THE RELATIONSHIP BETWEEN STORMWATER INFRASTRUCTURE AND AQUATIC BIODIVERSITY IN PARRAMATTA'S URBAN STREAMS AND IMPLICATIONS FOR MANAGEMENT

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Abstract

The Parramatta Local Government Area (LGA), located in the geographic heart of Sydney, is criss-crossed by numerous urban creeks and rivers. As is typical in urbanised areas, a network of stormwater infrastructure connects the impervious areas of the LGA to these sensitive receiving waters.

Limited work on the aquatic biological health of Parramatta's waterways has been carried out in the past, most notably in 1997, 2003 and 2004. More recently (2009/10), Council engaged consultants to re-assess the biological health of the waterways relative to the type of landuse and the level of total and effective imperviousness in the surrounding catchment. The work considered the outcomes of previous research published by Walsh (2004; 2006) in relation to Victorian stream protection.

Following a literature review and intense sampling of 20 representative sites across the local government area for macroinvertebrates, diatoms, fish, macro algae and physio-chemical parameters, the consultants investigated the correlation between species diversity and effective catchment imperviousness. The results of this work will assist Parramatta Council as it develops urban stream management objectives, revised development controls, stream restoration priorities and applies water sensitive urban design.

Introduction

Parramatta City Council is located near the geographic heart of Sydney, Australia, covering an area of 61 km^2, with 162,000 residents. The Local Government Area (LGA) contains about 65km of creeks and rivers.

Figure 1 - Map showing location of Parramatta (marked with a star) within the Sydney Metropolitan area

In November 2009 ("Spring") and April 2010 ("Autumn") a survey of the biological health of Parramatta's waterways was carried out. The survey encompassed 20 sites and 13 catchments, and measured such parameters as:-

- Physical water quality
- Macroinvertebrates (aquatic insects)
- Diatoms (microscopic single celled or colonial plants)
- Macroscopic algae / aquatic plants
- Fish

Using the results of the biological survey, the relationship between species compositions and "effective imperviousness" of the study catchments was investigated. Effective imperviousness ("EI") considers the degree of hydraulic connection of an area of impervious catchment to local creeks or rivers. For instance, within a catchment some impervious areas will be connected directly to a receiving creek by a stormwater system, whilst other impervious areas e.g. a concrete pavement with a grass verge may have no direct connection with a creek.

Various authors have suggested that EI is a better predictor of biological health in creeks than total imperviousness, with biological health increasing as EI decreases (Walsh *et al.* 2004; Walsh, 2006; Ladson et al, 2006). If similar relationships were observed for Parramatta's waterways, Parramatta Council hoped to use the data to assist in decision making procedures employed to manage local stormwater systems and minimise adverse ecological effects in creeks transporting large quantities of urban stormwater.

Methodology – calculation of effective imperviousness

Land uses within the LGA study catchments were broadly categorised in the following Classes - Residential, Commercial, Industrial, Parkland and Bushland. Only areas of bushland with no substantial cleared areas were considered to be Bushland, areas with both bushland and cleared lands including roads and grassed areas were considered as Parkland. Two representative sample areas within the LGA were analysed for each Class of land use, each between 2 to 4 hectares in size using aerial photography and GIS layers containing landuse zonings.

Within the representative sample areas impervious areas such as roads, roofs, paved driveways and swimming pools were considered to be directly connected to local waterways by the stormwater system. Disconnected impervious areas were identified as those being adjacent to, or surrounded by, pervious areas such as grass. It was assumed that runoff from these impervious areas was likely to drain into the surrounding pervious areas, rather than being directly connected to the stormwater system. (N.B. no ground truthing of this assumption was conducted).

The results from the sample areas were extrapolated to determine total and EI within each catchment area.

Methodology – data analysis

The relationship between the diversity of the diatom, aquatic macroinvertebrate and fish assemblages surveyed in the waterways and estimates of percentage EI were examined using linear regression analysis to determine the proportion of the variance in the biological indicator that could be explained by EI.

