

# **Carbon and water dynamics of peat soils in the Australian Alps**

Submitted by  
Samantha Patricia Power Grover, B.A., B.Sc.(Hons)

A thesis submitted in total fulfillment  
of the requirements for the degree of  
Doctor of Philosophy

Centre for Applied Alpine Ecology  
Department of Agricultural Sciences  
School of Life Sciences  
Faculty of Science, Technology and Engineering

La Trobe University  
Bundoora, Victoria 3086  
Australia

May 2006

## Table of Contents

Index of Tables .....	7
Index of Figures .....	8
Summary .....	14
Statement of Authorship .....	15
Acknowledgements .....	16
Definitions and abbreviations .....	18
Chapter 1. General introduction .....	20
1.1 Peat .....	21
1.1.1 What is peat? .....	21
1.1.2 The importance of peat .....	21
1.2 Carbon cycling .....	22
1.3 Hydrology .....	27
1.4 Peat in the tropics and the southern hemisphere .....	31
1.5 Peat in Australia .....	34
1.5.1 Vegetation .....	36
1.5.2 Soil and water .....	38
1.5.3 Hypotheses about bog function .....	42
1.6 Aims of my research .....	43
Chapter 2. Site description and monitoring of environmental properties .....	44
2.1 Introduction .....	44
2.2 Methods .....	47
2.2.1 Profile descriptions .....	47
2.2.2 Vegetation .....	47
2.2.3 Mapping peatland properties: peat depth, peat type, pH .....	47
2.2.4 Monitoring environmental properties .....	47
2.2.4.1 Rainfall .....	47
2.2.4.2 Air temperature .....	48
2.2.4.3 Soil temperature .....	48
2.2.4.4 Soil water content .....	48
2.2.4.5 Watertable depth .....	48
2.3 Results .....	49
2.3.1 Profile descriptions .....	49

2.3.2	Vegetation descriptions.....	53
2.3.3	Aerial photo and maps .....	53
2.3.4	Environmental properties: Air and soil temperature .....	57
2.3.5	Environmental properties: Rainfall and soil water content.....	58
2.3.6	Environmental properties: Rainfall and watertable depth .....	60
2.4	Discussion.....	64
2.4.1	Profile descriptions.....	64
2.4.2	Vegetation.....	64
2.4.3	Whole peatland properties .....	65
2.4.4	Environmental properties: Soil temperature and soil water content .....	65
2.4.4.1	Decomposition.....	65
2.4.4.2	Plants.....	67
2.4.4.3	Hydrology.....	67
2.4.5	Environmental properties: Watertable.....	68
2.4.5.1	Hydrology.....	68
2.4.5.2	Decomposition.....	70
2.4.5.3	Plants.....	70
2.4.6	Limitations .....	71
2.5	Conclusions.....	71
Chapter 3.	Carbon cycling I - Chemistry and laboratory incubations .....	72
3.1	Introduction.....	73
3.2	Methods .....	75
3.2.1	Sampling .....	75
3.2.2	Carbon and nitrogen analyses .....	75
3.2.3	<sup>13</sup> C Nuclear Magnetic Resonance spectroscopy.....	76
3.2.4	Carbon mineralisation.....	78
3.2.5	Data analysis .....	81
3.3	Results .....	83
3.3.1	Carbon and nitrogen analyses .....	83
3.3.2	<sup>13</sup> C Nuclear Magnetic Resonance spectroscopy.....	84
3.3.3	Influence of chemical composition on mineralisation of carbon from peat.....	92
3.3.4	Influence of particle size on mineralisation of peat carbon .....	94
3.3.5	Influence of water content on mineralisation of peat carbon.....	95
3.3.6	Comparison of carbon mineralisation from fresh and prepared peat .....	96

