RE-ENGINEERING URBAN STREAMS: THE EFFECTS OF DAYLIGHTING ON STREAM ECOLOGY

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ABSTRACT

The culverting of streams is widespread in cities and has been described as the most severe form of stream modification, because most interactions between the stream and the surrounding environment are lost. Daylighting, which involves recreating an open stream from a buried channel, has been promoted by some agencies (e.g. US EPA, CIWEM). Whilst daylighting can theoretically restore stream systems and natural processes, a review of projects across the world found that there were no empirical assessments of the effectiveness of daylighting projects.

The daylighting of two stream reaches in Auckland in 2013 provided an opportunity to address this knowledge gap and assess the effects of daylighting on stream ecology. Stream macroinvertebrates were sampled monthly pre- and post-daylighting and showed significant changes in community structure associated with improved habitat and increased food resources following daylighting. Whilst there were changes in the species living in the streams after daylighting, little change was observed in commonly used measures of stream health (i.e. species richness, MCI) post-daylighting. The response of the invertebrate community was different in the two reaches, with the reach that had more intact headwaters showing a greater change in ecology (71%) compared with the reach with extensively piped headwaters (58%).

KEYWORDS

Daylighting, deculverting, macroinvertebrates, urban streams, restoration

1 INTRODUCTION

The extent of urban areas across the globe is increasing as human populations become concentrated in cities, with widespread environmental consequences across the Earth's air, land and water resources (Paul & Meyer, 2001; Foley et al, 2005). The effects of urbanisation have been well described for streams, with numerous studies describing a degradation of morphological, chemical and biological stream condition associated with increasing urbanisation; a phenomenon that has subsequently been described as an Urban Stream Syndrome (Meyer et al., 2005; Walsh et al., 2005).

Recognition of the effects of urbanisation on streams has led to a change in the management and development of urban catchments through time, with progression from centralised systems that use piped drainage, to increasingly decentralised management using natural drainage features (Hale et al., 2015). These changes have been successful in reducing the impacts of urbanisation at the time of new development. However, there are numerous legacy issues arising from historical management approaches and there are few examples of significant recovery of urban streams arising from efforts to remedy these issues. This is largely because project outcomes are not monitored (Bernhardt et al., 2007), or where monitoring is carried out, it shows no significant difference between restored and non-restored streams (e.g. Violin et al., 2011).

One such legacy issue is the extent of culverted streams; culverting is widespread in many cities (Broadhead et al., 2013) and has been carried out largely to increase building platforms or manage flooding issues. Culverting has been described as the most severe form of stream modification because most interactions between the stream and the surrounding environment are removed (Elmore & Kaushal, 2008).

The concept of stream daylighting (also known as deculverting) has recently gained favour amongst some agencies (e.g. Scottish Environmental Protection Agency, Chartered Institution of Water and Environmental Management and Zurich City Council) as a tool for restoring culverted streams. Conceptually, stream daylighting is a radical form of stream restoration; effectively re-creating a stream from a buried or piped channel. As such, it had been suggested that daylighting can restore natural processes, stream function and biodiversity (Pinkham, 2000). However, there are no studies reporting the effects of daylighting urban streams, rather success is assumed or reported anecdotally (Wild et al., 2011; Broadhead et al., 2013). Given efforts to promote stream daylighting as a restoration tool, it is important that the effects of daylighting are understood.

In this paper we report on a study of the changes in the invertebrate community in two streams that were daylighted in 2013. Invertebrates are commonly used as indicators of stream health because;

- They are ubiquitous and abundant in rivers
- Sampling procedures are well developed, easy to apply and inexpensive
- Comprehensive keys are available for identification
- Macroinvertebrate communities are heterogeneous (species rich) offering a spectrum of responses to environmental conditions
- Macroinvertebrates are sedentary and therefore representative of the location where they are found.

As a result of the combination of the above characteristics, macroinvertebrates act as continuous indicators of the health of the river they inhabit and consequently they are established as the indicator of choice in most biological river monitoring programmes (Rosenberg & Resh, 1993). Importantly, invertebrate communities have been correlated with a wide range of chemical, biological and functional measures of river health and therefore can reliably be used as an indicator for these other measures.

We predicted that daylighting would lead to significant changes in the invertebrate communities in the two streams and our objective was to assess the short term (2 years) stream invertebrate community response to daylighting.

2 METHODS

2.1 STUDY SITES

Two stream reaches in the La Rosa Reserve, Auckland were daylighted in April and May 2013. The reaches were located on the Waitahurangi (North) and Parahiku (South) Streams, both of which are in the predominantly urbanized Avondale Stream catchment (Figure 1).

The daylighting in each stream reach consisted of the removal of 180 metres of concrete piped channel (1500mm diameter), which was replaced by soft-engineered stream channels and banks (Figure 2). Newly created stream banks and riparian areas were planted with native species.

Whilst both streams are heavily urbanized, the contributing upstream catchments of the two stream reaches differed in character (Table 1). The Parahiku Stream had a larger catchment (126 ha), with a greater extent of un-piped channel (45%) compared with the Waitahurangi Stream (63 ha and 17% un-piped). The Parahiku Stream had a lesser extent of urban cover (79%) when compared with the Waitahurangi Stream (94%), and the Parahiku Stream had a large area of native Podocarp forest in its headwaters.

