

**ECOLOGY OF PLANT COMMUNITIES IN KU-RING-GAI
CHASE NATIONAL PARK, NEW SOUTH WALES:
AN EXAMINATION OF VEGETATION AND
ENVIRONMENTAL PATTERNS**

by

Andrew Francis Le Brocque

1995

Submitted in fulfilment of the degree of Doctor of Philosophy (PhD),
University of Technology, Sydney.

CONTENTS

LIST OF FIGURES	iv
LIST OF TABLES	vi
ACKNOWLEDGEMENTS	viii
STATEMENT OF AUTHORSHIP	ix
ABSTRACT	xi
CHAPTER 1: GENERAL INTRODUCTION	1
Summary	1
1.1 INTRODUCTION	1
1.2 AN OVERVIEW OF AUSTRALIAN STUDIES	2
1.3 RESEARCH OBJECTIVES	4
1.3.1 Floristic Composition and Environmental Patterns (Chapter 3)	4
1.3.2 Structural Characteristics of Plant Communities (Chapter 4)	5
1.3.3 Species Richness and Environmental Relationships (Chapter 5)	6
1.3.4 General Discussion and Conclusions (Chapter 6)	7
CHAPTER 2: STUDY AREA AND DESCRIPTION OF SAMPLE SITES	8
Summary	8
2.1 GENERAL DESCRIPTION OF THE CENTRAL COASTAL BOTANICAL REGION	8
2.2 DETAILED DESCRIPTION OF THE STUDY AREA	10
2.2.1 Climate	10
2.2.2 Geology, Physiography and Soils	10
2.2.3 General Description of Vegetation	12
2.3 SITE SELECTION	13
2.3.1 Criteria	13
2.3.2 Site Location	14
CHAPTER 3: SPATIAL FLORISTIC AND ENVIRONMENTAL PATTERNS IN THE VEGETATION COMMUNITIES OF KU-RING-GAI CHASE NATIONAL PARK, NEW SOUTH WALES	15
Summary	15
3.1 INTRODUCTION	15
3.1.1 Gradient Analysis: Background	16
3.1.2 Review of Plant-Environment Relations (Central Coastal Region)	18
3.1.3 Objectives and Hypotheses	22
3.2 METHODS	24
3.2.1 Floristic Composition	24
3.2.2 Site Physical Characteristics	25
3.2.3 Soil Physical and Chemical Characteristics	25
3.2.4 Numerical Analyses	27
3.3 RESULTS	29

3.3.1 Floristic Patterns	29
3.3.2 Environmental Patterns	36
3.3.3 Correlation Between Environmental Variables	48
3.3.4 Relationships Between Floristic and Environmental Patterns	50
3.4 DISCUSSION	62
3.4.1 Community Composition	62
3.4.2 Environmental Patterns	65
3.4.3 Plant-Environment Relations	67
3.5 CONCLUSIONS	74

CHAPTER 4: STRUCTURAL CHARACTERISTICS OF PLANT COMMUNITIES OF KU-RING-GAI CHASE NATIONAL PARK, N.S.W.: MULTIVARIATE STRUCTURAL CLASSIFICATION AND ENVIRONMENTAL RELATIONSHIPS 76

Summary	76
4.1 INTRODUCTION	76
4.1.1 Specht's Classification Scheme	77
4.1.2 Multivariate Approach to Classification of Stand Structure	79
4.1.3 Relationship Between Stand Structure and Floristic Composition	82
4.1.4 Relationships Between Stand Structure and Environment	84
4.1.5 Objectives and Hypotheses	85
4.2 METHODS	87
4.2.1 Structural Characteristics	87
4.2.2 Numerical Analyses	88
4.2.3 Structural Formulae	89
4.3 RESULTS	90
4.3.1 Single-Stratum Classification	90
4.3.2 Multivariate Classification of Stand Structure	92
4.3.3 Comparison of Compositional and Structural Patterns	97
4.3.4 Structure-Environment Relationships	103
4.4 DISCUSSION	113
4.4.1 Single-Stratum Verses Multivariate Classification	113
4.4.2 Comparison of Structural and Compositional Patterns	115
4.4.3 Structure-Environment Relationships	118
4.4.5 Convergence in Stand Structure	121
4.5 CONCLUSIONS	123

CHAPTER 5: PLANT SPECIES RICHNESS AND ENVIRONMENTAL RELATIONSHIPS IN PLANT COMMUNITIES OF KU-RING-GAI CHASE NATIONAL PARK, N.S.W. 125