3.4 Discussion.....	97
3.4.1 Elemental data (C, N, C/N).....	97
3.4.2 <sup>13</sup> C Nuclear Magnetic Resonance analyses.....	97
3.4.3 General incubation characteristics.....	99
3.4.4 Influence of chemical and physical properties of peat on carbon mineralisation.....	99
3.5 Conclusions.....	103
Chapter 4. Carbon cycling II - Field measurements and future emissions .....	104
4.1 Introduction.....	105
4.2 Methods .....	107
4.2.1 Field incubation of mesh bags.....	107
4.2.2 Surface CO <sub>2</sub> emissions .....	108
4.2.3 Chemical analyses .....	109
4.2.3.1 Carbon and nitrogen.....	110
4.2.3.2 <sup>13</sup> C CP/MAS Nuclear Magnetic Resonance spectroscopy .....	110
4.2.4 Data analysis .....	110
4.3 Results .....	111
4.3.1 Field incubation of mesh bags.....	111
4.3.2 Chemical analyses .....	113
4.3.3 Chambers .....	116
4.3.4 Chamber biomass .....	117
4.4 Discussion.....	118
4.4.1 Field incubation of mesh bags and chemical analyses .....	118
4.4.1.1 Substrate quality .....	118
4.4.1.2 Environment .....	119
4.4.1.3 Depth.....	119
4.4.1.4 Implications for restoration and global warming .....	120
4.4.2 Chambers .....	121
4.4.2.1 Environmental properties .....	121
4.4.2.2 Predicted decomposition .....	122
4.4.2.3 Controls on decomposition.....	124
4.4.2.4 Comparison of bog peat and dried peat .....	124
4.4.2.5 Implications for climate change and restoration .....	126
4.5 Conclusions.....	127

Chapter 5. Water dynamics .....	128
5.1 Introduction.....	129
5.2 Methods .....	131
5.2.1 Sample collection .....	131
5.2.2 Water retention, bulk density and specific yield.....	131
5.2.3 Hydraulic conductivity .....	133
5.2.4 Carbon chemistry .....	134
5.2.5 Data analysis .....	134
5.3 Results .....	135
5.3.1 Water retention and specific yield.....	135
5.3.2 Hydraulic conductivity .....	138
5.3.3 Relationships between hydrologic properties and physical properties.....	139
5.3.4 Relationships between hydrologic properties and chemical properties....	140
5.4 Discussion.....	141
5.4.1 The effect of decomposition on pore size distribution and binding of water .....	141
5.4.2 The effects of irreversible changes upon drying on hydrologic properties .....	142
5.4.3 Conceptual model of peat hydrology and implications for catchment hydrology.....	143
5.4.3.1 Erosion .....	143
5.4.3.2 Temporary water storage.....	143
5.4.3.3 Water filtration and aeration.....	144
5.5 Conclusions.....	145
Chapter 6. Accumulation and attrition of peat soils in the Australian Alps.....	146
6.1 Introduction.....	147
6.2 Methods .....	149
6.2.1 Sample collection .....	149
6.2.2 <sup>14</sup> C dating .....	149
6.2.3 <sup>210</sup> Pb dating .....	150
6.2.4 Mass balance of carbon and lead.....	151
6.2.5 Data analysis .....	151
6.3 Results .....	152
6.3.1 <sup>14</sup> C dating .....	152

6.3.1.2 Bog peat .....	152
6.3.1.2 Dried peat .....	153
6.3.2 <sup>210</sup> Pb dating .....	154
6.2.3.1 Bog peat .....	154
6.3.2.2 Dried peat .....	155
6.3.3 Mass balance of carbon and lead.....	156
6.4 Discussion.....	157
6.4.1 The rate of peat formation.....	157
6.4.2 The parent material of dried peat .....	158
6.4.3 The timing of the change from bog peat to dried peat.....	158
6.4.4 The mode of the change from bog peat to dried peat .....	159
6.5 Conclusions.....	160
Chapter 7. General Discussion .....	161
7.1 Peatlands Past.....	161
7.1.1 Peat initiation .....	161
7.1.2 Bog growth.....	162
7.1.3 Dried peat formation.....	163
7.2 Peatlands Present.....	165
7.2.1 Bog peat model.....	166
7.2.2 Dried peat model .....	168
7.3 Peatlands Future.....	170
7.3.1 Predictions.....	170
7.3.2 Future research .....	170
7.4 Conclusions.....	171
References .....	172

