SUSTAINABLE CATCHMENT MANAGEMENT: THRESHOLDS FOR ECOLOGICAL SUSTAINABILITY

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ABSTRACT (200 WORDS MAXIMUM)

The majority of New Zealanders live in urban environments, and national and regional community surveys have shown that improving the state of our urban waterways and environment are high priorities. An understanding of the real and perceived driving forces and pressures contributing to the sustainability of the natural resources of urban (including peri-urban) catchments, and the thresholds at which development is no longer sustainable are necessary if management goals are to be met. The points or zones of change from one ecological condition to another, usually resulting from a change in 'pressure' or 'development' are key 'thresholds' of change in ecosystems. In this paper we present the results of reviews and investigations that consider threshold values for aquatic ecosystem sustainability in urban and peri-urban environments as measured by indicators of the state of stream health at the catchment level. In particular our focus is on connectivity and fragmentation of biophysical stream and catchment attributes. Threshold values can be used in sustainable catchment management planning or as goals for enhancement and restoration.

KEYWORDS

Catchment; sustainability; ecology; thresholds; ecosystem services; resilience

PRESENTER PROFILE

Ian is Principal Environmental Consultant and Team Leader Ecology with Golder Associates. Ian has over 25 years experience in environmental management, monitoring, policy, and research in the New Zealand freshwater environment. Ian has a keen interest in urban catchment sustainability and has pioneered several initiatives and frameworks for stream management in New Zealand. Ian continues to be an active research scientist with interests in the ecology, sustainability and resilience of urban ecosystems.

1 INTRODUCTION

More than 85 % of New Zealanders live in urban areas and nearly 72 % live in the 16 largest urban environments (Statistics NZ 2006) with over one million people (>30 % of New Zealand's population) living in Auckland (<2 % of New Zealand's land area). Housing, commercial and roading intensification places increasing pressure on the existing, and often already limited or highly-modified natural resources within towns and cities. The increasing demand for lifestyle living (i.e., peri-urban development) also increases threats to 'green' belts in areas surrounding urban centres. In all cases, increasing demand is being placed on the services provided by the local ecosystems. Services provided by ecosystems include stormwater runoff, wastewater disposal, potable water storage and supply and food provisioning). National and regional community surveys have shown that while on average New Zealanders consider our environment to be moderate to good, improving the state of our urban waterways and environment can be high priorities for urban dwellers (Boothroyd & Drury 2008).

Urban sustainability involves creating better places to live, work and play, while solving problems caused in and by our settlements (MFE 2003). Various frameworks exist for enabling sustainable management and it is inherent in the Resource Management Act (1991).

A focus on the decline of water quality in New Zealand has sharpened the focus on the sustainable management of our waterways and the frameworks that are available to achieve the desired outcomes for the use and services provided by freshwater. The report of the Land and Water Forum (2010) gave much consideration to issues such as water scarcity, setting limits for water quality and flows and rural water infrastructure and governance, and considered that changes were desirable to improve performance in areas of urban water supply, wastewater treatment and stormwater. In the 2002 report on sustainable development, PCE (2002) recognised that New Zealand's urban areas have not received the attention they need to promote sustainable urban environments and infrastructures.

In this paper the frameworks for sustainable catchment are discussed with an emphasis on the use of thresholds of change in waterways for use in urban catchment management. The examples are largely drawn from the Auckland region and particularly from work on Project Twin Streams in West Auckland.

2 CATCHMENT MANAGEMENT

2.1 CATCHMENTS AS A SPATIAL UNIT

Using catchments as a unit of environmental management is not new and has been in use for many years. The biophysical connections within catchments were most succinctly articulated by Hynes (1975): 'in every respect the valley rules the stream' where catchment character influences a river by large-scale controls on hydrology, sediment delivery and chemistry. Catchment management recognises that the stocks of water, sediment and contaminants are usually contained within topographical boundaries, being the river basin or catchment which forms the appropriate spatial unit (Fenemor et al. 2011).

A more recent focus on regional planning has moved the management framework away from the catchment to an overall regional perspective on ecosystem values and use and development of resources. In urban areas, catchment management has conventionally focused on flood management and in more recent times of the management of storm water. Stormwater management can challenge the notion of the single catchment as stormwater can be transported between catchments. However the development of a more 'integrated' catchment management approach (ICMP) has embraced a more multi-use purpose of catchment planning.

Integrated catchment management (ICM) is the co-ordinated and sustainable management of land, water, soil vegetation, fauna and other natural resources on a water catchment basis. ICM is a continuing social process that comprises the process as well as the outcomes of sustainable use of ecosystem services (Fenemor et al. 2011).

