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Original Research Article

A framework for assessing river health in peri-urban landscapes

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ABSTRACT

The definition and assessment of the health of river systems is a difficult and complex task. This is mainly because river systems are distributed over a large geographical space with unique biotic and abiotic characteristics attributed to a given catchment, the existence of competing perceptions of stakeholders and an inability to establish a clear rationale for a universal river health assessment methodology. Such complexity and uncertainty can be addressed through a river health assessment framework with step-by-step guidance to help river health management authorities develop site-specific tools suitable for their river systems by taking into account the local river ecohydrology, hydrobiology, water quality aspects and insights from river users. The present work proposes a river health assessment framework based on the key outcomes of a three year project and showcases the role of each step in the framework. The proposed framework consists of four steps: understand, identify, develop and apply. During the first step, a comprehensive understanding is obtained using historic and current water quality data. This information is supplemented with community understanding of the changing condition of river health. This knowledge is then used together with relevant multivariate stoical techniques to identify some key indicators for river health monitoring and assessment. Finally tools are developed to assess river health for community, environmental and management purposes. We developed two tools to assess the risk associated with river health for primary contact recreational activities and algal blooms using three key indicators.

1. Introduction

Rivers are complex ecohydrological systems in the landscape which can resist a higher degree of anthropogenic stress and maintain equilibrium without any human intervention. Many river systems, in both developed and developing countries are on the verge of irreversible degradation and the availability of a proper assessment methodology is needed to determine the level of degradation for sustainable river management purposes. Peri-urban zones are diffused territories existing between the urban and rural townships and becoming extremely vulnerable to anthropogenic pressures (Adell, 1999; Buxton et al., 2006). In particular, the river systems in peri-urban zones are threatened by pressures from both urban and rural landscapes (i.e., rapid expansion of population, land acquisition, deforestation) and effects of climate change (i.e., extreme weather conditions) in the last few decades. Due to the complex nature of the peri-urban regions, the planning and management

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of environmental assets in these regions cannot be simply achieved by extrapolation of similar tools previously applied for rural and urban regions alone (Allen, 2003).

To date, a number of river health assessment methodologies have been proposed towards achieving sustainable river management targets using water quality variables, aquatic species, riparian condition sediment health and combined indices (Brown et al., 1970; Simpson et al., 2000; Maddock, 2001; ISC, 2006). However we have not been able to develop comprehensive river health assessment methodologies for world river systems mainly due to large geographical differences, catchment characteristics and habitat-specific species attributed to river systems. One simpler way to overcome the spatial and temporal complexity associated with river health assessment is to establish a framework which can be used as a guide to develop necessary tools based on regional characteristics and local knowledge.

A framework refers to a hypothetical or analytical construction that simplifies a complex process. For example, a risk management framework could be used to educate workers about foreseeable risks in the workplace, solutions to assess risks and methods to minimise risks in a number of different scenarios (Jones et al., 1990). Frameworks are used in many disciplines today, viz., health, education, information technology, business, natural resource management and where multiple competing interactions and interests influence key outcomes of a process (Harris and Chapman, 1997; Ichinose, 2003; Huang et al., 2009; Solomon et al., 2007; Painuly et al., 2007). Some frameworks are theoretical and open, while others are analytical and closed providing a step-by-step guidance towards achieving a desirable outcome. The former is usually based on a number of generic theoretical knowledge in the literature and accepted standards by institutions (Zhou et al., 2004; Peterson, 2003). Frameworks of this nature remain mostly open, provide broadly described steps and do not indicate linkages between the steps. However, the latter guides the user through a step-by-step process considering most possible interactions involved in the process (Trenberth, 2004; Narumi et al., 2009). Such frameworks are also flexible, frequently provide the opportunity to link with previous steps and they are important in the assessment of natural resources which are often subjected to internal biological, chemical and physical interactions as well as competing interests of stakeholders.

The key objective of this article is to propose a simple framework for the assessment of river health and demonstrate its applicability using the Hawkesbury–Nepean River (HNR) system in New South Wales (NSW), Australia, as a case study. This framework was developed as a result of a detailed study conducted over three years in the HNR catchment which investigated how social and environmental aspects are linked in river health assessment. The study was largely supplemented by existing data records held by a number of government agencies such as Sydney Catchment Authority, NSW Department of Primary Industries and Bureau of Meteorology.

2. The need for a new framework

There has been an array of published scientific literature which describes relationships and dynamics of surface waters in relation to the diverse aquatic species therein over the last 50 years. Novel, assessment methodologies and frameworks are also proposed periodically for this purpose. However, many conventional river health assessment techniques published in the literature are now rapidly being substituted by novel applications and extremely scrutinised by their peers (Fairweather, 1999). Pinto and Maheshwari (2011) reviewed a number of widely available methods and argued that most predetermined national level river health assessment methodologies lack application in landscapes other than for which they were developed. This is due to uncertainty attributed to different national scale assessment methods, the difficulty in finding 'pristine' reference sites for comparison purposes and the inability in accounting for complex ecological interactions among aquatic species.

There are widely accepted frameworks suggested for the assessment of surface and groundwater resources, viz., the Water Framework Directive (WFD; 2000/60/EC) and the Freshwater Health Assessment (FHA) (WFD, 2000; FHA, 2013). The WFD came into effect in 2000 aiming at achieving 'good status' of all surface and groundwater resources in Europe by 2015. The FHA is based on four biophysical matrices, viz., water flow, water quality, fish diversity and benthic macroinvertebrates, to understand the health status of freshwater resources. The former claims its suitability for management of water resources in large spatial scale (i.e., all countries across Europe), the latter is suggested only for Canada and ignores stakeholder knowledge in the assessment.

Although countries like Australia have adopted well-established river health assessment framework from the United Kingdom (UK) to suit local conditions (AUSRIVAS from RIVPACS and SIGNAL from ASPT), the users of such frameworks have often failed to regularly update since their initial development (Wright et al., 1993; Chessman, 2001; Krogh et al., 2008). Similarly, attention was given to the development of various state and national level assessments without being consistent on one approach for extended time (Peter et al., 2008; Askey-Doran et al., 2009; ISC, 2006). This is opposed to UK, where data has been collected for a chosen index and measured consistently long-term thus obtaining a robust data set to make future predictions. Comparisons could have been efficiently made if Australia had been consistent with a single approach. Secondly, previous river health assessment methods strongly ignore the role that river health plays in society. No social indicators related to community satisfaction are included in current assessments although the community's role in river health definition has repeatedly been highlighted (Vugteveen et al., 2006; Pinto et al., 2012c). In addition much of the outputs derived from proposed methodologies also seem specifically made for a selected group of experts to be understood. Others indicate the health of river through colour coded point systems or report cards which may be difficult to understand because these are not risk based communication tools. We need