Use of invertebrate predictive models, the reference condition and causal criteria for ecological assessment of river condition

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Susan J. Nichols BAppSci(Hons)

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Institute for Applied Ecology, University of Canberra

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Abstract

This thesis presents my most significant contributions to the science of ecological assessment of river condition. The thesis traces the development of ecological assessment and shows where my work has made a significant contribution to knowledge of ecological assessment. I demonstrate the value of bioassessment and the 'reference condition approach' by describing applications and evaluation of the Australian River Assessment System (AUSRIVAS), which has been the national standard method of biological assessing river health for over a decade. AUSRIVAS includes a standardized invertebrate sampling method, the reference condition approach, predictive models, and software for assessing river health. However, new methods to aid the synthesis of ecological studies are imperative if the increasing body of scientific research is to improve management and outcomes for freshwater systems. My most recent work has contributed to establishing a new causal–criteria analysis method, 'Eco Evidence', for assessing evidence for and against environmental cause–effect hypotheses.

This thesis reviews bioassessment and AUSRIVAS predictive modelling, the reference condition approach, and the origins of Eco Evidence to provide background and context for my research. I have arranged the nine research articles that comprise the body of this thesis in three categories: 1) AUSRIVAS sampling method evaluation; 2) applications of AUSRIVAS; and 3) the synthesis of multiple studies for environmental causal assessment using Eco Evidence. In addition, the final chapter outlines problems encountered and future directions for the work.

A major contribution of my research has been to demonstrate the utility of the reference condition approach for (i) predicting reference (that is pre-impoundment) biota in the Cotter River (ACT); (ii) establishing reference biota within Kosciuszko National Park (Australia); and (iii) using the reference condition approach to assess the condition of Portuguese streams. This body of work is highly relevant to river managers wanting to apply the reference condition approach and (a) understand the consequences of sample variability on bioassessment results; (b) allocate resources appropriately for the level of replication required to detect an ecological response; and (c) avoid method-related bias where studies cross multiple jurisdictions that use different sampling methods. This research highlights the significance of standardized sampling of fixed sites (both test and reference) over long periods and demonstrates the value of the reference condition approach when assessing the biological

response to flow regulation. When applied within a robust study design and an adaptive management framework, the bioassessment program coped with changing questions and unforeseen events, such as extended drought. Application of AUSRIVAS has shown that management actions maintained the ecological resilience of the Cotter River, enabling it to recover when higher river flows returned after the drought.

This thesis also describes the recently published Eco Evidence method for systematic review of environmental science literature and draws together some lessons learned about the application of causal analysis to define ecosystem response to flow. The Eco Evidence method was adapted from epidemiological techniques for attributing causation. Such causal assessment can be necessary to inform management actions aiming to improve environmental condition. This work is highly relevant to researchers and environmental practitioners that require a method for quantifying and combining scientific evidence from multiple studies. The Eco Evidence weighting system for individual studies is a major advancement in environmental causal assessment. This research effort is part of a worldwide trend towards facilitating greater use of evidence-based methods in environmental assessment and management.

My research has contributed to advancing the understanding of ecological assessment that uses invertebrate predictive models, the reference condition approach and causal criteria analysis. Rigorous bioassessment studies and the reference condition approach when applied within the context of adaptive management, long-term assessment, and a framework for causal assessment, can provide the ecological evidence to inform current and future river management.

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[1] Ann Milligan (nee Ann Petch) is a former agricultural scientist and hydrogeologist who has been editing and writing reports and articles about freshwater ecology since 1998.

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Introduction

Humans rely heavily on freshwater resources and managing these resources requires an understanding and integration of the physical, chemical, and biological interactions that define aquatic systems (Dodds and Whiles 2010). The demands for water from industry, agriculture, and power generation that our lifestyle requires are threatening the quality and security of water resources in terms of the economic, cultural, aesthetic, scientific and educational values (Malmqvist and Rundle 2002; Dudgeon et al. 2006). Exposure to the effects of water abstraction, pollution and habitat degradation can damage the biological communities that inhabit aquatic ecosystems (Malmqvist and Rundle 2002; Dudgeon et al. 2006). Thus, the measurement of aquatic communities can signal declining ecological conditions, or in the case of restoration, can also quantify the ecological success of management activities (Hellawell 1986).

My scientific research has been in the fields of freshwater ecology and assessment of river condition. The aim of the work has been to advance the understanding of ecological assessment, particularly aspects of assessment that use invertebrate predictive models, the reference condition approach and causal criteria analysis. This thesis presents my most significant contributions to a body of research that has advanced the understanding of ecological assessment of river condition in Australia, and in the international arena. I demonstrate how the scientific principles of study design, statistical inference, and aquatic invertebrate ecology underpin the methods for biological assessment of river condition (Chapters 3 and 4) (Nichols and Norris 2006; Nichols et al. 2006b) and describe various applications of the Australian River Assessment System (AUSRIVAS) methods (Chapters 5–9) (Nichols et al. 2006a; Feio et al. 2009; Nichols et al. 2010b; Norris and Nichols 2011; White et al. 2012). As the body of research on stream-bioassessment has grown and expanded the knowledge base of freshwater ecology, extensive associated biological datasets have developed. This has presented opportunities to analyse the collected data in ways to provide further insights into ecological processes, such as the role of disturbance. Chapter 7 (Nichols et al. 2010b) emphasizes the importance of long-term ecological studies for capturing the ecological effects of, and recovery from, disturbances in our changing environment (which includes assessment of climate-related effects on stream biota). Chapters 8 and 9 (Norris and Nichols 2011; White et al. 2012) also demonstrate how bioassessment and continued ecological research on environmental flow manipulations has been combined with appropriate

study-design principles to achieve desired ecological outcomes, within an adaptive management framework. In Chapters 10 and 11 (Norris et al. 2012; Webb et al. 2012) I present my most recent research, which expands the theme of applying scientific principles and knowledge of study-design fundamentals to ecological assessment. These two chapters introduce a new causal criteria analysis method, 'Eco Evidence', to assess the evidence for and against environmental cause–effect hypotheses. These final two papers take the thesis beyond field-based studies and into desktop research drawing evidence from multiple studies within the largely underutilized pool of published scientific literature. Eco Evidence analysis has the potential to facilitate better use of the extensive research already published about ecological health, and change the way of doing environmental assessment in the future.

The structure of this thesis is as follows. Chapter 1 is a review of bioassessment and predictive modelling, the 'reference condition approach', and the origins of the Eco Evidence framework, to provide the research context. Chapter 2 is an overview of the contemporary relevance of each research output included in this thesis and the original and scholarly contribution they each make to knowledge in the disciplines of freshwater ecology and applied science. I briefly outline the principal significance of the findings and highlight the links between each published paper. I then present each paper as separate chapter (Chapters 3–11). The concluding chapter (Chapter 12) outlines problems encountered and proposed future directions for work in ecological assessment.