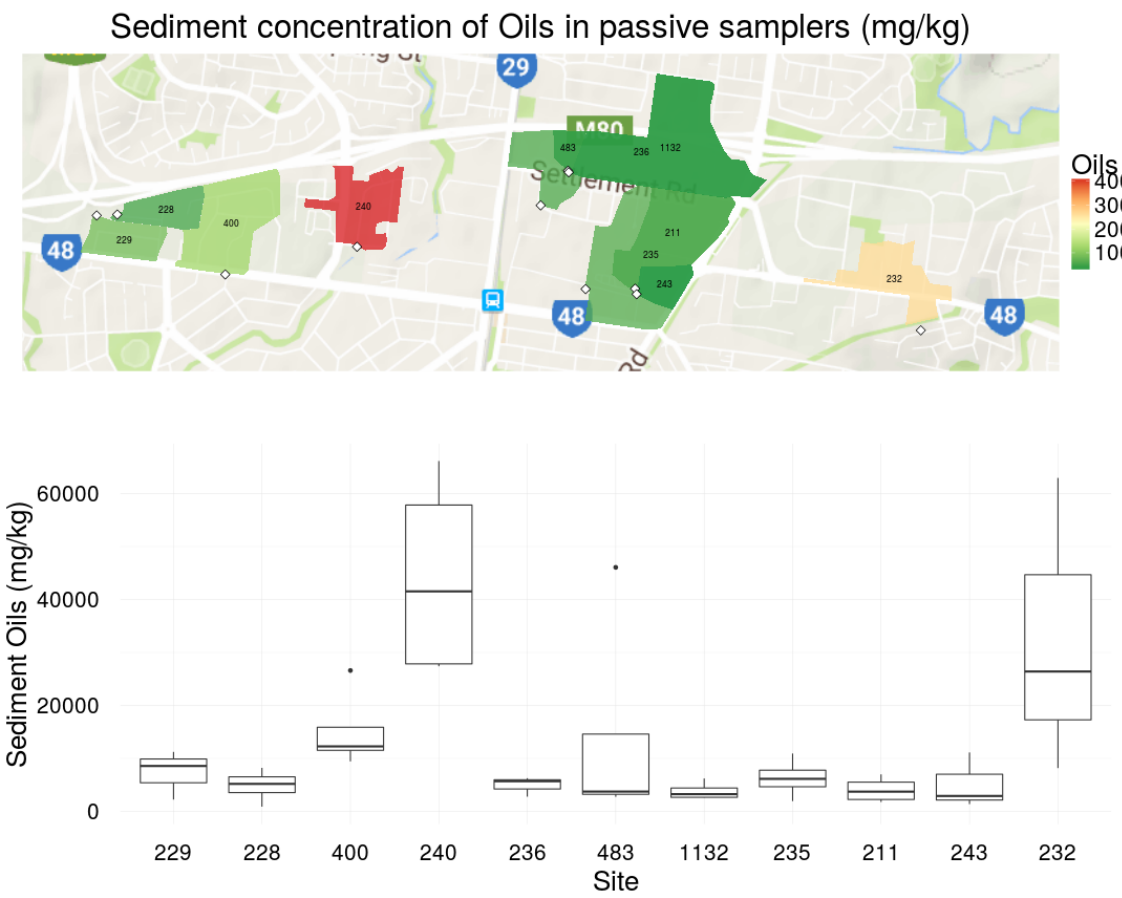

Figure 10. Spatial distribution of oil concentrations and variation between catchments.

TEMPORAL TRENDS

Following the beginning of the education program, pollutant concentrations generally decreased at educated sites, with significant reductions detected in oils and lead (Figure 11).