## Index of Tables

Table 1.1 Methods of measurement of plant productivity in studies of peat	24
Table 1.2 Methods of measurement of peat decomposition	25
Table 1.3 Properties of the two functional layers in a bog, the acrotelm and the catotelm, from Ingram (1978)	29
Table 1.4 Peatlands of Australia, from Whinam and Hope (2005) and Cambell (1983)	35
Table 1.5 Profile descriptions of raised bog peat and dried peat from Costin (1954)	39
Table 2.1 Profile description of bog peat from a hummock	50
Table 2.2 Profile description of dried peat	50
Table 2.3 Characteristic species of the bog peat and the dried peat	53
Table 3.1 Details of the preparation of peat used in incubation experiments	79
Table 4.1 Details of mesh bag incubation experiments of peat at Wellington Plain	107
Table 4.2 Annual CO <sub>2</sub> emissions from peat at Wellington Plain, predicted from Equation 4.2 and measured soil temperature and water content data (Chapter 2), under current environmental conditions and under four possible future climate scenarios of increased temperature and decreased soil water content, from Hennessey <i>et al.</i> (2003)	123
Table 4.3 Annual CO <sub>2</sub> emissions from Wellington Plain peatland, predicted from chamber and soil temperature results (March 2004-February 2005), and from mesh bag results integrated over depth using carbon chemistry, bulk density and carbon content (June 2004-May 2005)	123
Table 4.4 A comparison of the results from this study with maximum and minimum CO <sub>2</sub> emissions (g/m <sup>2</sup> /d) from the surface of peatlands in the northern hemisphere	124
Table 5.1 Sampling scheme for hydraulic conductivity and water retention	131
Table 5.2 Partial correlation coefficients ( <i>r</i> ) for the relationships between hydraulic conductivity (log transformed, ln <i>k</i> ), specific yield ( <i>Y</i> ) and chemical properties. Significant relationships are shown in bold	140
Table 6.1 Calibrated <sup>14</sup> C ages in years BP, from the surface and the base of each of six profiles of dried peat	153
Table 6.2 Activity of excess <sup>210</sup> Pb in the dried peat	155
Table 6.3. Mass balances of carbon and lead for one profile each of bog peat and dried peat	156

## Index of Figures

- Fig 1.1 A basic outline of the carbon cycle in peat. The relative size of fluxes, not the actual values, is representative of the carbon cycle in most peatlands. DOC is dissolved organic carbon. Negative values indicate a loss of carbon from the peatland and positive numbers indicate a gain of carbon to the peatland. The values were measured and estimated in a *Sphagnum* bog in Sweden in 1992, and resulted in a net carbon gain of 2 g C/m<sup>2</sup> (Waddington and Roulet 2000). 23
- Fig 1.2 A simple model of bog hydrology. The size of arrows indicates the size of water fluxes associated with each process. 28
- Fig. 2.1 The location of Wellington Plain in the Australian Alps and (inset) the Alps in Australia. 45
- Fig. 2.2 Profile photos of bog peat (top) and dried peat (bottom). 50
- Fig. 2.3 Top: foreground bog pool, midground bog landscape with *Sphagnum* hummocks and shrubs, background subalpine woodland; bottom left: bog hummock; bottom right: bog monolith. 51
- Fig. 2.4 Top: dried peat landscape after rain, note tussocks of *Poa* grasses; bottom: dried peat removed from sampling pit. 52
- Fig. 2.5 Aerial photo of peatland 1 on Wellington Plain with grid superimposed. Overlay shows the location of all equipment, excluding the rain gauge, air temperature logger and replicates of watertable loggers, which were located in peatland 2. 55
- Fig. 2.6 Properties of peatland 1: top, peat type; middle, peat depth; and bottom, peat pH. Peat type and peat depth were measured in the field. Peat pH was measured in duplicate in the laboratory. Points are measured values (not shown for peat depth), colours are interpolated maps constructed with ARCVIEW. 56
- Fig. 2.7 a) Daily average soil temperature measured at 10 cm depth in dried peat, b) daily average soil temperature measured at 10 cm depth in bog peat, c) daily average air temperature. All data were collected at Wellington Plain peatland, from 15/2/2004 to 25/1/2006. Gaps indicate periods of logger failure. 57
- Fig. 2.8 a) Daily average gravimetric soil water content measured at 5 cm and 10 cm depth in dried peat, b) daily average gravimetric soil water content measured at 10 cm and 20 cm depth in bog peat, c) daily rainfall. All data were collected at Wellington Plain peatland, from 15/2/2004 to 25/1/2006. Gaps indicate periods of logger failure. 58

Fig. 2.9 Variation in soil water content over three days, and the relationship with rainfall and soil temperature. In all graphs the x axis shows hours since midnight 17/2/2004. a) soil temperature at 10 cm depth in bog peat and dried peat, b) gravimetric soil water content in dried peat, c) gravimetric soil water content in bog peat, d) gravimetric soil water content in both bog peat and dried peat, and rainfall. Note the scales on the y axes are different in b) and c) than in d). 59

