Setting Appropriate Goals for Urban Stream Restoration: A Case Study from Blacktown City Council

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Key Points

- A key component of an adaptive management framework is feedback from adequate monitoring. Whilst significant funding resources are directed to implementing stream restoration works, frequently no resources are allocated to allow evaluation of whether predetermined objectives used to justify those works were achieved. Monitoring using appropriate indicators and over appropriate timescales should be included in creek restoration projects.
- Overarching objectives used to prioritize and guide urban stream restoration typically include asset protection, ameliorating erosion, flood mitigation, improving water quality, increasing native biodiversity and enhancing aesthetics. Stream restoration projects are unlikely to meet objectives linked to water quality and aquatic biodiversity improvement if broad scale stormwater management is not applied.
- Biodiversity outcomes are more likely to be achievable in the riparian zone when a mosaic of native plant species are used for revegetation.
- Given the limitations of reach-scale management, the objectives of reach-scale restoration projects should focus on what is realistic, including societal benefits.

Abstract

Lack of adequate monitoring after completion of urban stream restoration works is a major failing of urban stream management and is a significant barrier to refining the process of setting and achieving objectives for urban stream restoration projects. Blacktown City Council has recognised the need to pursue best practice management of urban streams, including monitoring of stream restoration projects. The restoration of Lalor Creek provided a case study of a monitoring strategy aimed at determining the effectiveness of restoration activities against project objectives, which were: 1) ameliorate and mitigate against bed and bank erosion; 2) improve water quality; and, 3) improve biodiversity. To determine if project objectives were met and assess timelines for detectable improvements, monitoring was done at an unrehabilitated stream reach, a reach rehabilitated three years ago, and a reach rehabilitated five years ago. Indicators included aquatic macroinvertebrates, benthic diatoms, riparian vegetation and stream channel condition. Results of the study revealed that the objective of mitigating against bed and bank erosion was achieved, but that biodiversity improvement occurred in the riparian ecosystem only and that there were no improvements in water quality. Aquatic biodiversity and water quality objectives were not achieved as the project did not address urban stormwater flows, and in hindsight were not realistic objectives given the type and scale of the restoration works. Results of this study provide waterway managers with valuable information on setting realistic and achievable objectives for urban stream restoration projects.

Keywords

Urban creek restoration, restoration, objectives, biodiversity improvement, monitoring

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Introduction

It is well known that urban stormwater run-off causes severe impacts to streams. The phrase 'urban stream syndrome' (Walsh et al 2005a) was coined to describe the multiple common symptoms occurring in urban streams, including degraded water quality, geomorphology, hydrology and biodiversity. Urban run-off also effects riparian ecosystems by altering riparian soil chemistry such to promote invasive plant colonisation and ultimately displace native species (Riley and Banks 1996, Grella et al 2014). Impacts to urban stream systems caused by stormwater run-off not only degrades the quality of urban ecosystems but also effects the overall amenity and livability that these areas offer the human population (Palmer et al 2014).

Over the past few decades, efforts have been made to rehabilitate urban streams and globally a multibillion dollar industry has emerged (Palmer et al 2005, Kenney et al 2012). A large majority of urban stream restoration projects aim to return the stream to a pre-development condition and improve aquatic biodiversity (as measured by various macroinvertebrate indices) (Shoredits and Clayton 2013, Smith et al 2015). The major shortcoming to this approach is that most urban stream restoration projects are conducted at the reach scale and focus on habitat restoration and channel reconfiguration (Palmer et al 2010), without mitigating landscape scale constraints on achieving restoration success.

In the urban context, the scale of land use change and the associated severity of stream degradation make it unlikely that a return to pre-development condition is achievable (Palmer et al 2012, Schueler and Brown 2004) without catchment scale intervention. Given that urbanization involves an increase of impervious surfaces, with concomitant alteration of flow and water quality of receiving waterways, effective mitigation of impacts primarily involves disconnection of the stormwater drainage network from urban streams (Walsh et al 2005b, Walsh et al 2004, Violin et al 2011). That is, if we wish for urban streams to perform multiple ecological, social and economic functions, we need to stop using them as drains.

