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**Multiple scales of biological variability  
in New Zealand streams**

A thesis presented in partial fulfilment of the requirements  
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## General Abstract

Stream fish communities in Taranaki, New Zealand, were studied for the patterns and drivers of their spatial ecology. The study was focused on three main themes: a) complementarity between geography and landuse in driving regional distribution patterns of stream fish, b) the impact of agriculture on community composition, structure and variability of fish and invertebrates, and c) concordance among environmental distance and community dissimilarities of stream fish and invertebrates.

Stream sampling and data collection for fish was conducted at regional scale using 96 sites distributed in the protected forest (44 sites) of Egmont National Park in Taranaki, and in surrounding farmlands (52 sites). Local scale sampling for fish and invertebrates was carried out at 15 stream sites in pasture (8 sites) and in adjacent forest (7 sites). Environmental data of geography, landuse and local habitat description were also gathered concurrently to biological sampling. The regional scale survey reported fifteen fish species, dominated by longfin eels (*Anguilla dieffenbachia*), redfin bullies (*Gobiomorphus huttoni*) and koaro (*Galaxias brevipinnis*), while 12 fish species and 69 different invertebrate taxa were recorded from the 15 sites at local scale.

Regional scale spatial patterns of fish were mainly driven by landuse pattern. Catchment landuse (characterised by percentage cover of farming/native forest) effectively partitioned the stream fish community structure in Taranaki. Within each level of catchment landuse (farming), abundance and richness of fish species were negatively correlated with the altitude. Moreover, the upstream slope in high elevations and intensive farming downstream limited the distribution of stream fish across the region.

Fish community composition differed significantly but weakly between forest and pasture in the immediate proximity. The dissimilarity of fish communities between forest and pasture increased from regional to local scale, and a similar result was found with stream invertebrate dissimilarity at the local scale. Stream communities (fish and invertebrates) were equally variable among streams between the two land use classes both at regional and local scales. Although the land use difference did not affect within-stream variability of fish, invertebrate communities were less variable within a pasture stream. Trends in in-stream variability of invertebrates were influenced mainly by altitude, stream morphology, pH, and riparian native cover.

In concordance analysis, Mantel and Procrustes tests were used to compare community matrices of fish and invertebrates and the environmental distance between stream sites. The spatial patterns of fish and invertebrates were significantly concordant with each other among the 15 streams at the local scale. Nevertheless, community concordance decreased with lower spatial scales, and the two communities were not concordant at local sites within a given stream. Agriculture had a negative impact on the concordance between fish and invertebrates among streams, and none of the communities correlated with the overall environmental distance between agricultural streams. Community concordance between fish and invertebrates was consistently higher than the community-environment links, and lower trophic level (invertebrates) linked to their environment more closely than the upper trophic level (fish). The overall results suggest a bottom-up control of the communities through the stream food web.

Finally, to inform the regional management and conservation decision, stream sites were partitioned according to the most important bioenvironmental constraints. The ecological similarity was measured by geography, land use pattern and the abundances of influential native fish species within the region, and the streams were clustered into seven distinct zones, using the method of affinity propagation. Interestingly, the dichotomy in proximal land use was not generally represented between zones, and the species diversity gradients were not significantly different across the zonal stream clusters. The average elevation of a given zone did not influence the community variability, while upstream pasture significantly homogenised fish communities between streams within a zone. Nonetheless the zones were based on river-system connectivity and geographical proximity.

This study showed separate effects of confounding geography (altitude) and landuse on stream fish community structure, which has not explicitly been explored by previous studies. Studies with a simultaneous focus on multiple biological (e.g. fish and invertebrates) and environmental (e.g. geography, landuse, stream morphology) scales in varying spatial scales are not common in freshwater ecology. Therefore, this study has a great contribution to the understanding of the spatial ecology of stream communities linked with the control of geography, landuse, environment and likely biological interactions between fish and invertebrates.

## Preface

This thesis is based on a research designed to investigate the environmental and biological drivers of freshwater community composition, structure and variability, in New Zealand streams. Taranaki streams were selected, because of the rich species diversity of freshwater fish and invertebrates, reported in previous studies. A special attention was paid to separate the effect of geography and land use, which was not explicitly covered by the other studies previously conducted in Taranaki. The first part of the study explores the important environmental drivers of the fish community in Taranaki, surveyed in a wider geographical extent (96 streams), compared to the study area of 15 streams, in the second phase of this research.

Most of the studies on biological variability cover large geographical areas from ecosystems to ecoregions. Particularly in New Zealand, previous studies have not mainly addressed the inter-site variability change across land-uses and the community concordance between fish and invertebrates, within a small geographical extent. Therefore, I attempted to address the knowledge gap in biological variability and community concordance of stream communities at the local scale, with a special concern about the human impacts to stream fish and invertebrates.

This thesis includes three individual research manuscripts, thus some repetition occurs in the introductions, methods and discussions across the chapters.

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