Concrete Stormwater Channels: Urban Stream Wasteland or Supercharged Ecosystems?

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- **Keypoints**
- Despite the volume of research regarding urban streams little is known about the biodiversity of concrete stormwater channels
- Macroinvertebrate richness did not vary significantly between concrete stormwater channels and urban streams with natural features however abundance was far greater in concrete channels
- This suggest that in urban streams riparian and instream habitat does not influence macroinvertebrate diversity
- Macroinvertebrates may not be a suitable indictor of urban stream restoration success as they lack the appropriate sensitivity

Abstract

Degradation of urban stream ecosystems caused as a direct result of stormwater runoff is well documented. The signs of degradation are universal and include altered hydrology, reduced stream function and significant declines in biodiversity. Within urban landscapes, concrete stormwater channels are ubiquitous. They are designed to efficiently transport stormwater runoff, which is typically achieved via the widening, deepening, straightening and concrete lining of what was once a complex stream ecosystem that performed multiple natural functions. In concrete channels the alteration of stream hydrology and physical structure are particularly stark, leading to the understandable perception that concrete channels are far more degraded than nearby urban streams. But, the validity of this perception has not been explored. Literature on the biodiversity of concrete stormwater channels is sparse and studies comparing biodiversity of urban streams to concrete stormwater channels are virtually non-existent. In this study, we set out to compare aquatic biodiversity of urban streams to that in concrete stormwater channels. We used aquatic macroinvertebrates as indicators of local in-stream habitat. Results show urban streams and concrete channels had similar macroinvertebrate community structure, however abundance was far greater in concrete channels. Results of this study imply that altered flow, not loss of local in-stream habitat is a highly significant factor effecting urban waterways.

Keywords

Concrete stormwater channel, urban creek rehabilitation, restoration, urban stream biodiversity, urban stream syndrome

Introduction

Concrete lined stormwater channels are ubiquitous across the urban landscape. These highly engineered structures are specifically designed to transport stormwater from the built environment to receiving waters, usually a creek, river or estuary, with maximum efficiency. Channel construction involves armoring of a natural drainage line which typically includes widening, deepening and straightening of the existing channel, removing riparian and instream habitats and transforming what was once a complex stream ecosystem into a homogenous drainage channel.

Across the globe urbanisation has had devasting effects on stream ecosystems. So much so that the term 'urban stream syndrome' (Walsh et al 2005a) is now used to describe the ever-present impacts caused by urbanisation which includes significant alteration of stream hydrology and physical form (Fletcher et al 2014, Vietz et al 2014) which leads to severe degradation of water quality, water quantity and biodiversity (Tippler et al 2014 and 2012). The channelisation of streams is the epitome of the urban stream syndrome.

The study of the ecological degradation of urban streams, has become a very popular topic of research with many thousands of articles being published over the last few decades. Even though concrete stormwater channels are ubiquitous across the urban landscape, study of the ecology of these waterbodies is all but absent. It is unclear why this is the case but Reid and Tippler (2018) suggest that the current perception is that they are thought to have minimal ecological integrity and are therefore overlooked.

Concurrent with the research effort associated with urban stream ecology, restoration of urban streams has become a burgeoning industry, attracting billions of dollars of global investment (Kenney et al 2012). Many of these projects are dedicated to returning concrete stormwater channels to a more natural state with a major assumption being that restoration works will improve aquatic biodiversity which is typically measured by using aquatic macroinvertebrates to prove success (Shoredits and Clayton 2013, Smith et al 2015). However, the limited amount of literature available on the results of urban stream restoration overwhelming highlight the failure of such projects to improve aquatic biodiversity (Tippler et al 2018).

To deepen our understanding of the use of aquatic macroinvertebrates as indicators of urban stream restoration success, or maybe more appropriately the failure of such projects, we pose the questions: do concrete stormwater channels contain diverse aquatic macroinvertebrate communities? and, how do these compare to urban streams?

To answer these questions, we conducted a pilot study to survey the aquatic macroinvertebrate communities of five concrete stormwater channels in the Georges River catchment and compare these with communities of five urban streams within the same waterway.

Results of this study will enable waterway managers to better understand the dynamic ecosystem of concrete stormwater channels and broaden the knowledge around selecting indictors for application to urban stream restoration projects.

Method

For this study, five urban streams were selected each containing reaches of concrete stormwater channel and natural stream. In each urban stream survey of the aquatic macroinvertebrate community was undertaken in both concrete channel and natural stream reaches. All concrete channels were devoid of riparian vegetation and natural stream reaches contained a vegetated riparian zone with a mix of native and exotic canopy trees, shrubs and groundcover. All waterways sampled were located within the Georges River catchment in south west Sydney.