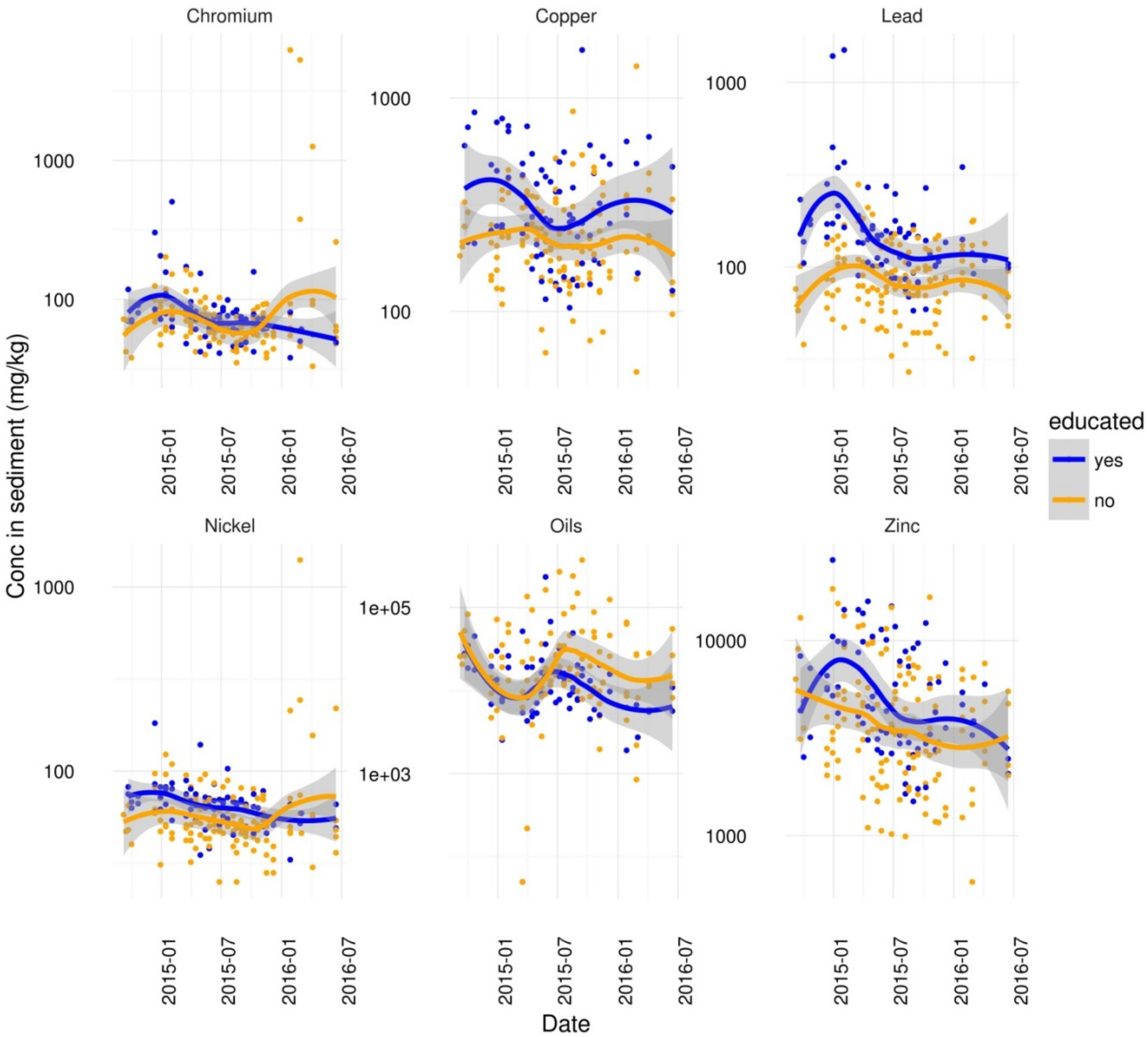

Figure 11. Temporal trends in pollutant concentrations between educated and control sites, Jul 1st 2014 to June 30th, 2016. Sites in catchments receiving the SEP indicated in blue, other sites indicated in orange. Smoother lines indicate a loess smoother fitted separately to each group.