Summary	125
5.1 INTRODUCTION	125
5.1.1 Some Definitions	127
5.1.2 Species Richness and Environment: Review	128
5.1.3 Components of Species Richness (Species Richness & Community Structure)	131

5.1.4 Statistical Approaches in the Study of Richness-Environment Relationships	133
5.1.5 Objectives and Hypotheses	135
5.2 METHODS	137
5.2.1 Species Richness	137
5.2.2 Numerical Analyses	137
5.3 RESULTS	139
5.3.1 Species-Area Relationships	139
5.3.2 Species Richness and Community Types	145
5.3.3 Species Richness and Environment - Between Soil Type Comparisons	151
5.3.4 Species Richness and Environment - Within Soil Type Comparisons	157
5.4 DISCUSSION	168
5.4.1 Community Species Richness	168
5.4.2 Species Richness and Environment	172
5.4.3 Management and Conservation Implications	180
5.5 CONCLUSIONS	181
CHAPTER 6: GENERAL DISCUSSION and CONCLUSIONS.	183
Summary	183
6.1 GENERAL DISCUSSION	183
6.1.1 Single-Nutrient Gradient Hypothesis	183
6.1.2 Complex Multivariable Environmental Gradient Hypothesis	186
6.1.3 Approach Taken in this Thesis	189
6.1.4 Implications for Further Research	191
6.2 CONCLUSIONS	193
6.2.1 Specific Conclusions	193
6.2.2 General Conclusions	194
REFERENCES	196
APPENDIX 1: Location of sample sites within Ku-ring-gai Chase National Park.	219
APPENDIX 2: Physical and chemical analysis of soil - detailed methods.	220
APPENDIX 3: Dendrogram showing ISA classification of importance score data into major vegetation types.	228
APPENDIX 4: General description of vegetation types (composition).	229
APPENDIX 5: General description of community environmental characteristics.	237
APPENDIX 6.1: NMDS of the composition data of the Hawkesbury Sandstone communities.	240
APPENDIX 6.2: NMDS of the structure data of the Hawkesbury Sandstone communities.	240
APPENDIX 7.1: NMDS of the composition data of the Narrabeen group communities.	241
APPENDIX 7.2: NMDS of the structure data of the Narrabeen group communities.	241
APPENDIX 8: Spearman rank correlation coefficients between species richness and measured environmental variables.	242

LIST OF FIGURES

Chapter 2

- Figure 2.1: Central Coastal botanical region of New South Wales showing location of the study area. _____ 9
- Figure 2.2: Ku-ring-gai Chase National Park showing location of sample sites. _____ 11

Chapter 3

- Figure 3.1: Dendrogram showing ISA classification of floristic data (frequency scores) into major vegetation types. _____ 30
- Figure 3.2.1: Dendrogram of species groups as identified by ISA classification of frequency score data. _____ 33
- Figure 3.2.2: Continuation of dendrogram showing ISA classification of species groups. _____ 34
- Figures 3.3.1 - 3.3.16: Comparison of coefficients of variation for environmental variables for vegetation types as identified from ISA classification. _____ 40
- Figure 3.4: Environmental Variability Index (ENVAR) for vegetation types as identified by ISA classification. _____ 47
- Figure 3.5: Ordination of sample scores from correspondence analysis of the complete data set. _____ 52
- Figure 3.6: Biplot of sample scores and environmental vectors from canonical correspondence analysis of the complete data set. _____ 52
- Figure 3.7: Ordination of sample scores from correspondence analysis of the Hawkesbury Sandstone communities. _____ 55
- Figure 3.8: Biplot of sample scores and environmental vectors from canonical correspondence analysis of the Hawkesbury Sandstone communities. _____ 55
- Figure 3.9: Ordination of sample scores from correspondence analysis of the Hawkesbury Sandstone communities; communities 1 & 2 ('heath' communities) omitted. _____ 57
- Figure 3.10: Biplot of sample scores and environmental vectors from canonical correspondence analysis of the Hawkesbury Sandstone communities; communities 1 & 2 ('heath' communities) omitted. _____ 57
- Figure 3.11: Ordination of sample scores from correspondence analysis of the Narrabeen group communities. _____ 59
- Figure 3.12: Biplot of sample scores and environmental vectors from canonical correspondence analysis of the Narrabeen group communities. _____ 59
- Figure 3.13: Ordination of sample scores from correspondence analysis of the Narrabeen group communities; community 11 ('closed forest') omitted. _____ 61
- Figure 3.14: Biplot of sample scores and environmental vectors from canonical correspondence analysis of Narrabeen group communities; Community 11 ('closed forest') omitted. _____ 61