Results – calculation of effective and total imperviousness

Calculated values of imperviousness for each of the 5 land use classes are presented below, in Table 1

Land Use Category	Effective Imperviousness (%)	Total Imperviousness (%)
Residential	43.0	51.6
Commercial	84.5	84.7
Industrial	89.8	90.5
Parkland	0.0	2.9
Bushland	0.0	0.5

Table 1 - Calculated effective and total imperviousness for 5 land use classes

The results showed that EI and TI were similar for all land use classes, except for Residential. For Commercial and Industrial areas, nearly all rain that falls on impervious areas will directly enter local waterways through stormwater channels. For Parkland and Bushland, levels of impervious areas were very low and all water that accumulates on these small impervious areas would run directly into surrounding pervious areas resulting in reduced overall runoff. The difference in EI and TI was most notable for Residential areas, reflecting increased variability in built form in these areas which resulted in a mixture of pervious and impervious areas in close proximity to each other.

The data in Table 1 was combined with information about the proportions of land use within each of the catchments to generate summary Table 2 showing the variation in effective and TI in the catchments studied.

Catchment Name	Catchment Area (ha)	% Effective imperviousness	% Total imperviousness	% variance EI to TI
Coopers Creek	426.1	45.4	53.0	-7.6
Hunts Creek	783.6	46.1	51.6	-5.5
Quarry Branch Creek	322.3	35.3	42.7	-7.4
Pendle Hill Creek	550.5	43.2	50.2	-7.0
Toongabbie Creek	1280.0	45.8	51.7	-5.9
Domain Creek	148.6	33.3	40.1	-6.8
Finlaysons Creek	613.6	43.5	50.9	-7.4
Subiaco Creek	372.7	48.9	55.1	-6.2
Vineyard Creek	402.2	33.6	40.3	-6.7
Ponds Creek	471.5	36.2	43.2	-7.0
Duck River	4063.9	49.9	55.6	-5.7
Terrys Creek	1011.8	40.1	47.4	-7.3
Devlins Creek	1504.5	36.5	43.6	-7.1
Average	919.3	41.4	48.1	-6.7

Table 2 - Effective and total imperviousness for 13 creek catchments in the Parramatta area

Results – Comparison of effective imperviousness and biological diversity

Because of the highly urbanised nature of the Parramatta Local Government Area, the average EI across the 20 sites or 13 sub-catchments was approximately 41% (range 33-50%). It was found that macroinvertebrate species diversity and EI was NOT correlated in Spring 2009 (number of samples, $n=19$, degrees of freedom, $DF=n-2$, correlation coefficient, $r=.012$, probability, $P>.5$) or Autumn 2010 ($n=19$, $DF=n-2$, $r=.244$, $P<.5$). Results for example, from Autumn 2010 are shown in Figure 2 (below).