Significant decreases in lead ($F_{(1,197)}$ = 6.62, p=0.011) and oils ($F_{(1,164)}$ = 5.74, p=0.018) were associated with the education program. Although zinc ($F_{(1,197)}$ = 2.06, p=0.152), chromium ($F_{(1,197)}$ = 2.19, p=0.140), copper ($F_{(1,197)}$ = 1.88, p=0.172) and nickel ($F_{(1,197)}$ = 1.16, p=0.283) concentrations also decreased after the SEP, the magnitude was not significant compared with trends at non-educated sites.

TOXICITY IN RECEIVING WATERS

Sediment toxicity in Edgars and Darebin creeks is summarized in Figure 12. Mortality at sites above and below the industrial catchment was higher in 2016 than 2014. Although this suggests pollution may have increased during this period, these two samples represent a snapshot of toxicity at each point in time and should be interpreted cautiously. Further surveys would be required to reliably establish a long-term trend.

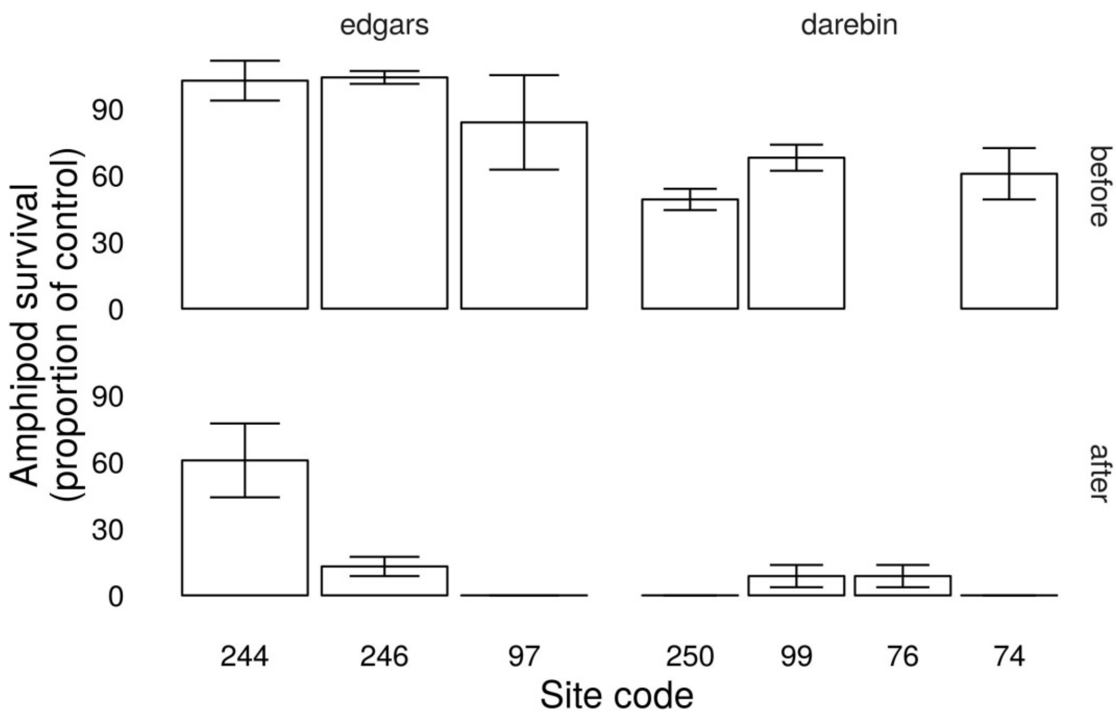

Figure 12. Sediment toxicity to amphipods along Darebin and Edgars creek above and below the industrial area. Bars indicates mean mortality after 21 days exposure relative to control sediment, plus or minus standard errors.