Aquatic macroinvertebrates

At each study site aquatic macroinvertebrates were collected following the method outlined by Chessman (2003). In summary, 10 m of a 100 m stretch of the waterway was sampled using a kick net (frame of 30 x 30 cm and 250 µm mesh). 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 abundance and taxon richness were calculated for each sample.

Statistical analysis

Multivariate analysis was used to assess and compare the macroinvertebrate community structure between concrete stormwater channels and urban streams. To determine the influence of abundance, non-metric multidimensional scaling (NMDS) was performed on a similarity matrix that was calculated on untransformed data using the Bray–Curtis dissimilarity measure (Clarke 1993). To determine the influence of species diversity non-metric multidimensional scaling (NMDS) was performed on a similarity matrix that was calculated on presence/absence transformed data data using the Bray–Curtis dissimilarity measure. Two-dimensional ordination plots were generated to give a representation of the dissimilarity between waterways. Data were grouped by waterway type (concrete stormwater channel and urban stream). To test the significance of the relationship between waterway types, two-way analysis of similarity (ANOSIM) (Clarke 1993) was undertaken. Statistical analysis was undertaken using PRIMER 7 software package.

Results

A total 4613 individual specimens were collected by this study, 417 specimens were collected from natural streams and 4196 from concrete channels (Figure 1). The highest and lowest family diversity was found in concrete channel (13 and 1 families) (Figure 1) however mean diversity was slightly higher in natural streams (8.8 +/- 2.8) when compared to concrete channels (7.4 +/- 4.8).

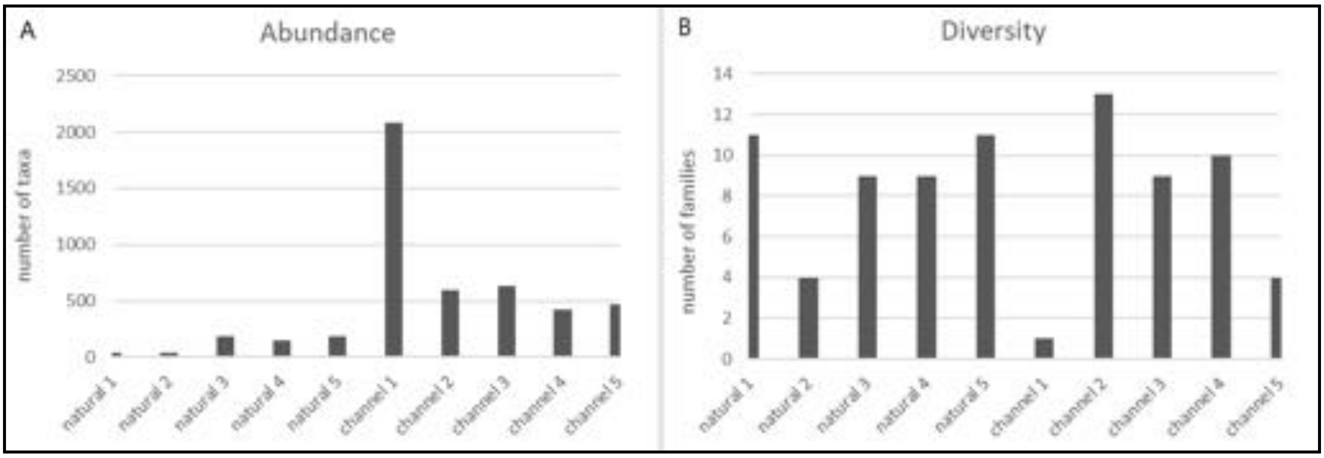

Figure 1: Macroinvertebrate abundance(A) and richness (B) of natural stream and concrete channels.

Four taxa were found to dominate the macroinvertebrate community assemblage of both waterway types. *Chironomidae* (midges) was the most abundant with 3645 individuals recorded and of these 3476 were found in concrete channels. Next most abundant was *Hydrobiidae* (NZ mud snail) followed by *Simulidae* both of which were most abundant in stormwater channels and then *Oligochaete* (worm) which were most abundant in natural streams.

Results of multi variate analysis show that when no transformation is applied to abundance data a pattern of grouping can be seen in the 2D ordination (Figure 2) with natural streams and channels clustering discreetly from one another indicating an apparent difference in community structure between waterway types. In contrast, when presence/absence transformation was applied to the data, clustering is less defined, and sites can be seen to overlap in the 2D ordination which is indicative of similarity in community composition between waterways (Figure 2).

