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# **The impact of extreme climatic events on the ecology of grasslands**

A thesis presented in partial fulfilment of the requirements for the degree of

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**To Mac and Mary**

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## Abstract

The impact of extrinsic factors, such as climate, fertility and disturbance, on plant communities has traditionally been determined at constant levels, spatially and temporally. However, projected future increases in climate variability dictate that a greater emphasis is needed on understanding plant species and community responses to fluctuations in climate. In particular, stochastic, transient but highly disruptive extreme climatic events are predicted to become more prevalent. Their impact on the dynamics and structure of productive grassland communities in New Zealand are the focus of this thesis.

Particular emphasis was placed on quantifying plant functional traits of common grassland species. This was achieved by laboratory screening methods that targeted both regenerative and established life-cycle stages. Field screening methods were also used to quantify functional traits and group species into functional types. Photosynthetic pathway, relative growth rate and life-history were identified as key functional traits differentiating grassland species.

Regenerative phase functional traits were determined on a total of 26 grassland species. Differences in the dependency on warm temperatures for germination and seedling desiccation tolerance were used to generate predictions of species invasiveness.  $C_3$  species were predicted to have a greater ability to invade than  $C_4$  species. Seed size and life-history were also found to be related to invasiveness.

The competitive abilities of five  $C_4$  grassland species were determined relative to a common  $C_3$  grass, *Lolium perenne*, in a glasshouse pot experiment. The most competitive  $C_4$  species were the annuals, *Digitaria sanguinalis* and *Panicum dichotomiflorum*. The impact of extreme climatic events on competition and competitive ability was examined by exposing plants to extreme temperature (frost and heat) and extreme water (drought and flood) events. Species responses from these simple mixtures were extrapolated to predict the impacts of extreme climatic events on grassland communities.

Field and laboratory screening predictions were tested in a large-scale field experiment, which employed novel techniques to simulate extreme heating and rainfall events over grassland. Species with  $C_4$  photosynthesis, fast-growth and short life-histories (collectively named FT1 species) were confirmed as being the species to be most advantaged by an extreme heating event.

Functional traits possessed by species (species identity) were found to be more important in determining community sensitivity to extreme climatic events than the number of species (species richness). Competition was identified as highly important in limiting the invasion of C<sub>4</sub> species into solely C<sub>3</sub> grasslands. Extreme heating events are expected to suppress competition and promote the invasion of C<sub>4</sub> species, in particular, the FT1 species.

By examining responses to short-term fluctuations in climate, this set of investigations has shown that fluctuating temperature and water levels can have important consequences for plant species and the ecology of their communities. Key evolutionary specialisations were recognised as important in determining climate response, and with further development, they could lead to a new functional type classification for use in vegetation-climate analysis. In future, there should be greater emphasis in ecology on the role of short-term but extreme fluctuations in climate in determining plant community dynamics and structure. This will increase the predictive power of ecology in relation to vegetation responses to current and future climates.

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## **Structure of Thesis**

This thesis is based on a series of papers. Chapter Four has been accepted for publication in *Global Change Biology*. Chapters Two, Three and Five have been prepared for submission to *Functional Ecology*, *New Zealand Journal of Agricultural Research* and *Global Change Biology*, respectively. The only difference between the chapters and paper manuscripts is the formatting of the headings and the insertion of figures and tables into the body of the text. The references relevant to individual chapters are at the end of each chapter.

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