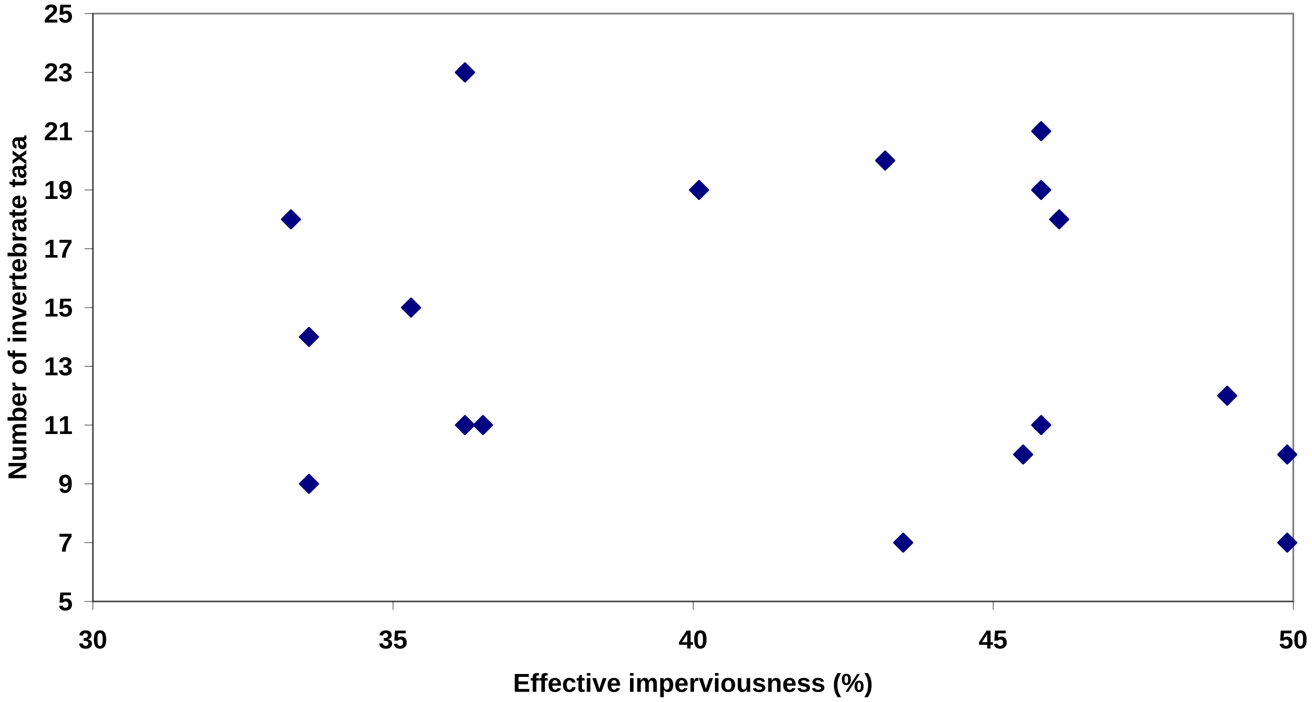

Figure 2 - Invertebrate species diversity vs. effective imperviousness, Autumn 2010

However, fish species diversity and EI were found to be positively correlated in both Spring 2009 (n=20, DF=n-2, r=.462, P<.05) and Autumn 2010 (n=20, DF=n-2, r=.513, P<.05), i.e. as EI increases so does fish species diversity (Figure 3 below).