Fig. 2.10 a) Watertable depth in the dried peat, b) watertable depth in bog flat peat, c) watertable depth in bog hummock peat and d) daily rainfall. All data were collected at Wellington Plain peatland, from 15/2/2004 to 25/1/2006. Gaps indicate period of logger failure. 60

Fig. 2.11 Variation in watertable depth over three days, and the relationship with rainfall. In all graphs the x axis shows hours since midnight 17/2/2004. a) detail of the daily variation in watertable depth in the dried peat, b) detail of the daily variation of watertable depth in (left axis) the bog flat peat and (right axis) the bog hummock peat, c) watertable depth over three days in bog flat peat, bog hummock peat and dried peat, and the response to rain. Note the scales on the y axes are different in a) and b) than in c). 62

Fig. 2.12 Response of the watertable to rainfall in a) bog flat peat and bog hummock peat, and b) dried peat. All rain events greater than 5 mm, from 15/2/2004 to 25/1/2006, were included. Note the different scales on the y axes. 63

Fig. 3.1 Carbon content, nitrogen content and carbon/nitrogen ratio from five profiles each of bog peat (a-c) and dried peat (d-f). Profiles 1 to 5 are each represented by a different symbol, as indicated in the legends in a and d. Values are the average of duplicate measurements. 83

Fig. 3.2 Percentage of organic carbon observed ( $C_{obs}$ ) in CP/MAS  $^{13}C$  NMR analyses of a) bog peat profiles 1-5 and b) dried peat profiles 1-5. Note  $T_{1\rho}H$  was measured for all samples in profiles 2-5 (bog peat and dried peat), but only for some samples from profiles 1 (bog peat and dried peat). 85

Fig. 3.3 Spectrum from solid-state  $^{13}C$  NMR analyses top) cross polarization and bottom) direct polarization of a sample of bog peat from profile 5. 85

Fig. 3.4 Solid state  $^{13}C$  CP/MAS NMR spectra from peat and the major biopolymers found in natural organic materials: cellulose, gliadin (protein), lignin, and stearic acid (lipid). 86

Fig. 3.5 Solid state  $^{13}\text{C}$  CP/MAS NMR spectra from bog peat (profile 4) and dried peat (profile 4). Both profiles were sampled continuously from the surface to the underlying substrate, and a selection of representative spectra is presented. The depth of each sample is indicated adjacent to the spectrum. 88

Fig. 3.6 Distribution of relative signal intensities (%) of alkyl, O-alkyl, aryl and carbonyl carbon with depth for bog peat profiles (a-e) and dried peat profiles (f-j), derived from  $^{13}\text{C}$  NMR spectra. 89

Fig. 3.7 Alkyl:O-alkyl ratios (derived from CP/MAS  $^{13}\text{C}$  NMR spectra) versus depth, for five profiles each of a) bog peat and b) dried peat. Note the different scales on the y axes (depth). 90

Fig. 3.8  $\text{CO}_2$  emitted over the duration of the incubation in Experiment 1. Error bars are  $\pm$  the standard deviations from four replicates. 92

Fig. 3.9 a) Mineralisable carbon pool and b) rate constant for each peat type in Experiment 1. Error bars are  $\pm$  the standard deviation of treatment mean values with  $n=4$ . Columns labelled with different letters are significantly different from one another (Tukey's HSD). 93

Fig. 3.10 a) Mineralisable carbon pool and b) rate constant for each combination of peat type and particle size in Experiment 2. Error bars are  $\pm$  the standard deviation of treatment mean values with  $n=4$ . Columns labelled with different letters are significantly different from one another (Tukey's HSD). 94

Fig. 3.11 a) Mineralisable carbon pool for each combination of peat type and water content, and the rate constant for each peat type (b) and each water content (c) in Experiment 3. Volumetric water content is in units of  $\text{cm}^3/\text{cm}^3$ . Error bars are  $\pm$  the standard deviation of treatment mean values with a)  $n=4$ , b)  $n=16$ , c)  $n=8$ . Columns labelled with different letters are significantly different from one another (Tukey's HSD). 95

Fig. 3.12 a) Mineralisable carbon pool and b) rate constant for each combination of peat type and preparation in Experiment 4. Error bars are  $\pm$  the standard deviation of treatment mean values with  $n=4$ . Columns labelled with different letters are significantly different from one another (Tukey's HSD). 96

