The impact of extreme climatic events on the ecology of grasslands

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

Doctor of Philosophy

Massey University, Palmerston North
New Zealand

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1999

To Mac and Mary

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_4 species into solely C_3 grasslands. Extreme heating events are expected to suppress competition and promote the invasion of C_4 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.

Acknowledgements

First and foremost, I would like to thank my two supervisors, Dr. Bruce Campbell and Dr. Peter Kemp. I thank Bruce for his critical evaluation, encouragement and tremendous enthusiasm, and for making excellent office and support facilities available to me. I equally thank Peter for his encouragement, and for providing a relevant but an often over-looked perspective on the research.

I received tremendous technical assistance from many people during this study. I would particularly like to acknowledge the time and effort Phillipa Nicholas devoted to my experiments. I sincerely thank Chris and Derryn Hunt for their continual assistance with different aspects of the study and also for their good humour and friendship. Many thanks to Yvonne Gray, the staff of the AgResearch, Herbage Dissection Laboratory and the staff of the HortResearch, National Climate Laboratories.

I received invaluable statistical advice from Dr. David Baird, Dr. Fred Potter, Duncan Hedderley and Robert Fletcher. Thanks also to Stuart McHardy, Ross Sainsbury and the Massey University Farms Administration for providing the experimental field sites. I would also like to acknowledge the staff members at AgResearch for their willingness to answer questions and give advice. In particular, scientific advise from Dr. Grant Edwards, Dr. Harry Clark and Andrew Carran, and Information Technology support from Dave Scammell, Joanne Morris and Helen Little.

The Agricultural and Marketing Research and Development Trust provided me with financial support during this research project. I would sincerely like to thank this organisation for their role in encouraging and facilitating careers in science in New Zealand. I would also like to acknowledge the New Zealand Foundation for Research, Science and Technology for providing funding for the experiments.

I am forever grateful to my friends, who have stuck by me during the good and the bad times. In particular, Mark (Slop) Hyslop, an excellent bloke who taught me everything I know in HPV engineering, weather forecasting and wind-assisted fishing, and also Rainer Hoffman, who put up with my constant interruptions for questions and general discussions.

Finally, I am greatly indebted to my family. Your love, support and devotion has inspired me to achieve all my life.

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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