2.2 CONCEPT OF ABIOTIC AND BIOTIC THRESHOLDS

A framework that can specify ecosystem processes and how these processes can be linked can be valuable in preventing their degradation or as a means to seek to reverse the downward spiral to degradation. King and Hobbs (2006) describe two linked conceptual frameworks towards preventing or restoring degraded ecosystems: structure and function, and abiotic and biotic components. The structural approach focuses on static patterns whereas the functional approach assesses the processes that contribute to the static patterns. Typically in the ICM frameworks applied to date the focus has been assessed and managed on the structural approach using static biotic and abiotic measures.

3 THRESHOLDS OF CHANGE IN URBAN CATCHMENTS

3.1 THRESHOLDS

For the purpose of this paper, thresholds of change are defined as the points where even small changes in environmental conditions will lead to large changes in system state (Suding & Hobbs 2009). There is a growing recognition that threshold models can apply to a broad range of systems. In urban catchments, with the exception of the impervious cover model (ICM, see below), there has been little attention given to other thresholds of change, despite information being available in the literature. In this paper the focus is on a small number of threshold figures of connectivity and fragmentation of biophysical stream and catchment attributes that influence stream ecosystem health: impervious cover, landuse, riparian management and catchment infrastructure.

3.2 IMPERVIOUS COVER

The points or zones of change from one ecological condition to another are not new to urban catchment management. The influence of increasing impervious surfaces (IC) within catchments (resulting in less infiltration to ground by rainwater) is a well known phenomenon. By almost any measure of stream health, stream ecosystems degrade as imperviousness increases as a percentage of catchment landcover (Herald 2003). In a survey of the literature, Schueler et al. (2009) found that 69 % of the global studies investigated confirmed the general findings of ICM. The general predictions of ICM are:

- Stream with <10 % catchment IC: streams function as sensitive streams
- Stream with 10 % - 25 % catchment IC: streams behave as impacted streams
- Stream with 25 % - 60 % catchment IC: degrading of non-supporting of ecosystem function
- Stream with >60 % catchment IC: highly modified ecosystem function and classified as urban drainage.

3.3 CATCHMENT LANDUSE

Despite the significance of the ICM as a threshold framework for catchment management, other landuse thresholds have been identified. As a corollary to impervious cover, it is intuitive to suggest that a proportion of non-impervious landuse would provide an alternative threshold within a catchment. However, percent forest cover is a measure of the intactness of forest, whereas imperviousness strictly relates to urbanisation.

As part of a PSR study of Project Twin Streams in the former Waitakere City, measures of landuse were related to various indicators of stream health. The Macroinvertebrate Community Index (MCI) is a measure of water quality in streams (Boothroyd & Stark 2000) and was applied as an indicator of stream health to the Project Twin Streams. Most low MCI scores (<80) occurred at Project Twin Stream monitoring sites where there was <50 % catchment forest cover and >10 % catchment imperviousness (Fig. 1). All high or excellent MCI scores (scores >100) were at sites with >50 % forest cover above the site.

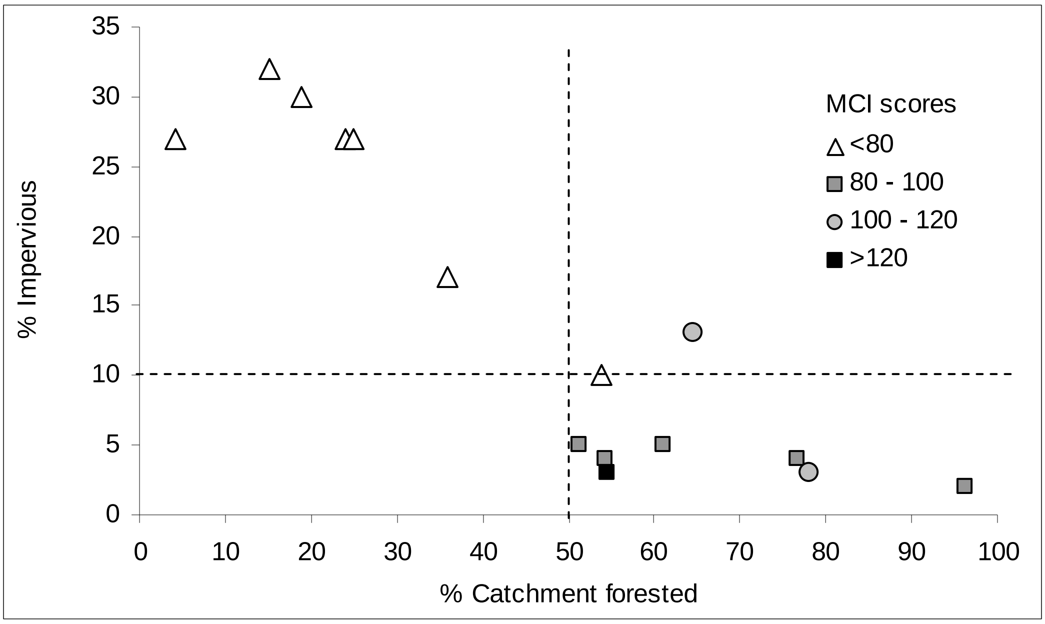

Figure 1: Relationship between landuse indicators (catchment forest and imperviousness cover), and macroinvertebrate community index (MCI) scores.