2.2 INVERTEBRATE SAMPLING METHODS

Prior to daylighting, invertebrate samples were collected from the culverts to be removed in the two streams. Two samples were collected from the Waitahurangi Stream in March and April 2013 (daylighted in late April 2013) and one sample from the Parahiku stream in May 2013 (daylighted in late May 2013).

Daylighted reaches were then sampled monthly through to June 2015, representing 25 samples from the Waitahurangi Stream and 23 from the Parahiku Stream post-daylighting.

As there is no standard method for sampling invertebrates in culverts, we used a modified version of the standard national protocol for streams (Protocol C1; Stark et al., 2001). Prior to daylighting, invertebrates were sampled by inserting a net into the culvert and disturbing the accessible substrate.

Subsequent to daylighting, invertebrate samples were collected using the standard protocol for hard bottom streams (Protocol C1; Stark et al., 2001). Briefly, a fixed area (0.2 m^2) of stream bed was disturbed upstream of a kick-net at five locations within each of the daylighted reaches. These five sampling units were pooled to give one sample per reach per month. Samples were preserved in ethanol and sorted and identified following standard protocols (Stark & Maxted, 2007).

2.3 DATA ANALYSIS

The taxonomic information that is generated from invertebrate samples is commonly summarised into indices. The use of indices aids communication of the taxonomic information and allows rapid comparisons among numerous sites and samples. In this paper the invertebrate data were summarized using four indices that are commonly used in New Zealand; taxon richness, total abundance, Macroinvertebrate Community Index (MCI) and EPT (Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies)) richness. Change over time in these indices was analysed using the Mann Kendall trend test.

Changes in invertebrate community pre- and post-daylighting were assessed using Similarity Percentages (SIMPER) in the PRIMER package. SIMPER gives an indication of the relative change in invertebrate community arising from the daylighting activity.

Figure 1: Map showing the location of the daylighted stream reaches. Sampling locations are shown by white circles. The opaque polygon shows the location of the La Rosa reserve and the sampling locations within this polygon represent the daylighted reaches. In the wider catchment, open channels (un-piped) are indicated by white lines and piped channel is shown as black lines.

Figure 2: Time series photographs showing the change in channel appearance of the Waitahurangi Stream pre- and post-daylighting.