Despite the availability of guidelines to rehabilitate urban streams (e.g. Schueler and Brown 2004, Riley 2016) it seems there is a widespread misconception about how successful an urban stream restoration project can be in terms of resurrecting a pre-development stream condition and increasing aquatic biodiversity. Given that many stream restoration projects have been completed throughout the world, there is very little documentation on the outcomes of such projects, with only a limited subset addressing urban projects. However, what is available overwhelmingly highlights the failures of stream restoration projects to improve biodiversity. For example, Palmer et al (2010) evaluated the ecological outcomes of 78 stream restoration projects undertaken in a mix of urban, farmland and forested streams and found that only two (i.e. < 3%) had significant gains in biodiversity. In recent studies, Cockerill and Anderson (2014) showed no significant ecological outcomes were achieved in a study of four urban stream restoration projects, while Rundus (2017) reported a mixed response from various ecological indicators used to gauge project success.

The lack of information highlighting the results of urban stream restoration projects is owing to several factors, including inadequate planning, lack of funding and poorly designed comparative studies (Kondolf and Micheli 1995, Louhi et al 2011). Yet there is a multitude of literature stating that without broad scale disconnection of stream catchments from the urban stormwater system, improvement to stream hydrology, geomorphology and aquatic biodiversity is unlikely (e.g. Palmer et al 2010, Walsh et al 2004, Ladson et al 2006).

So, the question remains, why do urban stream managers continue to undertake reach scale restoration projects with aquatic biodiversity improvement highlighted as a project objective when the proposed project does not address catchment scale disconnection from the urban stormwater system?

Cockerill and Anderson (2014) noted that there is strong evidence that waterway managers do not consult relevant literature and that there is a notable communication disconnect between waterway managers and researchers. This inevitably continues the cycle of projects failing to achieve their proposed objectives, particularly those with objectives to improve aquatic biodiversity (Cockerill and Anderson 2014).

In this study, we evaluate if a reach scale stream restoration project met its objectives of ameliorating and mitigating against bed and bank erosion, improving water quality and improving biodiversity and, whether those objectives were realistic. We set out to measure project success/failure by applying a range of commonly used indicators of stream condition which includes aquatic macroinvertebrates and rapid assessment of stream channel and riparian vegetation.

Outcomes of this research will assist waterway managers to better frame their project objectives and implement a monitoring program to assess outcomes against objectives.

Study area

Lalor Creek is in the Blacktown Local Government Area (LGA) of western Sydney. The catchment is approximately 730 ha, with ~37% of that area being impervious (Blacktown Council 2017). Catchment land use is mainly residential, whilst there is also a small area of land with commercial uses: most land use intensification occurred in the late 80's and early 90's. The reach subject to restoration is in the mid to upper catchment and is approximately 850 m in length. Restoration of the creek has occurred in two distinct stages across two adjacent reaches. The first stage of restoration was completed in 2012 and the second stage was completed in 2014. Restoration works had an approximate cost of $1.3 M and consisted of stream realignment, bed and bank armoring with sandstone blocks and revegetation of the riparian zone.

As part of the restoration works, Blacktown Council identified three key target areas to address which were:

i) ameliorate and mitigate against bed and bank erosion;

ii) improve water quality; and,

iii) improve biodiversity.

Method

For this study, three stream reaches were identified;

- Reach 1, a stretch of approximately 150 m of unrestored creek which is located in the upper most section of the study area and directly upstream of the rehabilitated reaches.
- Reach 2, directly downstream of Reach 1, where restoration was completed approximately three years prior to the present study and works consisted of bank stabilisation, installation of in-stream bank and flow mitigation structures and replanting of native riparian vegetation across approximately 450 metres of the stream.
- Reach 3, directly downstream of Reach 2, is approximately 400 metres long and had similar restoration works to Reach 2, but those were implemented approximately five years prior to the present study.

Creek channel and riparian vegetation

To assess the relative condition of riparian vegetation and creek channel, the Rapid Riparian Assessment (RRA) developed by Findlay et al (2011) and later refined by Dean and Tippler (2016) was applied. This method combines the assessment of both instream and riparian habitat metrics and was developed in the Sydney region for visual assessment of urban streams. Assessments were undertaken at 100 m intervals, which resulted in a total of 10 assessments being conducted; one (1) in Reach 1, five (5) in Reach 2 and four (4) in Reach 3.

Aquatic macroinvertebrates

Along each assessment Reach, three (3) quantitative benthic macroinvertebrate samples were collected from random locations. Each sample was collected in a kick net (frame of 30 x 30 cm and 250 µm mesh) from within a 1 m x 1 m area of creek edge substrate that was disturbed for 30 seconds. Net contents were then placed into a sorting tray, and all taxa live-picked from the sample and preserved in ethanol for later identification. Specimens were identified to the taxonomic level of Family, with exception of Chironomidae (non-biting midges) which were identified to subfamily and oligochaetes which were identified to class.

