The development of predictive models to enhance biological assessment of riverine systems in New Zealand

A thesis presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Ecology
At Massey University, Palmerston North, New Zealand

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Ph.D. CANDIDATE DOCTORAL EXAMINATATION APPLICATION

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Thesis title: "The development of predictive models to enhance biological assessment of riverine systems in New Zealand"

Statement regarding the nature and extent of any assistance received during the doctoral research:

For all chapters, my input was the greatest, I planned the research, undertook all fieldwork, analysed all data, and wrote all manuscripts. My main supervisor Russell Death gave assistance in the following fields: the development of the original project concept, editing manuscripts, overseeing project administration and funding and discussing ongoing developments. My other two supervisors Prof Brian Springett and Dr R. M. McDowall gave no direct assistance apart from general discussions and administrative duties.

None of the material in this thesis has been used for any other degree or diploma.

The first 4 chapters of the thesis have been published or are in press, the other two chapters are under review with journals. Details on publications:

Chapter 1 Joy, M. K., and R. G. Death. 2002. Predictive modelling of freshwater fish as a biomonitoring tool in New Zealand. Freshwater Biology **47**:2261-2275.

Chapter 2 Joy, M. K., and R. G. Death. 2003. Biological assessment of rivers in the Manawatu-Wanganui region of New Zealand using a predictive macroinvertebrate model. New Zealand Journal of Marine and Freshwater Research **33**:367-379.

Chapter 3 Joy, M. K., and R. G. Death. In Press. Neural network modelling of freshwater fish and macro-crustacean assemblages for biological assessment in New Zealand. *in* S. Lek, M. Scardi, and S. E. Jorgensen, editors. Modelling community structure in freshwater ecosystems. Springer Verlag.

Chapter 4 Joy, M. K., and R. G. Death. In Press. Assessing biological integrity using freshwater fish and decapod habitat selection functions. Environmental Management.

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Statement regarding doctoral thesis:

This statement confirms that the candidate has pursued the Doctoral Course in accordance with the University's Doctoral regulations.

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Statement regarding thesis:

1. Reference to work other than that of the candidate, has been appropriately acknowledged,
2. Research practice, ethical and genetic technology policies have been complied with as appropriate, and
3. The thesis does not exceed 100,000 words (excluding appendices)

Supervisor Russell G. Death

Candidate Michael K. Joy

Abstract

A suite of new regional and national lotic freshwater bioassessment tools were developed for New Zealand. This work permits the inclusion of freshwater fish in bioassessment, a component of the fauna previously largely ignored. The multivariate predictive models developed gave a number of advantages over the existing albeit overextended single-index approach (the macroinvertebrate community index) used by regional authorities. To acquire the data for constructing the models more than 500 sites were sampled over three North Island regions. The sites were selected to represent least impacted conditions known as reference sites so that the biotic communities sampled would representing the best attainable or the goal for resource managers. Models were constructed to predict the biota representing best available conditions based on the non human influenced physicochemical variables defining the sites. The predicted and observed assemblages were then compared using an observed over expected ratio *(O/E)* so that scores less than 1 represent less species observed than expected. This *(O/E)* ratio is more than simply the assessment of species richness, as only those species predicted are included in the ratio. Reference site multivariate predictive models using fish and macroinvertebrate assemblage groups were developed for bioassessment in the Manawatu-Wanganui Region. Two reference site multivariate predictive models using individual fish and decapod species were developed for the Auckland region. The first used traditional linear discriminant function analysis and the second used artificial neural networks (ANNs). A model to predict the spatial occurrence of fish and decapods was developed for fish in the Wellington Region using Geographic Information Systems (GIS) and ANNs. The remotely sensed data was available for all rivers in the region so the predictions could be extended over the entire stream network to produce a fish map. Finally an index of biotic integrity (IBI) using fish was developed for the entire country and evaluated using remotely assessed environmental data. Exhaustive evaluations of predictions from all the models confirmed their credibility as a biomonitoring.

Acknowledgments

Each Chapter has its own acknowledgments section. Here I thank those people whose assistance was not specific to any one part of the project.

First, I thank my first supervisor, Russell Death for giving me the confidence to tackle this project right from its beginnings in my Masters research. His encouragement and support from inception to final write-up has been comprehensive and inspirational. I also owe his wife Fiona a debt of gratitude for her support and missing out on family time with Russell so he could spend time on this project.

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Note on text and authorship

Each Chapter is set out largely in the style of the journal it was published in or has been submitted to. Consequently there is some inevitable repetition, especially in the methods sections, and there are minor stylistic differences between the chapters. For each paper the only co-author is my principal supervisor Russell Death this recognises his contribution in developing the original project concept, editing manuscripts, overseeing project administration and funding and discussing ongoing developments. For all chapters, my input was the greatest. I planned the research, undertook all fieldwork, analysed all data, and wrote all manuscripts.