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Title: Sustainable resource management: A Pressure-State-Response framework for sustainability in the urban environment

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Abstract

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) environments and the real and perceived human, social (including cultural) and economic contexts are critical to achieving sustainability. The effectiveness of achieving a balanced human-ecosystem relationship can be explored through frameworks such as the Pressure-State-Response (PSR) framework and the application of management tools such as integrated catchment management. The Ministry for the Environment have adopted the OECD's stress-response (PSR) framework approach to measuring sustainability. The PSR model is based on the concept of causality; human activities exert pressures on the environment, altering the quality and quantity of environmental resources that lead to responses in human behaviour. Using case studies from Auckland we will present a model of sustainability applied to urban stream environments that aims to identify what attributes are likely to contribute to the advancement of sustainability in urban environments. We will present the results of a study using the PSR framework and indicate how the results can be applied. Limitations of the PSR framework will also be highlighted along with progress towards a greater socio-ecological integration.

Introduction

Increasing urbanisation of our landscape places increasing pressure on the existing and often already limited or highly-modified natural resources. Intensification and development within towns and cities, and growing demand for lifestyle living in areas surrounding urban centres (i.e., peri-urban development) has increased demand for services from these ecosystems (i.e., for stormwater

runoff or wastewater disposal). The most recent statistics show that more than 85% of New Zealanders live in urban areas and nearly 72% live in the 16 largest urban environments with over one million people (>30% of New Zealand's population) living in Auckland (< 2% of New Zealand's land area) (Statistics NZ 2006).

Sustainable development is the context by which achieving such progress can be managed and measured. Urban sustainability involves creating better places to live, work and play, while solving problems caused in and by our settlements (MFE 2003). 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 we focus on sustainable catchment management and investigate the effectiveness of the use of frameworks such as the Pressure-State-Response (PSR) framework and the application of management tools such as integrated catchment management for achieving balanced human-ecosystem outcomes. A key component of is to understand how sustainability will be achieved by the relationships of pressures and state of the environment, and how human communities can influence each of these.

Driving Forces

Several factors are behind the thinking and practice towards sustainable development and sustainable catchment management. In urban areas, community well-being is at the heart of sustainability initiatives; for example, the overarching principle of the Greater Christchurch Urban Development Strategy is sustainable prosperity and requires an understanding of the systems that support life in the community. Similarly, the Auckland Regional Growth Strategy aims (amongst four key goals) to sustain strong and supportive communities. Although human sentiments are important, most catchment planning has provided little focus on the social-emotional context of sustainable management. Nevertheless, 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 are high priorities for urban dwellers.

Pressure-State-Response framework

The pressure-state-response (PSR) model, and variations of the PSR are based on the concept of

causality; human activities exert pressures on the environment, altering the quality and quantity of environmental resources that lead to responses in human behaviour (Hughey et al. 2004). In this way, the framework integrates environmental and development issues (i.e. pressure and state) to enable better informed policy decisions and behavioural changes (i.e. social response) to be implemented at appropriate levels to achieve sustainability. In particular, the PSR model provides a means for selecting and organising data and indicators in a manner useful for decision makers and the public, and ensuring that important considerations are not overlooked. The PSR is in wide use in New Zealand as a framework for state of the environment monitoring programmes, but has rarely been applied to questions of sustainability.