Fig. 3.13 The relationship between the EOD of peat (measured by the Alkyl:O-alkyl ratio) and a) the mineralisable carbon pool and b) the rate constant from Experiment 1.  $r^2$  values indicate the fit of the line. 100

Fig. 4.1 Experiment 1. Mean proportional loss of ash-free dry mass of five peat types, incubated for one year in mesh bags at the depth of collection. Error bars are  $\pm$  standard deviation from duplicate bags at ten locations. Columns labelled with different letters are significantly different from one another (Tukey's HSD) 111

Fig. 4.2 Experiment 2. Mean proportional loss of ash-free dry mass for a) each peat type and b) each depth. Peat was incubated in mesh bags for one year. Error bars are  $\pm$  standard deviation of treatment mean values with a)  $n=20$  and b)  $n=30$ . Columns labelled with different letters are significantly different from one another (Tukey's HSD). 112

Fig. 4.3 Chemistry of peat before and after incubation a) carbon b) nitrogen c) C/N ratio. Results are the average of duplicate measurements. 113

Fig. 4.4 Chemistry of peat before and after incubation, determined with CP/MAS  $^{13}\text{C}$  NMR. The signal intensity of carbon in the alkyl (0-45), O-alkyl (45-110), carbonyl (110-165) and aryl (165-215) spectral regions is shown for each of five peat types a-e.  $C_{\text{obs}}$  is the NMR observable carbon. The alkyl:O-alkyl ratio, a measure of the extent of decomposition of the organic material, is shown for each peat type; in f. 114

Fig. 4.5  $\text{CO}_2$  measured in chambers on the surface of the bog peat and the dried peat on 18 different occasions during 2004 and 2005. Error bars are  $\pm$  the standard deviation from 24 chambers. 116

Fig. 4.6 Average oven-dry ( $40^\circ\text{C}$ ) biomass from chambers on the bog peat and chambers on the dried peat, collected 27/5/2005, after the final  $\text{CO}_2$  measurement. Error bars are  $\pm$  the standard deviation from 12 replicate chambers. 117

Fig. 4.7 a)  $\text{CO}_2$  measured in chambers on the peat surface (bog peat and dried peat) versus soil temperature, measured at 10 cm and b)  $\text{CO}_2$  measured in chambers on the peat surface (bog peat and dried peat) versus gravimetric soil water content, measured at 10 cm. 121

Fig. 4.8 Daily  $\text{CO}_2$  emissions from the surface of bog peat and dried peat, predicted from measured soil temperature and soil water content (Chapter 2) and Equation 4.2. 122

Fig. 5.1 Water retention curves (volumetric water content versus log (suction) from 0 to 1500 kPa suction) for each of three profiles of bog peat (a-c) and each of four profiles of dried peat (d-g). Error bars are  $\pm$  the standard deviation from 4 replicate cores. The depth that each sample was collected from is indicated in the individual graph keys. The bog peat was sampled at the surface and in the fibric, hemic and

sapric layers, and the dried peat was sampled at the surface and one or two subsequent depths, see Table 5.1 for details. 136

Fig. 5.2 Comparison of the properties of the seven different peat layers: surface bog peat, fibric bog peat, hemic bog peat, sapric bog peat, surface dried peat, mid dried peat and base dried peat. a) volumetric water content at saturation (0 cm), b) volumetric water content at 100 cm suction, c) specific yield and d) bulk density. Columns labelled with different letters are significantly different from one another (Tukey's HSD). Error bars are  $\pm$  the standard deviation from 4 replicate cores. 137

Fig. 5.3 Comparison of the hydraulic conductivity (k) of the seven different peat layers: surface bog peat, fibric bog peat, hemic bog peat, sapric bog peat, surface dried peat, mid dried peat and base dried peat. Columns labelled with different letters are significantly different from one another (Tukey's HSD). Error bars are  $\pm$  the standard deviation from 4 replicate cores. Note that hydraulic conductivity is on a log scale. 138

Fig. 5.4 Relationships between hydraulic conductivity (log transformed) and a) bulk density, b) total porosity, c) specific yield and d) large pores as a proportion of total porosity. Homogeneity of slopes analysis revealed a distinct relationship for each peat type for bulk density, and one relationship across both peat types for total porosity, specific yield and large pores. 139

Fig. 5.5 Conceptual model the hydrology of bog peat and dried peat. The rate of water movement is hydraulic conductivity and the volume of water released is specific yield. 144

