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Re-engineering buried urban streams: Daylighting results in rapid changes in stream invertebrate communities

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ABSTRACT

Stream daylighting is a radical form of restoration which aims to improve morphological, chemical and ecological condition through the re-creation of an open channel from a buried or piped channel. Whilst empirical assessments of its efficacy are lacking, it is hypothesised that the substantial changes in habitat, channel form and energy supply arising from daylighting would lead to a significant changes in stream invertebrate communities, particularly where source populations of macroinvertebrates exist upstream. In this first published study of the ecological outcomes arising from a daylighting project, changes in the invertebrate community were assessed in two reaches of an urban stream catchment in Auckland, New Zealand's largest city, which were daylighted in early 2013. The two reaches allowed a paired assessment, where one of the reaches had a large area of intact native forest in its headwaters. Stream macroinvertebrates were sampled monthly pre- and post-daylighting to assess changes in stream macroinvertebrate communities.

Community composition significantly changed pre- to post-daylighting (PERMANOVA Pseudo-$F = 2.0978$, $P = 0.0018$), where communities in different reaches changed by 58% and 71%, respectively. Taxonomic richness did not change with daylighting; however taxa replacements were apparent with 44 new taxa being collected in daylighted reaches and 11 taxa disappearing. Daylighting resulted in marked changes in energy resources and improved habitat in the short-term which altered invertebrate communities from biofilm feeding collector-browser communities to algal grazer communities. Although daylighting did not fully restore these streams from the effects of urbanisation, it is one practical option for the management of urban streams. Further, the presence of a local source population was an important determinant of stream community structure. Where source populations existed upstream community responses to daylighting were greater, including increased abundances of sensitive taxa.

1. Introduction

Increases of urban land-use have been associated with decreases in biodiversity, homogenisation of stream geomorphology, and a reduction in stream function; a phenomenon known as the urban stream syndrome due to the similarity of effects across cities (Meyer et al., 2005; Walsh et al., 2005). In particular, stream ecological health is often substantially reduced in urban streams, which become dominated by stress tolerant species because of hydrological impacts, pollutants, structural channel modifications and loss of riparian vegetation (Paul and Meyer, 2001; Roy et al., 2003; Walsh et al., 2005; Cuffney et al., 2010). As such, urban stream channels can be modified in numerous ways; however culverting, the burial or diversion of streams into pipes (Broadhead et al., 2013), has been described as the most severe form of modification, as most interactions between the stream and its surrounding environment are removed (Elmore and Kaushal, 2008). Culverting is widespread across many cities (Broadhead et al., 2013; Hale et al., 2015), for example, 66% of streams in Baltimore City, U.S.A., are culverted (Elmore and Kaushal, 2008).

As recognition of the problems associated with urban streams has increased, so have efforts to restore or rehabilitate streams to enhance habitat quality, biodiversity and reinstate ecosystem function (Bernhardt and Palmer, 2007; Schwartz et al., 2014). However, restorative actions have typically been at the reach scale and been unsuccessful in increasing biodiversity due to the

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overriding effects of catchment scale processes (Palmer et al., 2010; Wahl et al., 2013). Yet there are no such studies reporting the effects of daylighting urban streams; an activity that is considered one of the most radical forms of stream restoration, and involves recreating an open 'naturalised' stream from a buried or piped channel, thus theoretically restoring natural processes and increasing biodiversity (Pinkham, 2000). Daylighting projects can hypothetically reduce the environmental impact of urbanisation on streams by restoring natural stream structure and opening up the channel to sunlight and aerial colonisation. Furthermore, such projects may have many associated social and economic benefits (Smith, 2007; Shin and Lee, 2006; Pinkham, 2000). However, empirical assessments of the effectiveness of daylighting are lacking and success is assumed or reported anecdotally (Pinkham, 2000; Wild et al., 2011; Broadhead et al., 2013). Even in Zurich, Switzerland, a city which has been described as a pioneer for daylighting buried streams and where the City Council has had a planning policy to encourage daylighting since 1988, there remains an absence of an independent, published assessment of the ecological benefits of daylighting streams (Broadhead et al., 2013). Given efforts to promote stream daylighting as a restoration tool (e.g. SEPA, 2006; CIWEM, 2007; EPA, 2010), it is important that the ecological effects of daylighting are understood.

Stream macroinvertebrate communities are strongly affected by urbanisation with most communities dominated by a restricted range of tolerant taxa (Jones and Clark, 1987; Walsh et al., 2001; Paul and Meyer, 2001; Brown et al., 2009). Macroinvertebrates are subject to and respond to changes in environmental conditions over life spans of species (weeks to months), therefore species composition and abundance provide an integrated assessment of stream health (Metcalf, 1989; Karr, 1999). It is however, unknown how these communities respond to the substantial changes associated with stream daylighting. Here we report on a study of the invertebrate community response to daylighting in two reaches of adjacent streams (the Waitahurangi and Parahiku streams) in Auckland, New Zealand. This daylighting project not only provided an opportunity to assess invertebrate responses to daylighting, but the proximity of the two streams allowed a comparison of daylighting effects in streams with different land use characteristics, with minimal variation in potentially confounding temporal (i.e. similar project timescales) and spatial (i.e. similar biogeography) factors.