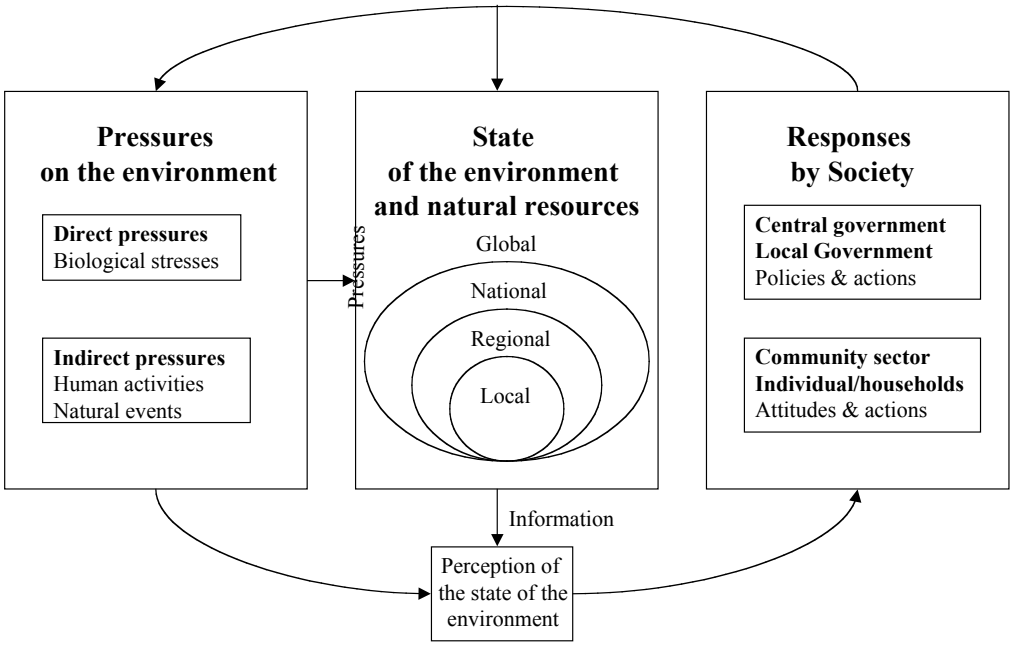

Fig. 1: Pressure-State-Response framework for environmental reporting in New Zealand (from MFE 1997, Drury et al. 2003).

The need to assess the state of the environment and provide feedback loops for management has led to the development of indicators or performance measures. The PSR framework integrates environmental and development issues (i.e. pressure and state) to enable better informed policy decisions and behavioural changes (i.e. response) to be implemented at appropriate levels.

PSR and Auckland streams

The PSR model has been applied to Auckland urban streams (Drury et al. 2003) and most comprehensively to Project Twin Streams in the Waitakere City Council (KML 2006). The

outcomes clearly show a relationship between increasing urbanization and a loss of sustainability, as measured by various water, sediment quality and ecological condition indices. However, key social, economic, cultural and historical attributes have been omitted from the model. Previous measures of social indicators for Project Twin Streams found that two-thirds of the respondents rate the streams as passable or better for water quality.

Drury et al. (2003) found that pressures can vary within a stream type, although stream typing or classification will minimise variation. Amongst the clearest patterns was where pressures are high, water quality is poor, but ecological health can be variable (Table 1). This occurs as response initiatives have been implemented and improve habitat in particular. This is particularly evident in Oakley Creek, where habitat improvements in the lower catchment have resulted in a moderate ecological health state.

Table 1: Summary of pressure ratings, water quality and ecological health indicators for nine catchments in Auckland region (from Drury et al. 2003).

	Stream type	**Pressure rating**	**Estuarine sediments**	**Ecological health rating**
Otara Stream	Large non-urban	Low-mod	Poor	Mod-Good
Lucas Creek	Large urban stream	Low-mod	Good	Mod-Good
Henderson Creek	Large urban stream	Mod-high	Poor	Mod
Pakuranga Stream	Large urban stream	Mod-high	Poor	Very poor
Meola Creek	Small urban stream (low-lying)	Mod-high	Poor	Mod
Motions Creek	Small urban stream (low-lying)	High	Poor	Poor
Oakley Creek	Small urban stream (steeper)	High	Poor	Mod
Taiaotea Creek	Small urban stream (steeper)	Mod	Good	Poor
Wairau Creek	Concrete channel	Mod-High	Good	Very poor

On the other hand, implementation of the PSR framework in the Project Twin Streams catchments revealed clear patterns of reduced water quality and ecological health associated with increased urban development. In particular, increased catchment imperviousness was associated with increased turbidity, elevated concentrations of heavy metals (dissolved and sediment-associated), nitrogen, bacteria, and PAHs, and a reduction in macroinvertebrate community health (Table 2). Overall, the state of water quality and aquatic ecology was good in upstream sites, poor in downstream urban sites, and intermediate at rural or peri-urban sites.

Table 2: Summary of effects of increased urban development (percent impervious area) on measures of the state of water quality and ecological health of Twin Streams waterways. Arrows indicate increase (up) or decrease (down) in indicator (from KML et al. 2006).