It is also possible the increased sediment toxicity was caused by pollution not detected by the chemistry survey, since the regular survey covered only hydrocarbons and the most common heavy metals. More extensive chemistry surveys conducted during the ecological effects surveys found high concentrations of pesticides in sediment, and these may have had a greater impact on toxicity than heavy metals and oils. Given the SEP was not focused on general stormwater management rather than pesticide use, the apparent increase in sediment toxicity during the study period should not be taken to indicate a failure of the SEP, rather that the pollution issues facing urban streams such as Darebin and Edgars creeks go beyond heavy metals and hydrocarbons. A more integrated whole-of-catchment approach is needed to address pollution from more cryptic sources such as pesticides.

POLLUTION REPORTS

Pollution incidents reported to EPA Victoria each month during the study are summarized in figure 13 below. Water pollution reports declined in the second half of 2014, although linking this decline with the SEP is possibly ambitious since the total numbers are low and heavily influenced by the high number of pollution reports in Aug 2014 (Fig 13).

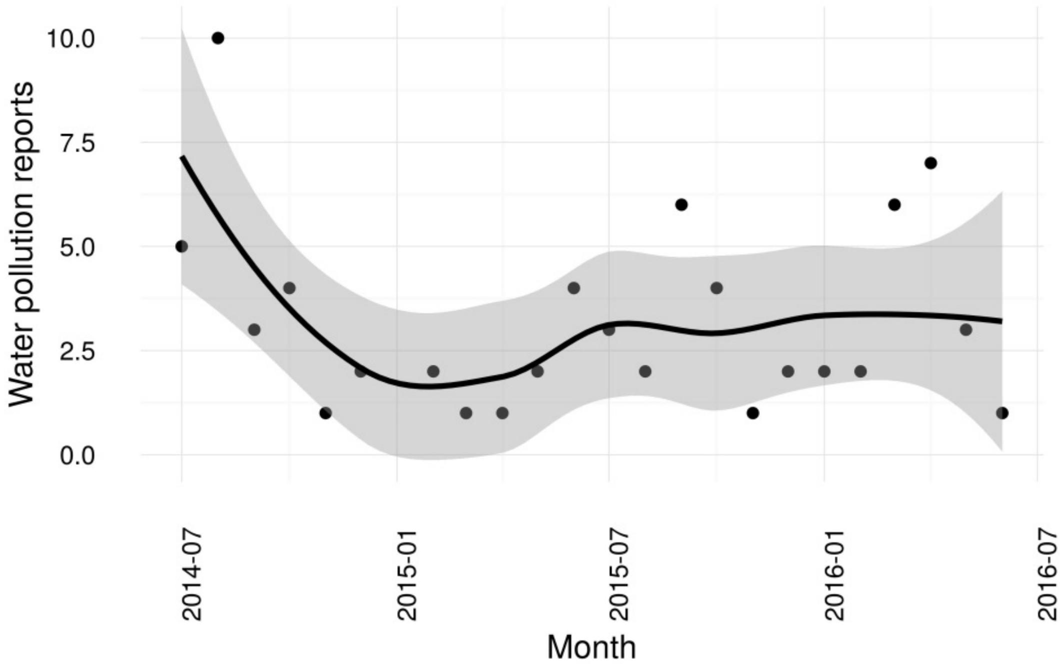

Figure 13. Monthly counts of water pollution reports to EPA Victoria made by the public to the pollution watch hotline. Points represent the sum of all water-related pollution reports for each calendar month. Trend line represents a local polynomial regression (loess, span = 0.75) plus or minus standard error.

The vast majority of pollution reports received by the EPA are related to littering from motor vehicles and noise complaints. By comparison, water related reports comprise just 4.5% of the total received between Jun 2014 and Jul 2016 in this area. Although it is encouraging to see a decline in pollution reports, the small numbers and relative scarcity of water pollution reports mean we are cautious in attributing this to the SEP.

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