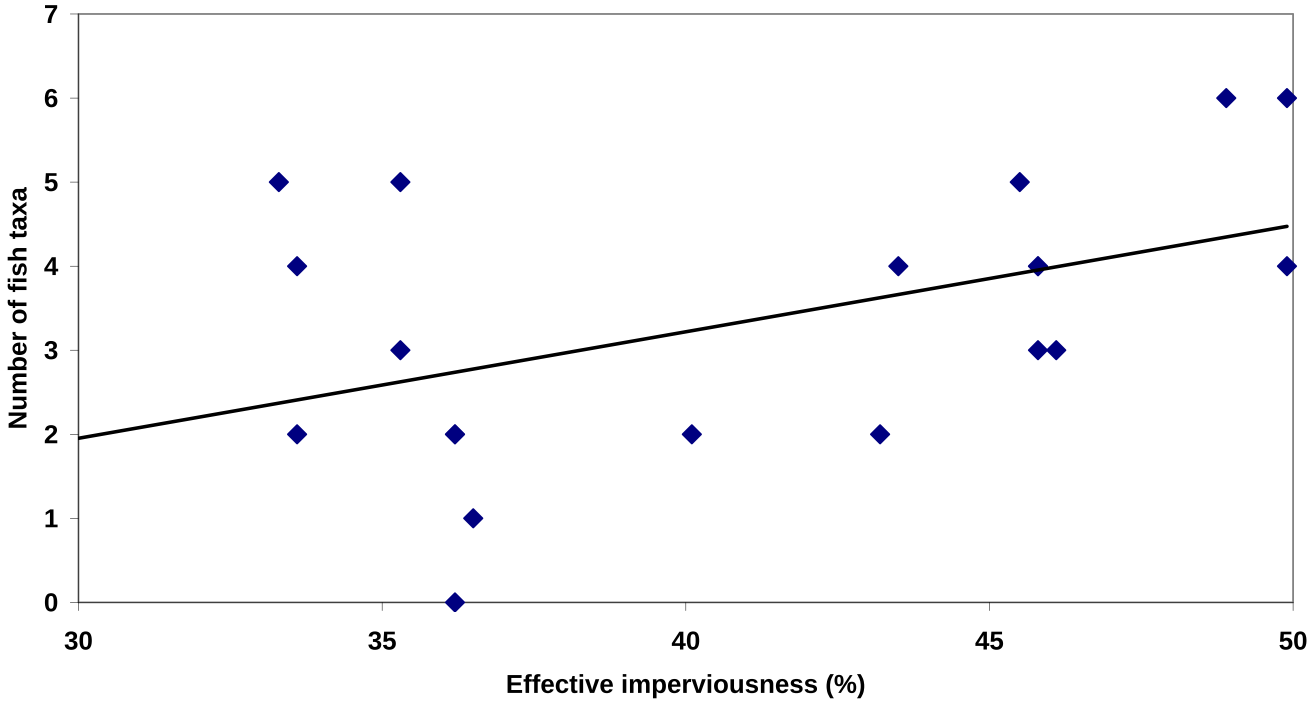

Figure 3 - Fish species diversity vs. effective imperviousness, Spring 2009

This relationship is the opposite of the negative correlation reported in Walsh *et al.* (2004), in which fish diversity decreases with increasing EI.

Diatom species diversity and EI correlations were not as clear cut. In Spring 2009 the correlation between diatom diversity and EI was found to be positively correlated (n=20, DF=n-2, r=.547, P<.02) (Figure 4). However, there was no statistically significant correlation between diatom diversity and EI during the Autumn 2010 sampling exercise, although a positive trend is observed (n=20, DF=n-2, r=.428, P<.1).

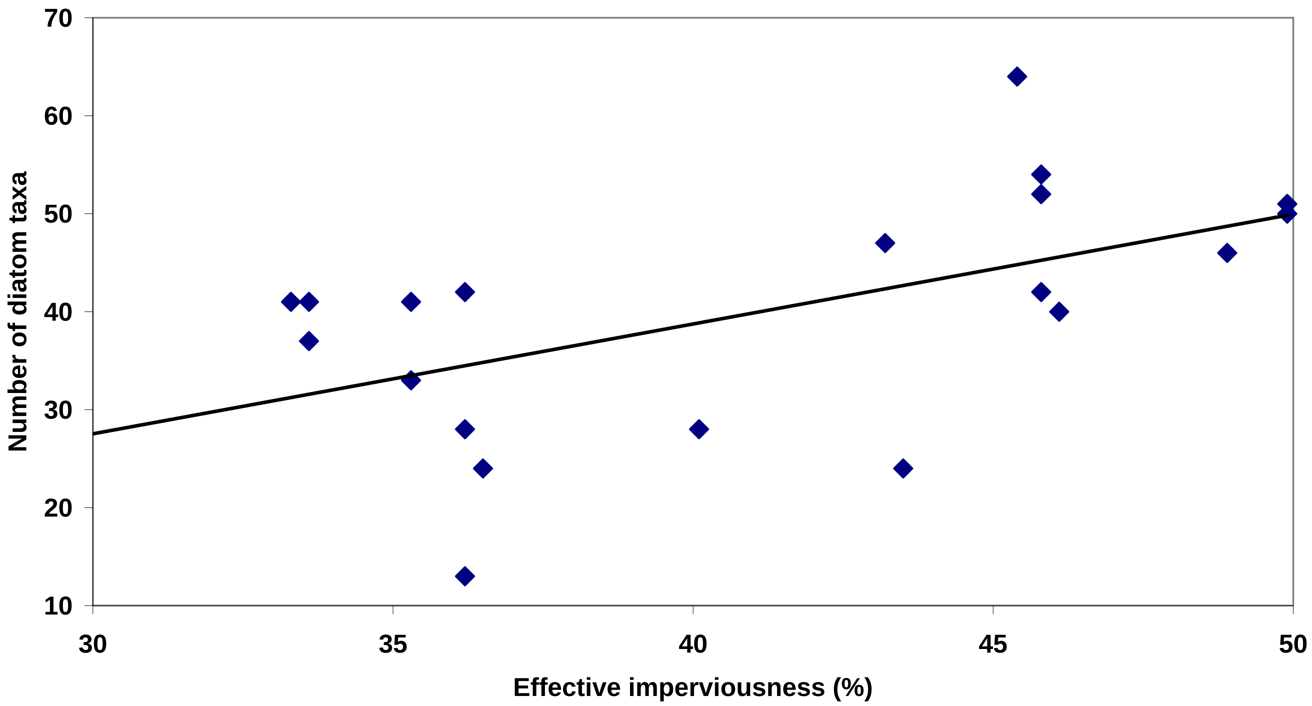

Figure 4 - Diatom species diversity vs. effective imperviousness, Spring 2009

Discussion

The catchments surveyed in the Parramatta LGA are highly urbanised systems. For instance, the land use in one of the 13 catchments surveyed (Coopers Creek) consisted of 95% residential / commercial / industrial land use with only 5% parkland. Walsh (2004) and Ladson et al (2006) have suggested that a 10% threshold of catchment imperviousness usually results in an increasingly degraded biological condition of the waterway.