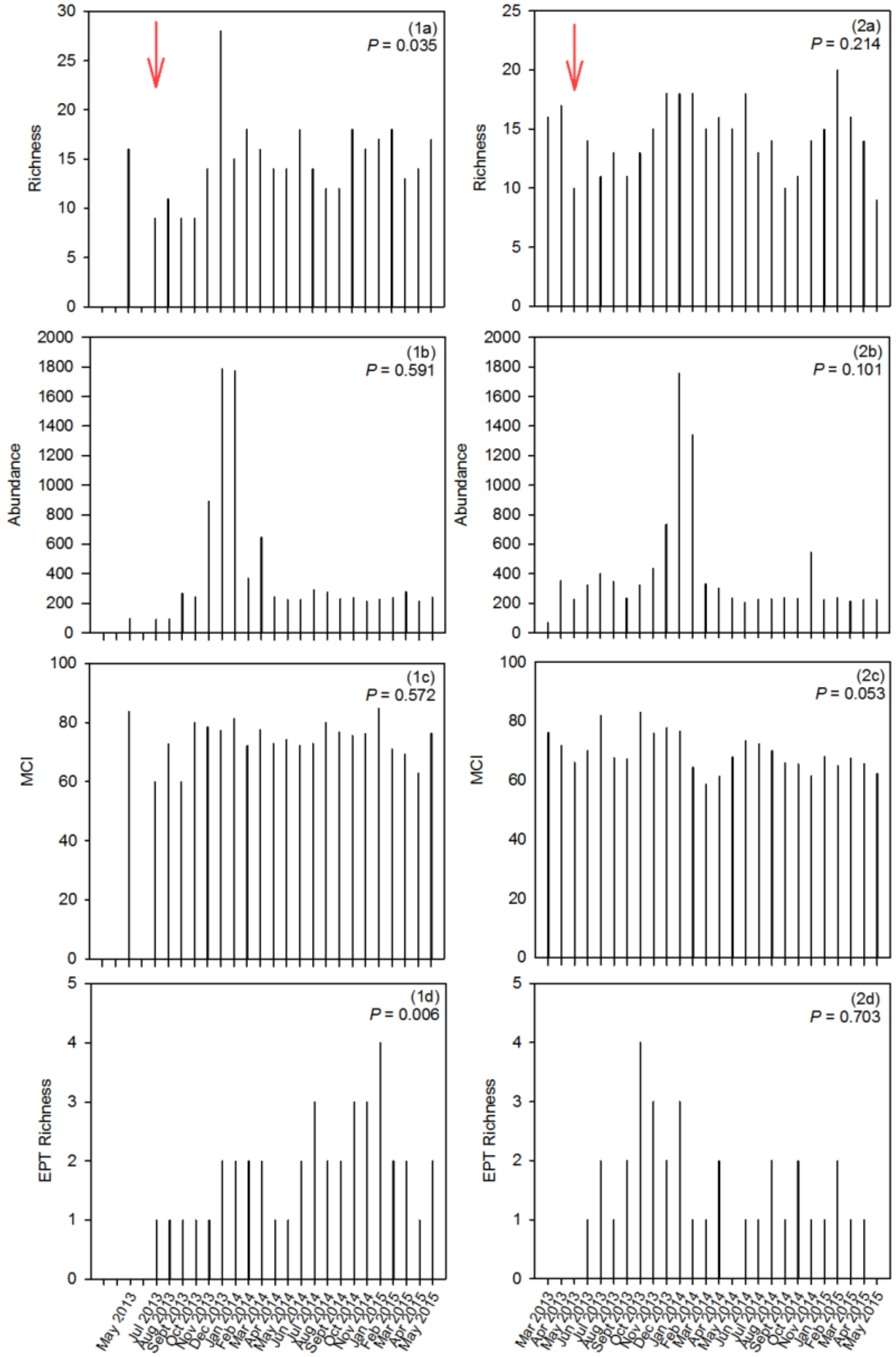
3 RESULTS

A total of 69 invertebrate taxa were recorded from the 51 samples that were collected from the two daylighted stream reaches. Twenty-four taxa were recorded both before and after daylighting, whereas 46 taxa were collected only after daylighting. These 46 new taxa included nine taxa belonging to the sensitive EPT groups, including two Ephemeroptera (the mayflies *Neozephlebia* and *Zephlebia*), one Plecoptera (the stonefly *Acroperla*) and six Trichoptera (the caddisflies *Orthopsyche, Oxyethira, Paraoxyethira, Plectrocnemia, Polyplectropus* and *Psilochorema*).

Significant changes in invertebrate community were observed in both streams. However, SIMPER analysis of the change in invertebrate community composition indicated a greater change in the Parahiku Stream (71% dissimilarity) than in the Waitahurangi Stream (58%). In both streams the taxa which contributed the most to the dissimilarity between pre- and post-daylighted invertebrate communities were *Potamopyrgus (the New Zeland mudsnail), Acroperla (stonefly),* Oligochaeta (worms), *Polypedilum* and Orthocladiinae (both midges).

Only two of the eight possible trends tests (four metrics at two sites) returned a statistically significant result (Figure 3), both of which were in the Waitahurangi Stream. EPT richness increased post-daylighting in both reaches, however this difference was only significant in the Parahiku Stream (Sen Slope 0.789, P = 0.006). The only other significant trend was for taxa richness at Parahiku Stream (Sen Slope 2.554, P = 0.035).

Figure 3: Stream ecological health pre- and post- daylighting as described by four indices in 1) Waitahurangi Stream and 2) Parahiku Stream. Where dates are not shown on the x-axis no samples were collected. The red arrow indicates the first post-daylighting sample.



4 DISCUSSION

Stream daylighting is at the extreme end of the continuum of stream restoration options, representing a dramatic and almost immediate change in the appearance and morphology of a stream. Daylighting has been widely advocated as a management option for urban streams for over ten years (Pinkham, 2000), yet this is the first study to empirically assess the effects of daylighting on stream ecology.

Invertebrate community structure changed significantly as a result of daylighting in both of the streams, including the appearance of 46 taxa not found prior to daylighting. The changes in community composition were more pronounced in the Parahiku Stream. We hypothesise that the presence of forested headwaters above the daylighted reach in the Parahiku Stream was the primary driver of this greater change. Auckland Council State of the Environment data indicates a relatively healthy invertebrate community in these forested headwaters, which likely provided a source of colonists for the newly daylighted stream.

We recorded 46 taxa post-daylighting that were not recorded in the pre-daylighting samples. We posit that this large increase in diversity following the daylighting of the streams is an indication of an improvement in the ecological health of these streams. Similarly, we consider that the increases in sensitive EPT taxa observed at both sites represent an improvement in stream health.

The absence of significantly improving trends in the commonly used metrics of stream health (particularly MCI) is somewhat disappointing. However, change in these metrics following restoration may occur over longer timescales than the data presented here. Alternatively, the improvement in local habitat arising from daylighting may be overwhelmed by catchment scale impacts (Miller et al., 2010). This is a distinct possibility in these streams as the catchments are primarily urban and extensive lengths of piped channel remain upstream in both catchments.

5 CONCLUSIONS

Whilst daylighting had a significant effect on invertebrate community composition, particularly the positive increases in the presence of sensitive EPT taxa, there were not concordant improvements in stream health metrics commonly used in New Zealand (e.g. MCI).

Daylighting streams may provide some local improvements in habitat that are associated with changes in invertebrate communities, but significant recovery of urban streams is likely to require the management of catchment scale factors in addition to localized restoration activities such as daylighting. To maximize the potential ecological improvements arising from daylighting streams, it is important to consider the source of colonists that may colonise any improved stream habitat.

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