Chapter 4

Figure 4.1:	Dendrogram showing ISA classification of the structure data for all quadrats. _____	94
Figure 4.2:	NMDS ordination of the composition data of the complete data set. _____	98
Figure 4.3:	NMDS ordination of the structure data of the complete data set. _____	98
Figure 4.4:	Centroids biplot from NMDS of the composition data (c) and Procrustes NMDS of the structure data (s) of the complete data set. _____	99
Figure 4.5:	Centroids biplot from NMDS of the composition data (c) and Procrustes NMDS of the structure data (s) of the Hawkesbury Sandstone communities. _____	102
Figure 4.6:	Centroids biplot from NMDS of the composition data (c) and Procrustes NMDS of the structure data (s) of the Narrabeen group communities. _____	102
Figure 4.7:	Biplot of attribute and sample scores from correspondence analysis of the complete data set. _____	104
Figure 4.8:	Biplot of sample scores and environmental vectors from canonical correspondence analysis of the complete data set. _____	104
Figure 4.9:	Biplot of attribute and sample scores from correspondence analysis of the Hawkesbury Sandstone communities. _____	106
Figure 4.10:	Biplot of sample scores and environmental vectors from canonical correspondence analysis of the Hawkesbury Sandstone communities. _____	106
Figure 4.11:	Biplot of attribute and sample scores from correspondence analysis of the Hawkesbury Sandstone communities; communities 1 & 2 ('heath' communities) omitted. _____	108
Figure 4.12:	Biplot of sample scores and environmental vectors from canonical correspondence analysis of the Hawkesbury Sandstone communities; communities 1 & 2 ('heath' communities) omitted. _____	108
Figure 4.13:	Biplot of attribute and sample scores from correspondence analysis of the Narrabeen group communities. _____	110
Figure 4.14:	Biplot of sample scores and environmental vectors from canonical correspondence analysis of the Narrabeen group communities. _____	110
Figure 4.15:	Biplot of attribute and sample scores from correspondence analysis of the Narrabeen group communities; Community 11 (closed forest) omitted. _____	112
Figure 4.16:	Biplot of sample scores and environmental vectors from canonical correspondence analysis of the Narrabeen group communities; Community 11 (closed forest) omitted. _____	112

Chapter 5

Figures 5.1.1 - 5.1.11:	Species-area curves for total species richness and richness of growth-form types (trees, shrubs & herbs) from nested sub-quadrats within the community types identified in Chapter 3. _____	140
Figures 5.2.1 - 5.2.4:	Total species richness and richness of growth-form types (trees, shrubs & herbs) for the community types. _____	147

LIST OF TABLES

Chapter 3

Table 3.1:	Summary of floristic and environmental variables measured within each quadrat. _____	24
Table 3.2:	Summary of plant community types identified by indicator species analysis of frequency score data. _____	31
Table 3.3:	Two-way table showing structurally dominant (D) and characteristic (C) species of communities identified by ISA classification. _____	35
Table 3.4:	Environmental characteristics of vegetation communities identified by ISA classification. _____	39
Table 3.5:	Matrix of Spearman rank correlation coefficients for environmental variables. _____	49
Table 3.6:	Transformations applied to environmental variables. _____	50

Chapter 4

Table 4.1:	Structural formulae for structural types identified by multivariate classification of foliage projective cover of eight strata. _____	82
Table 4.2:	Classification of quadrats based on single-stratum scheme for foliage projective cover of tallest stratum. _____	91
Table 4.3:	Structural formulae of the 100 quadrats sampled in terms of structural characteristics based on height/life-form and FPC categories. _____	95

Chapter 5

Table 5.1:	One-way analysis of variance of total species richness and richness of growth-form types (trees, shrubs & herbs) within 11 community types. ____	150
Table 5.2:	Mean richness of growth-form types expressed as a percentage of total species richness for each community. _____	150
Table 5.3.1:	Summary results of the first pass of the GLM fitting procedure for total species richness. _____	152
Table 5.3.2:	Parameter estimates from the final (5 th) pass of the GLM fitting procedure for total species richness. _____	152
Table 5.4.1:	Summary results of the first pass of the GLM fitting procedure for tree species richness. _____	154
Table 5.4.2:	Parameter estimates from the final (3 rd) pass of the GLM fitting procedure for tree species richness. _____	154
Table 5.5.1:	Summary results of the first pass of the GLM fitting procedure for shrub species richness. _____	155
Table 5.5.2:	Parameter estimates from the final (6 th) pass of the GLM fitting procedure for shrub species richness. _____	155
Table 5.6.1:	Summary results of the first pass of the GLM fitting procedure for herb species richness. _____	156
Table 5.6.2:	Parameter estimates from the final (5 th) pass of the GLM fitting procedure for herb species richness. _____	156