It was found that for the 20 sites sampled there was no correlation between EI and macroinvertebrate species diversity. This may be because Parramatta's waterways have relatively high EI's of between 33 and 50% and do not have the wider range of EI's reported in Victorian studies (e.g. approximately 5 to 50% - (Ladson, 2006)). Due to the difficulty in finding local references sites which are relatively undisturbed (EI < 5%) future studies in Parramatta would have to rely upon work done in National Park draining catchments in adjoining councils.

The Parramatta study revealed that for edge and riffle habitats, the AusRivAS scores for all sites were either severely or significantly impaired and for SIGNAL2, all sites scored as severely degraded based on except for the riffle habitat at two locations.

Ladson et al (2006) reports that the 'urban stream syndrome' produces consistent effects on stream flow and runoff volumes; geomorphology including stream form, erosion and deposition; water quality and pollutant loads; and stream ecology including aquatic biological indicators such as those reported in this paper. In the case of Parramatta's streams some additional factors potentially contributing to poor invertebrate species diversity could be:-

- Clearance of riparian vegetation
- Channel modification including substratum composition
- Dumping of rubbish
- Changes in the flow regime caused by the construction of weirs or other infrastructure barriers

For fish, a positive correlation was seen between EI and species diversity. This was in contrast to the negative correlation seen in Victoria's waterways (Walsh *et al.*, 2004). This positive correlation could be attributed to greater volumes of water from a catchment reaching the associated watercourse as EI increased. Increased volumes of water would potentially increase available habitat by widening and deepening streams, allowing for better fish passage within habitats and providing deeper pools that would provide refuges for fish during long, dry periods typical of Sydney. The benefits to fish associated with larger volumes of water reaching the rivers and creeks appear, for pollution resistant fish species at least, to outweigh the disadvantages of inhabiting a stream heavily impacted by the pollutants associated with urban stormwater.

For diatoms a positive correlation was seen in Spring 2009, supporting the similar observations seen in fish species, but no significant correlation was seen in Autumn 2010. Further studies are needed to clarify this discrepancy, but a positive trend can still be seen in the Autumn 2010 diatom data, suggesting that EI could be one of the factors influencing diatom species diversity during this season.

Conclusions

The monitoring of aquatic life in Parramatta's waterways indicates that creek / river water quality and biological health are very poor. The calculated impervious of each catchment has revealed a range between 33 and 50% resulting in high connectivity and detrimental impacts on both stream form and health.

For the Parramatta LGA either no correlation between EI and aquatic species diversity was seen, or if there was a correlation it was a positive correlation. Although all waterways within the LGA currently exceed the '10% rule' further work needs to be done in terms of setting objectives for ecosystem protection across all catchment owned lands. Council has recently reviewed and updated its principal planning instruments (the Local Environment Plan and Development Control Plan) in terms of objectives and targets for water quality, pollutant loads, runoff volumes and environmental protection for new development. However, in a highly urbanised setting such as Parramatta the implications for managing existing urban development and the inherent connected drainage systems become a primary focus. On one hand Council had historically tried to increase the hydraulic efficiency of the stormwater drainage system so as to minimise the impact of flooding and floodplain risk. On the other, reducing hydraulic efficiency serves to decrease the connection between impervious surfaces and waterways.

Council's approach has been two pronged, using a combination of planning controls and forward planning retrofits to the local urbanised catchments in order to promote rainfall and stormwater detention and retention through direct interception, storage, reuse, infiltration and treatment. At the same time, Council has been prioritising sites for waterways restoration and habitat rehabilitation by mimicking as many natural elements as possible.

In order to identify the major factors influencing the biological indicators of degraded urban systems in the Sydney region, a more holistic approach needs to be adopted that considers a range of factors that impact upon aquatic ecosystem and riparian health, beyond a simple EI / TI metric.

References

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