It was anticipated that daylighting would markedly change the ecology of the stream reaches because of the combined effects of increased light, connectivity, and habitat heterogeneity and despite the limited spatial extent of the project have significant effects on invertebrate communities (Fig. 1). Thus, the objective of the study was to assess the short-term stream invertebrate community response to daylighting. In particular, two hypotheses were tested; (1) Invertebrate communities, and measures of stream ecological health based on them, would change post-daylighting and (2) The response to daylighting would differ based on the catchment characteristics of the daylighted stream.

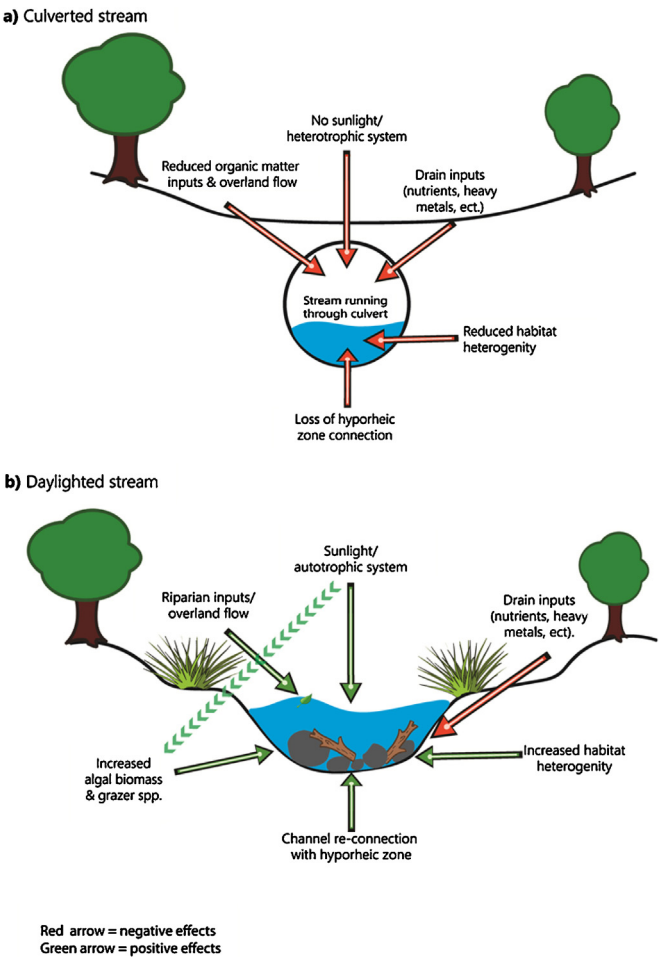

Fig. 1. Conceptual diagram of the hypothetical changes in stream ecology arising from daylighting.

2. Methods

2.1. Study sites

Two reaches in the Waitahurangi (North) and Parahiku (South) Streams were daylighted in April and May 2013, respectively (Fig. 2). Both streams run through a public park (La Rosa Reserve) and are part of the Avondale Stream catchment located in Auckland, New Zealand. Approximately 180 m of 1500 mm diameter concrete piping were removed as part of the daylighting project (90 m per stream reach) and replaced by soft-engineered stream channels and banks. The channels were converted from a continuously dark environment to one with a natural light regime; and from a uniform concrete substrate to one comprised of 30% boulders, 50% cobble, 20% woody debris and 10% silt. Stream banks and riparian areas were planted with native species (e.g. *Carex* spp., *Austroderia fulvida*).

The streams were in predominately urbanised catchments with urban land cover percentages of 94% in the North reach and 79% in the South reach; however, the South reach had a large area of native podocarp forest in its headwaters (~1 km upstream) and a greater proportion of open channel (Table 1). Whilst the decision to undertake a daylighting project in Auckland was politically driven, the choice of location was based in part on environmental criteria. This location was selected in particular because of the presence of native forest in the catchment that could act as a source of drifting invertebrate colonists and the absence of large scale point source pollution issues, but also that the proximity of two streams were amenable to undertaking a paired effects trial within one daylighting project. The processes of daylighting resulted in significant physical disturbance to the stream reaches from April to May 2013.

2.2. Collection and analysis of stream macroinvertebrate communities

Stream macroinvertebrate samples were collected prior and subsequent to daylighting to detect changes in stream health. Prior to daylighting, two samples were collected from the southern culvert ('South') in March and April 2013 (daylighted in late April 2013 (Fig. 3)) and one from the northern culvert ('North') in May