The fact that both imperviousness and forest cover landuse show strong correlations with water quality and ecological indicators illustrates their value as thresholds of change in aquatic systems resulting from landuse and urban pressures. The change does not just reflect urban development pressures, but landuse intensification and change in general, as forest is also cleared for agricultural development, which often occurs many years before urbanisation.

The international literature supports this landuse threshold level for remnant indigenous forest cover in stream catchments. Goetz et al. (2003) found streams in excellent health occurred where a greater than 50 % tree cover and <5 % landuse occurred in the mid-Atlantic region of the USA. However, impervious cover remained the primary predictive model followed by riparian planting in a stepwise regression. In study in Connecticut, USA, Urban et al. (2006) showed that remnant forest cover explained 70 % of the stream biodiversity.

An advantage of collecting data on both remnant indigenous forest and urban pressures is the ability to track how these values change over time and to see what influence this has on indicators of ecological state. For example, if significant proportions of runoff from the existing impervious urban stormwater catchment were to be captured and treated, then one might expect an increase in MCI scores in the upper left of Fig. 1. Alternatively, if there was a shift in the existing farming landuse to more intensive agriculture, and if best-management practices were not used (e.g., fencing stock from waterways), then lower MCI scores may occur with no change in catchment forest cover.

3.4 CATCHMENT CONNECTIVITY AND RIPARIAN MANAGEMENT

The benefits of streamside or riparian management have long been recognised in New Zealand and it is generally agreed that such zones can serve a number of functions (Quinn et al. 1993, Large & Petts 1996, Quinn et al. 1993). Corridors are lengths of vegetation or habitat connecting otherwise isolated remnants (Hobbs 1992). Corridors along streams provide migratory pathways as well as a buffer to the effects of reduced 'patch' size on habitat availability outside of the stream margins. Catchment connectivity (as riparian corridor measurements) were applied to Project Twin Streams (mainstem of the rivers only). Narrow riparian corridors and a low percentage of the total stream length that was vegetated both result in low catchment connectivity scores. Stream health indicators (MCI scores, %EPT, Fig 2) were low where catchment connectivity scores were ≤10. In the Twin Stream catchments, it was considered that low catchment connectivity was associated with urbanisation and results in reduced water quality and ecological health. Catchment connectivity also provides important habitat and corridors for native birds, arboreal lizards, and terrestrial invertebrates.

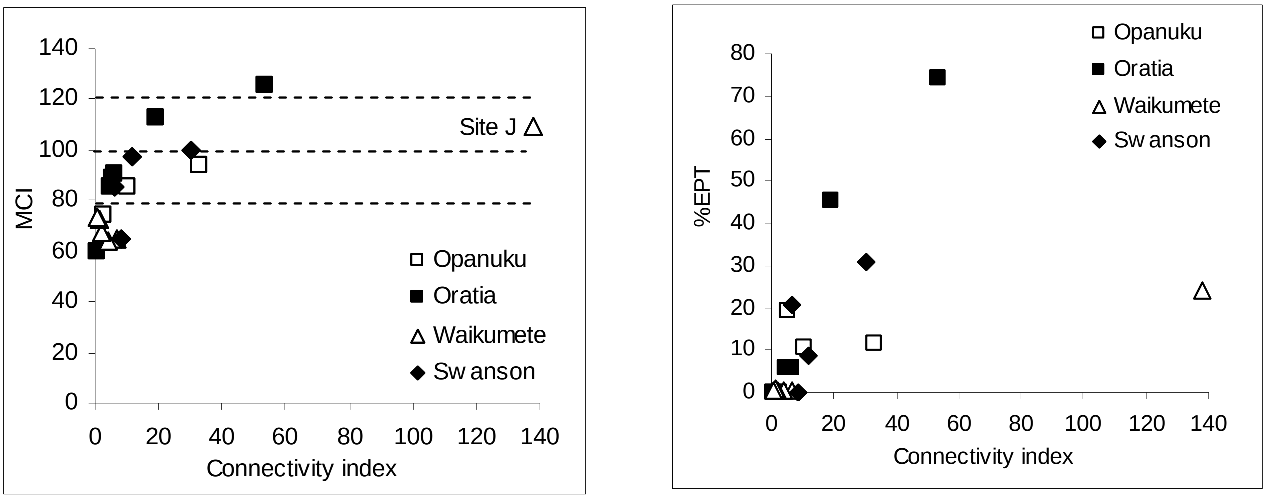

Figure 2: Relationship between catchment connectivity index, and MCI scores and the proportion of community EPT taxa.