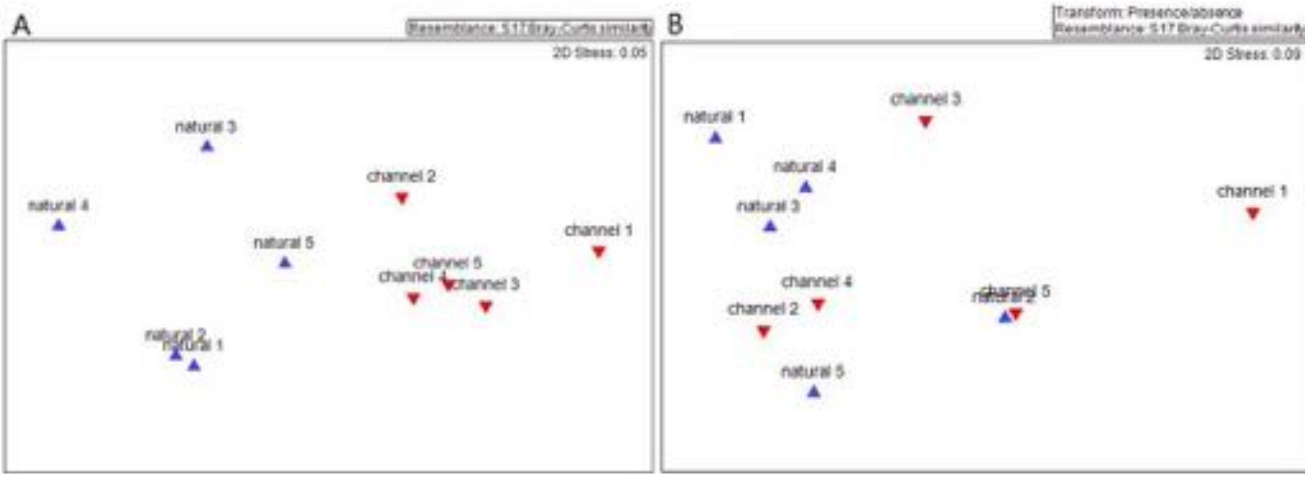

Figure 2: 2D ordination of macroinvertebrate community structure of natural streams and channels using untransformed data (A) and presence/absence transformed data (B).

Analyses by ANOSIM confirmed that differences in community structure between natural streams and concrete was highly significant when abundance was considered i.e untransformed data (R=0.784, p =0.8%). However, when only presence/absence was considered no significant difference was apparent. This result reflects those shown in both Figures 1 and 2.

Discussion

Results of this study show that macroinvertebrate richness found in urban streams was comparable to that found in concrete channels however abundance was far greater. The most common taxa found by this study were fast colonising insects, a snail which can tolerate harsh conditions and high flow and worms which preference enriched organic sediment. The former three being dominant in concrete channels which is likely a reflection of their ability to rapidly colonise waterways and preference for hard substrates (Hawking and Smith 1997). Oligochaetes were more abundant in natural streams, a result which likely reflects the availability or organic detritus common to urban streams which is mostly absent from concrete channels.

The concrete channels surveyed by this study did not have riparian vegetation and therefore are exposed to long periods of year-round sunlight and frequent enrichment from urban stormwater. These factors will no doubt increase productivity and lead to a supercharging of the aquatic ecosystem resulting in disproportionally high abundance of opportunistic taxa.

It is clear from this study that macroinvertebrate community structure does not vary between urban streams with instream and riparian habitat and homogenous concrete channels. A simplistic rationale to explain this is that, in the urban context, habitat is not an important driver of macroinvertebrate diversity however habitat, or lack thereof is highly influential on abundance. It is more than likely that flow is the major driver influencing aquatic diversity in urban streams (Walsh et al 2005b).

Interpreting the results of this study in the context of using macroinvertebrates as an indicator of urban stream restoration success indicates they are not likely to be a reliable or sensitive indictor of change. Unless urban stormwater flows are significantly mitigated it is unlikely a significant response by the macroinvertebrate community will occur (Tippler et al 2018, Palmer et al 2010, Cockerill and Anderson 2014).

However, an alternate way to manage the restoration of concrete channels instead of attempting a return to a natural state maybe to consider transforming them into wetland complexes to treat stormwater and mitigate flows to protect downstream natural stream reaches. This approach was successfully applied by Greenway (2015) and results of that study show a positive response by the macroinvertebrate community.

Conclusions

This pilot study showed there was no difference in macroinvertebrate community structure when compared between concrete stormwater channels and urban streams with natural features. However, abundance in concrete stormwater channels was significantly higher in concrete channels. In the context of urban stream restoration these results provide valuable information on the suitability of macroinvertebrates as indictors of project success. We advocate that they should not be used to attempt to justify improvement to aquatic ecosystems as they lack the sensitivity required.

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