Indicator	Effect of Urbanisation?	Currently acceptable? Comply with Guidelines?
Water quality		
Temperature	⇧	✓
Clarity	⇩	✗
Ammonia	✗	✓[1]
Heavy metals	⇧	✗
Faecal bacteria	⇧	✗
Nitrogen	⇧	✓
Phosphorus	⇩	✓[2]
Sediment quality		
Heavy metals	⇧	✗
PAHs	⇧	✓
Residual agricultural quality		
DDT (disused pesticide)	⇧?	✗
Dieldrin (pesticide)	✗	✓[1]
Ecology		
Habitat	✗	✓
Periphyton	✗	✓
Invertebrate community health	⇩	✗
Fish diversity	✗	✓

[1]Except for Hibernia Stream at Ceramco Park (Site K, Waikumete).
[2]Guidelines exceeded at Oratia upstream sites.

However, in separate surveys of perceptions of Project Twin Streams, two-thirds of the respondents (n = 305) rate the streams as passable or better for water quality (only 8% regard it as clean) with only a minority rating cleanliness highly. This is consistent with other surveys of quality of life and perceptions of the environment. For example, in comprehensive surveys of quality of life, most New Zealand urban residents describe their quality of life positively with 88% rating it as good (60%) or extremely good (28%) (Gravitas 2005).

Hughey et al. (2004) found that, on average, New Zealanders consider the state of their environment to be adequate to good. Even when focused on the built environment, most residents (>70%) stated that air, water and noise pollution had not been an issue over the previous 12 months (Gravitas 2005).

Limitations of PSR

Some commentators observe that the PSR logic that is often used to assess and frame environmental policy is reactive and remedial, focusing on 'alleviating' pressures, protecting environmental 'states' and 'mitigating' impacts (Hindmarch et al. 2006). These authors go on to suggest that a more appropriate framework is to include environmental and ecosystems thinking into high-level policy thus rendering many interventions redundant, as causal factors are addressed.

The framework that has been developed has a number of limitations, largely resulting from the availability of suitable data to develop the relationships between pressures and state of the environment indicators, and the lack of long-term data. In addition, the manner by which data and information is gathered and stored varies between Councils, and is not always in a suitable format for environmental reporting.

It is our experience that water managers are presented with a near-impossible task of raising urban catchment conditions to some 'pristine' or high quality, with the threshold criteria too extreme to meet and existing sustainability indicators unsuitable for urban environments. Thus the application of many state of the environment programmes may measure little improvement as progress in state fails despite improvements at the human-ecosystem interface, or progress is in response to perceived rather than realised and quantified pressures. Alternatively, a change in state might be measured but with no real understanding of what shift in pressures or responses led to alterations. Reasons for this are complex but Hodge (1997) identified that any conceptual framework for dealing with sustainability would need to build from fundamentals that both underpinned and

bridged existing knowledge and understanding. Furthermore, the SOE programmes lack an understanding or measure of people's perceptions of the state of the environment that may also be important (Hughey et al. (2004). There is a need to consider social and cultural, and economic resources, processes and outcomes, as well as the sustainability of ecosystem processes.

It is clear that the PSR framework would benefit from further testing as a model for urban sustainability, with raw data collected as necessary and additional exploration undertaken on relationships. The environmental reporting framework results in an alignment of pressures and state for urban streams, and allows an explanation of patterns and the reporting of trends and signals for reporting on sustainability. A key component of any framework for urban sustainability will be scale. As stream ecosystems are largely controlled by physical patterns and processes which interact at a range of spatial scales such that hydrological and physical variables at any point in a river reflect the integrated effect of controlling factors in the catchment above that point (Boothroyd et al. 2003).

Implications for Management

The implementation of the PSR framework has shown how catchment-scale processes (rather than local-scale effects) can be an overriding factor influencing stream health and sustainability. One implication is that for areas with significant upstream urban development, and poor stormwater treatment, restoration of streams is unlikely to improve or sustain stream health. International research has also shown that catchment-scale processes associated with increased impervious area is responsible for structuring aquatic communities, rather than more local-scale effects of habitat simplification. If a management goal is to improve the overall sustainability (including ecosystem health) of catchments then whole catchment solutions are required. An understanding of whole-catchment change can be obtained by the use of the PSR framework; as well as an ability to incorporate other factors such as community perceptions and environmental history.

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