Specimens were identified using the identification keys by Hawking and Smith (1997) and Gooderham and Tsyrlin (2002).

Biotic indices of taxon richness and SIGNAL-SF scores were calculated for each sample. Results for each sample were combined to provide an average for each assessment Reach.

Benthic diatoms

From each assessment Reach, one (1) diatom sample was collected from rock substrata, following the methods provided by Chessman et al (no date). This was achieved by scraping organic matter from hard rock substrata from three areas within the lower end of each assessment Reach. Samples were preserved in 100% ethanol and sent for identification and count by a taxonomic specialist. The proportion of diatom taxa was determined for each assessment Reach.

Algal diatoms were analysed with OMNIDIA 7 software to calculate the metrics of relative abundance, diversity and Diatom Trophic Index (DTI) (Lecointe et al 1993 and 2003) which provides an assessment of the tropic status of freshwaters. The higher the DTI, the more eutrophic (i.e. nutrient enriched) is the assessed water body.

Results

Riparian Vegetation and Creek Channel Condition

Results of riparian vegetation and creek channel condition assessment using the Rapid Riparian Appraisal show all assessment sites, with exception of Lalor-31 (Reach 2) and Lalor-28 (Reach 3) were in poor condition (Table 1). Therefore, at the time of assessment, there were no apparent differences in the overall condition of riparian vegetation and channel between assessment Reaches.

This result reflects the width of the riparian buffer along the creek typically being less than 40 m, with surrounding land being a mix of parkland, residential and road. The ongoing presence of weeds contributed to low RRA scores and although the regenerated riparian vegetation community along Reach 3 was re-planted with a mosaic of native canopy species, planting was dense and excluded establishment of midstory and groundcovers which detracted from the vegetation index score (Table 1). However, the vegetation index scores for Reach 2 were higher than those at Reach 1 and 3 which reflects the complexity of plantings along this reach and the presence of a native midstory and well-established ground cover.

Bed and bank stabilisation works along Reaches 2 and 3 were found to have reduced erosion, as indicated by erosion index scores at those Reaches being higher than at the unrestored Reach 1 (Table 1). In addition, in the rehabilitated reaches there were less restrictive channel bars deposited owing to sedimentation, indicated by higher deposition index scores (Table 1).

The channel feature index score was considerably higher in the unrehabilitated Reach 1 when compared to Reaches 2 and 3. This is due to the absence of large woody debris and riffle zones and less percentage cover of overhanging vegetation along the rehabilitated reaches, which were surrounded by replanted vegetation at immature growth stages (Table 1).

Table 1: Results summary of assessment of riparian vegetation and creek channel condition by application of RRA. Reach 1 had no restoration works, Reach 2 had restoration works completed three years prior to this study, and Reach 3 had restoration works completed five years prior to this study.

Reach	Site	Site Features x/26	Channel Features x/13	Vegetation x/46	Deposition x/3	Erosion x/1	Site Total x/89	Site Condition
1	Lalor-35	5.6	7	-1.5	-2	-6	3.1	**poor**
2	Lalor-30	-12.8	-5	8.1	0	0	-9.7	**poor**
2	Lalor-31	-3.8	1	12	-1	0	8.2	**fair**
2	Lalor-32	-6.2	-3	8.2	1	0	0.0	**poor**
2	Lalor-33	-7.2	-1	9.3	-1	0	0.1	**poor**
2	Lalor-34	-12.4	1	15.5	1	1	6.1	**poor**
3	Lalor-26	-6.6	1	-0.6	-1	1	-6.2	**poor**
3	Lalor-27	-13.4	1	4.8	-1	1	-7.6	**poor**
3	Lalor-28	-8	4	13.6	0	0	9.6	**fair**
3	Lalor-29	-12.8	2	2.5	0	0	-8.3	**poor**

Aquatic macroinvertebrates

Mean macroinvertebrate taxon richness was marginally higher at Reach 2 than Reach 1 (where no restoration works were implemented) and lowest at Reach 3, where restoration actions were first implemented.