3.5 HABITAT

Measures of river condition are focused primarily on water quality and ecological data, with physical variables of aquatic systems considered as characteristics of secondary importance to stream ecosystems (Suren et al. 2004). Although several attributes of habitat quality are regularly measured, they are often not reported consistently. Protocols for the consistent assessment of habitat are now available (Harding et al. 2009); previously Regional Councils have used their own habitat score protocols. The Auckland Regional Council Habitat Score, a single score derived from some 20 habitat attributes was applied to the PTS PSR study. In that study, habitat score was generally the best correlate with biological health, with a correlation coefficient of 0.65 with MCI. However, when sites with high impervious cover >20 %, were excluded (cf. Waikumete Stream sites) the habitat score was strongly positively correlated with MCI (rs=0.78) and taxa richness (r=0.83, P<0.001) (Fig. 3). This is a significant finding, as it suggests that habitat quality is related to ecological state in areas with less intensive urban development, but for sites where catchment imperviousness exceeds around 20 %, the negative effects of catchment-scale urban disturbance will outweigh the potential benefits of localised good quality habitat.

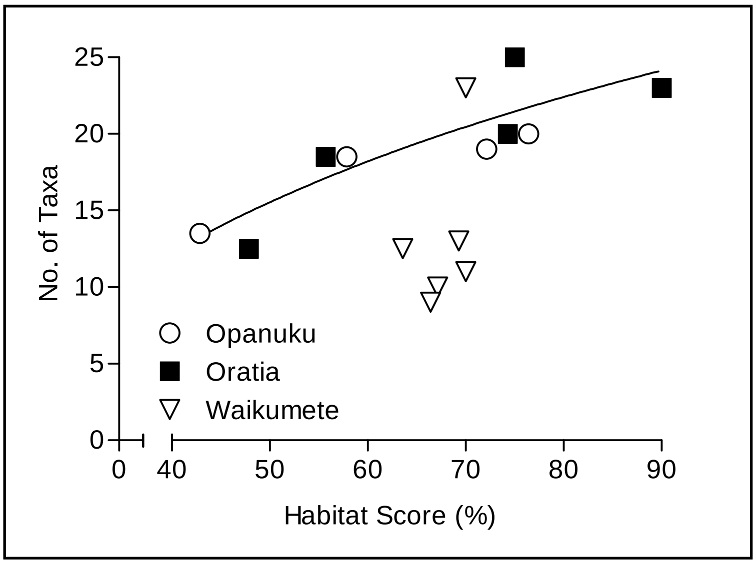

Figure 3: Relationship between habitat score and taxa richness, Project Twin Streams 2004.

4 IMPLICATIONS AND CONCLUSIONS

The ability to adapt to change but maintain structure, function and identity is a key element of the resilience of all systems. For catchment management, retaining the attributes of structure and function of stream ecosystems is preferable to attempts to restore or rehabilitate streams.

In particular, the finding that stream habitat quality had no relationship to invertebrate community health for sites with >20 % impervious area has important implications for stream management and restoration goals. One implication is that for areas with significant upstream urban development, and poor stormwater treatment, restoration of stream habitat is unlikely to improve macroinvertebrate community health. This contention is supported by the findings of a field experiment undertaken in several urban streams in Australia. Walsh and Breen (1999) found no improvement in invertebrate community health or community structure when graded rock riffles were placed in three sites in urban streams. The authors concluded that the lack of change in invertebrate community composition after habitat enhancement suggests that catchment-scale processes associated with increased impervious area were responsible for structuring invertebrate communities, rather than more local-scale effects of habitat simplification.

More tellingly, Walsh et al. (2007) concluded that riparian forest cover may influence richness of some macroinvertebrate taxa, but catchment urbanisation probably has a stronger effect on sensitive taxa. In catchments with even a small amount of conventionally drained urban land, riparian revegetation is unlikely to have an effect on indicators of stream biological integrity.

If a management goal is to retain or to improve the overall ecosystem health of ecologically impaired urban sites, then mitigation options will need to include such features as retro-fitting stormwater treatment devices to existing reticulated stormwater systems. Riparian planting alone is unlikely to be sufficient as a full mitigation against potential stormwater impacts for green fields urban development; new urban developments will also need appropriate stormwater detention and treatment to ensure downstream ecosystem health does not decline. Although reducing the impacts of catchment urbanisation through dispersed, low-impact drainage schemes is likely to be effective, planning to prevent the breach of thresholds is desirable to retain or reduce the impacts of development on stream catchment ecosystem health.

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