Table 5.7.1:	Summary results of the first pass of the GLM fitting procedure for total species richness of the Hawkesbury Sandstone communities. _____	158
Table 5.7.2:	Parameter estimates from the final (2 nd) pass of the GLM fitting procedure for total species richness of the Hawkesbury Sandstone communities. _____	158
Table 5.8.1:	Summary results of the first pass of the GLM fitting procedure for total species richness of the Narrabeen group communities. _____	159
Table 5.8.2:	Parameter estimates from the final (4 th) pass of the GLM fitting procedure for total species richness of the Narrabeen group communities. _____	159
Table 5.9.1:	Summary results of the first pass of the GLM fitting procedure for tree species richness of the Hawkesbury Sandstone communities. _____	161
Table 5.9.2:	Parameter estimates from the final (3 rd) pass of the GLM fitting procedure for tree species richness of the Hawkesbury Sandstone communities. _____	161
Table 5.10:	Summary results of the first pass of the GLM fitting procedure for tree species richness of the Narrabeen group communities. _____	162
Table 5.11.1:	Summary results of the first pass of the GLM fitting procedure for shrub species richness of the Hawkesbury Sandstone communities. _____	163
Table 5.11.2:	Parameter estimates from the final (1 st) pass of the GLM fitting procedure for shrub species richness of the Hawkesbury Sandstone communities. _____	163
Table 5.12.1:	Summary results of the first pass of the GLM fitting procedure for shrub species richness of the Narrabeen group communities. _____	164
Table 5.12.2:	Parameter estimates from the final (4 th) pass of the GLM fitting procedure for shrub species richness of the Narrabeen group communities. _____	164
Table 5.13.1:	Summary results of the first pass of the GLM fitting procedure for herb species richness of the Hawkesbury Sandstone communities. _____	166
Table 5.13.2:	Parameter estimates from the final (2 nd) pass of the GLM fitting procedure for herb species richness of the Hawkesbury Sandstone communities. _____	166
Table 5.14.1:	Summary results of the first pass of the GLM fitting procedure for herb species richness of the Narrabeen group communities. _____	167
Table 5.14.2:	Parameter estimates from the final (4 th) pass of the GLM fitting procedure for herb species richness of the Narrabeen group communities. _____	167
Table 5.15:	Comparison of total species richness of various plant communities within eastern Australia. _____	169

Chapter 6

Table 6.1:	Summary of relationships between the vegetation attributes (floristic composition, stand structure & species richness) and their major environmental correlates. _____	187
------------	--	-----

ACKNOWLEDGEMENTS

I would like to thank my supervisor, A/Prof. Rod Buckney for enabling me to undertake this research, for his support and advice, and for reading and re-reading all the drafts of this thesis. I am also grateful for Rod's continued assurances that I would complete this project. I would particularly like to thank Dr David Morrison, who gave much critical input into the design and numerical analyses of this research and for his valuable comments on drafts of this thesis. David constantly gave his advice even though my constant bothering, resulted in his constant (good-humoured?) abuse and sarcasm.

I thank my fellow post-graduate students for their support and for putting up with me for a seemingly endless candidature, particularly, Ricky Krassoi, Rob Paterson, Rob Fullerton, Ben Pearson, Rebekah Gomez-Forte, Craig Allen, Ian Anderson, Geoff Cary and Stuart Pengelly. Rob Fullerton and Ben Pearson also willingly reviewed early drafts of the thesis, and gave some valuable comments. Geoff Cary and Stuart Pengelly also gave valuable feedback on this research. Ricky Krassoi gave me suitable distraction in the form of arguments against a holistic approach in the study of ecology and discussions on general philosophy.

I thank the National Parks & Wildlife Service (NSW) for permission to sample within Kuring-gai Chase National Park and the staff of NP&WS, Northern Metropolitan Region for access to fire history data.

Narelle Richardson assisted with AAS and freely gave advice in regards to general laboratory analyses for which I am grateful. The technical staff (Dept. of Applied Biology), Sue Fenech, Barbara Almond, Jimmy Carey and Peter Ralph were helpful in the carrying out of this research. I thank Sally Scholfield and Greg Hampshire (Gore Hill Library, UTS) who assisted greatly in going out of their way to ensure access to the relevant literature and for not imposing fines for grossly overdue items.

I am grateful to the late Dr Sam Huxham (Dept. of Statistics, UTS) for access to the GLIM3.77 computer package and technical manual.