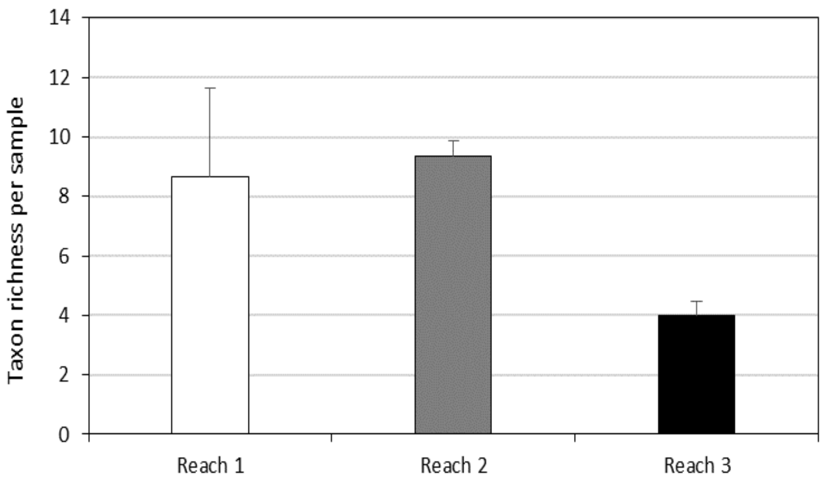

Figure 2: Mean taxon richness of macroinvertebrate communities (+ 1 SD) at Lalor Creek assesssment reaches. Reach 1 had no restoration works, Reach 2 had restoration works completed three years prior to this study, and Reach 3 had restoration works completed five years prior to this study.

Results of SIGNAL SF calculations show all Reaches fell within quadrant 3 of the SIGNAL-SF v. taxon richness biplot, indicative of all being subject to harsh physical conditions and/or toxic pollution (Figure 3). On that biplot, Reach 2 was close to the border with quadrant 4, which is associated with particularly harsh conditions owing to human development.

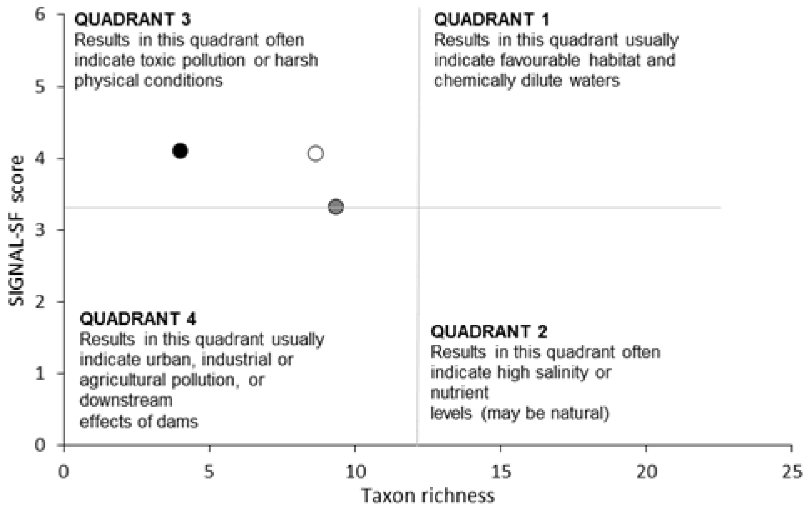

Figure 3: Bi-plot of mean SIGNAL scores and taxon richness for macroinvertebrate communities. Reach 1 – white circle. Reach 2 – grey circle. Reach 3 – black circle. See Figure 2 for brief description of differences in timing of restoration works across Reaches.

Benthic diatoms

Benthic diatom communities in each Reach were found to have only slight variation in taxon richness and Trophic Diatom Index (TDI). Reach 2 had the lowest diatom taxon richness and TDI but, the difference between reaches was marginal (Figure 4) and these results indicate the consistent presence of elevated nutrients and low oxygen, a result which is typical of urbanised streams.

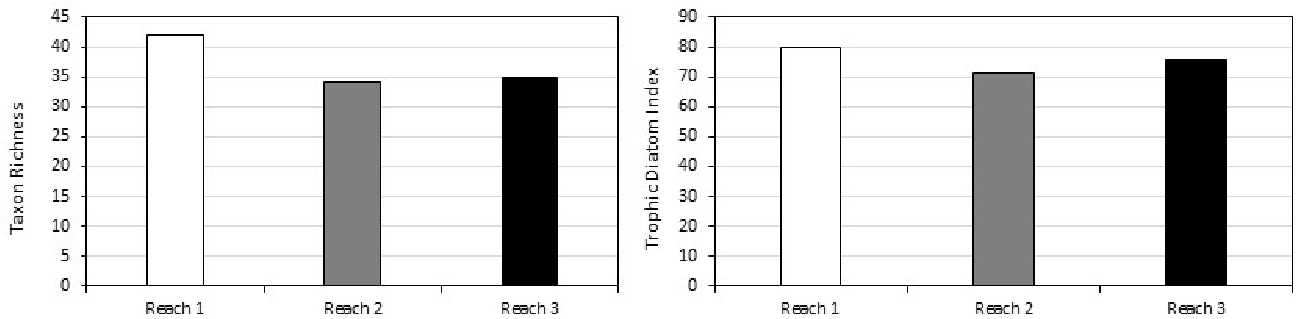

Figure 4: Benthic diatom taxon richness and Trophic Diatom Index for Lalor Creek. See Figure 2 for brief description of differences in timing of restoration works across Reaches.

Discussion

Two of three objectives of the restoration works were met. Mitigation and amelioration against bed and bank erosion was achieved in both rehabilitated Reaches. Sandstone block lining of the bed and bank appeared to have stabilized the creek and evidence of sediment deposition was observed. In comparison, the upstream unrehabilitated Reach continued to be deeply incised, with significance bank slumping, undercutting and lack of sedimentation. It is unsurprising that the objective of erosion control was achieved. Significant investment and hard engineering was applied to meet this investment and the end result is an approximately 850 m rock armoured channel which has been designed to protect the creek from further erosion which may become threatening to neighbouring property.

The objective of water quality improvement was not achieved. Benthic diatoms are a robust indicator of water quality and are less influenced by changes in flow owing to land use intensification than macroinvertebrates (Sonneman et al 2001). There were only marginal differences in taxon richness and TDI, which indicates water quality in all three Reaches was eutrophic. This is reflective of no change in water quality occurring as water flows from the upstream unrehabilitated Reach through the downstream rehabilitated Reaches. This result is also reflected by the SIGNAL index, which indicates the macroinvertebrate communities at all Reaches were affected by toxic pollution and/or harsh physical conditions, with no notable differences between study Reaches. It is unsurprising that the objective of improving water quality was not achieved. It is well documented that to improve water quality of urban waterways effective stormwater management is required (e.g Walsh et 2005b, Bernhardt and Palmer 2007). No broad scale disconnection of Lalor creek from the stormwater system was included in the restoration and therefore no capacity for significantly improving water quality in the creek was achieved.

Biodiversity improvements were achieved in the riparian vegetation zone where native vegetation was replanted, but not in aquatic habitats (for either macroinvertebrates or diatoms) as initially proposed.

Although the initial concept was for improvement to aquatic biodiversity, it is unlikely this objective could be met without effective stormwater management and disconnection of Lalor Creek from the conventional stormwater system (Booth 2005, Walsh et al 2005b). However, biodiversity gains, in the form of plant richness, were made in the riparian vegetation zone which, although was not a major consideration, is an important outcome. Riparian corridors in urban settings are known to provide important habitat for urban biodiversity (Ives et al 2007, Pennington et al 2008) and in our opinion should be the focus of restoration in urban settings as biodiversity outcomes may be more easily 'won' in this environment rather than in the aquatic zone.

The failure of stream restoration projects to meet objectives is not uncommon, particularly when improvement to water quality and aquatic biodiversity are a focus. As highlighted it is unlikely that reach scale restoration will achieve these outcomes without broad scale stormwater management and results if this study reiterates this.

Although most indicators assessed during this project showed marginal change between assessed reaches, this should not be reason to conclude that future change will not occur. There is likely to be considerable time lag between implementation of restoration works and any detectable ecological response (Harding et al. 1998). With only five years since the first phase of the restoration was implemented it may be too early to determine the full extent of physical and ecological change, as these may take decades to occur (Rutherfurd et al 2004).

It is recommended that objectives for future stream restoration do not include improvement to water quality and aquatic biodiversity if the project is reach based. These objectives should only be included if the planned works incorporate the inclusion of WSUD features in the upper catchment to reduce stormwater quantity and/or improve water quality entering the system.

It is also recommended that monitoring frameworks are embedded into waterway management projects. Careful consideration should be given to electing metrics and indicators that are best suited to assessing the objectives, whilst monitoring should be conducted over time scales that account for lags between works and detectable improvements.

Conclusions

Results of this study reiterate that change to water quality and aquatic biodiversity are unlikely outcomes of reach scale creek restoration projects that do not address the effects of stormwater. We advocate outcomes be focused on asset protection, riparian biodiversity improvement and incorporate social outcomes. We also advocate that creek restoration projects include a long-term monitoring strategy to assess the success of such projects.

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