I would particularly like to thank my family for their support. Robyne Callinhan provided valuable input into the phrasing and grammar of parts of this thesis for which I am grateful. My parents, David and Sylvia, greatly supported and constantly encouraged me in my studies, and always provided a hearty meal when I was visiting. Lastly, I thank my wife, Kathy, whose love and encouragement enabled me to complete this project. Kathy always provided positive support when I was finding things difficult, even though my demands on her patience and understanding often conflicted with her own studies.

This research was undertaken while in receipt of a University Doctoral Scholarship provided by the University of Technology, Sydney, for which I am grateful. I would also like to thank the Dept. of Applied Biology which financially supported this research.

STATEMENT OF AUTHORSHIP

I, Andrew Francis Le Brocque, declare that, except where acknowledged, all work presented in this dissertation is original. I claim full right of ownership of all intellectual property in relation to this dissertation. No part of this dissertation is to be copied without prior written consent.

I also certify that this thesis has not already been submitted for any degree and is not being submitted as part of candidature for any other degree.

With respect to originality, the multivariate classification system developed in Chapter 4 is, in part, the result of collaboration with Robert Fullerton, PhD student at the University of Technology, Sydney. The multivariate approach was developed independently; however, the final structural formulae presented is the result of discussions with Robert.

Signature of Candidate

Production Note:

Signature removed prior to publication.

5/2/1995

Andrew F. Le Brocque

Parts of the research reported here (sections of Chapter 3) have been published in the *Australian Journal of Ecology*:

Le Brocque A.F. and R.T. Buckney (1995) Vegetation and environmental patterns on soils derived from Hawkesbury Sandstone and Narrabeen substrata in Ku-ring-gai Chase National Park, New South Wales. *Australian Journal of Ecology*, 20: -

'Trees seek the environment suited to them, and this does not only apply to rare and special trees but even to common species which spring up everywhere. Some like dry places, others prefer wet or cold or sunny or shady places. Natural affinity draws each species to an appropriate and suitable locality when wild plants grow on their own accord.'

Theophrastus c. 320BC

ABSTRACT

Patterns in the floristic composition, stand structure, species richness and environmental characteristics of plant communities at a number of spatial scales were examined in Ku-ring-gai Chase National Park, New South Wales. Vegetation patterns in eastern Australia have often been related primarily to a single environmental variable, soil phosphorus concentration. This study examines the 'single-nutrient' hypothesis regarding the distribution of plant species. If soil phosphorus concentration is the major factor affecting the distribution of plant species, then this variable should be highly correlated with spatial patterns in the floristic composition of plant communities within the study area.

Floristic composition was determined as the frequencies of all vascular species occurring within duplicate 500 m² quadrats from fifty sites within the Park. Environmental data consisted of 21 variables, including soil physical and chemical characteristics, from each quadrat. The patterns in floristic composition and environmental factors are described and the relationships between composition and environment were examined through indirect and direct gradient analyses. The measured environmental factors showed strong correlations with floristic patterns; however, two scales of species distributions were apparent: between and within soil type. Direct gradient analyses of composition and environmental data showed soil phosphorus concentration was inadequate in explaining the observed patterns in floristic composition. An alternative hypothesis suggests that patterns in the floristic composition of plant communities are a response to complex multivariable environmental gradients.

The structural characteristics of vegetation stands were examined through the development of a multivariate approach to the classification of stand structure. This multivariate approach is essentially a modification of an existing scheme utilising foliage projective cover of various recognisable strata within the stands. Multivariate classification and ordinations of plant communities based on structural characteristics showed strong correspondence to that obtained by compositional analyses. The complex multivariable environmental gradient hypothesis is supported from results examining stand structure-environment relationships.

The relationship between species richness and richness of three growth-form types (trees, shrubs and herbs) and environmental variables were examined through

generalised linear models. The measured environmental variables showed strong relationships with species richness, consistent with the results found multivariately with floristic composition and stand structure. No single measured environmental variable adequately predicted the observed patterns in species richness, rather species richness showed strong relationships with complex multivariable environmental gradients.

This study clearly demonstrates that the 'single-nutrient' or 'phosphorus' hypothesis is inadequate in explaining all the patterns in the various components of vegetation within Ku-ring-gai Chase National Park. The complex multivariable environmental gradient hypothesis suggested by the relationships between floristic composition and environmental variables is supported by the relationships exhibited by two other attributes of vegetation communities: stand structure and species richness. Further studies testing the significance of the complex multivariable environmental gradient hypothesis are required.