Fig. 6.1 Calibrated  $^{14}\text{C}$  age versus depth for four profiles of bog peat. Each profile is indicated by a different colour. Logarithmic trend lines are associated with the data points of the same colour. 152

Fig. 6.2 Depth versus activity of excess  $^{210}\text{Pb}$  for the bog peat. Note the x axis is on a log scale. The y error bars indicate the depth of the sample and the x error bars are  $\pm$  the error associated with each measurement. The upper green layer is the 'growing moss layer', analogous to the 'mixed surface layer' seen in profiles of lake sediment. 154

Fig. 6.3 Model of age versus depth derived from  $^{210}\text{Pb}$  results for the bog peat. 155

Fig. 7.1 Flow chart of carbon and water in peat soils. Processes in bold constitute a cycle of increasing carbon accumulation. When interrupted by drainage, (indicated by the X) a cycle of carbon loss is initiated (plain text). 165

Fig. 7.2 Model of bog peat, developed from the properties measured in this study.

Terms in italics were not measured in this study. 167

Fig. 7.3 Model of dried peat, developed from the properties measured in this study.

Terms in italics were not measured in this study. 169

## Summary

This research investigated carbon dynamics, water dynamics and peat formation at Wellington Plain peatland in the Victorian Alps. The properties of bog peat and dried peat were measured, and the ensuing results are outlined below.

The carbon chemistries of both bog peat and dried peat displayed changes with depth consistent with an increase in the extent of decomposition of the organic material. Representative changes in the alkyl:O-alkyl ratio down the profile were 0.14 to 0.96 for bog peat and 0.28 to 1.07 for dried peat. Laboratory incubations on the influence of chemistry, particle size, water content and sample preparation indicated that, in the absence of confounding factors, peat chemistry was the most important factor in determining the size of the mineralisable carbon pool. Water content was the most important factor in determining the rate of carbon mineralization. In the field, both bog peat and dried peat emitted an average of 2 g CO<sub>2</sub>/m<sup>2</sup>/d from the surface. Carbon mineralisation was related to both soil temperature and soil water content, and this relationship was used to model peat mineralisation under a range of possible future climate scenarios. Below the surface, however, I measured lower rates of decomposition in the dried peat than in the bog peat.

The water-holding capacity of peat was measured in the laboratory, as was the rate of water movement through peat. Specific yield decreased down the profile in both bog peat (0.88 to 0.45 cm<sup>3</sup>/cm<sup>3</sup>) and dried peat (0.36 to 0.11 cm<sup>3</sup>/cm<sup>3</sup>). Hydraulic conductivity also decreased down the profile in both peats: 5.1x10<sup>-4</sup> to 3.0x10<sup>-6</sup> m/s in bog peat, and 1.0x10<sup>-4</sup> to 7.0x10<sup>-6</sup> m/s in dried peat. Relationships between the hydrologic properties of peat and its physical and chemical properties were identified. In the field, fluctuations in the watertable were monitored in concert with rainfall. These laboratory and field measurements enabled me to develop models of the hydrology of bog peat and dried peat.

Radioisotope dating indicated that both bog peat and dried peat began forming around 3300 years ago. The bog peat appeared to have drained to form dried peat between 131 and 139 years ago. Since that time, erosion appeared to have contributed more to the loss of organic material from dried peat than carbon mineralisation had.

## **Statement of Authorship**

Except where reference is made in the text of the thesis, this thesis contains no material published elsewhere or extracted in whole or in part from a thesis submitted for the award of any other degree of diploma.

No other person's work has been used without due acknowledgment in the main text of the thesis.

This thesis has not been submitted for the award of any degree of diploma in any other tertiary institution.

Samantha Patricia Power Grover

25<sup>th</sup> May 2006

## **Acknowledgements**

Sincere thanks to all of my supervisors: Jeff Baldock, Warwick Papst, Ken Rowe and Judy Tisdall. A disparate and somewhat unwieldy team, the unique contribution that each of you made to this research has been extremely valuable. On questions chemical, botanical, ecological, grammatical, statistical and geological, I always had somewhere to turn, and I thank you all for your patience, enthusiasm and encouragement.

I have been fortunate to work with staff from a number of institutions, each of whose input has added to the breadth of this research. Thanks to the following people: from La Trobe University, Wolfgang Yunker, Joe Edwards, Jaikiran Singh Gill and Lesley Taskis; from Parks Victoria Heyfield, Peter Lawrence and Wayne McCullum; from CSIRO Land and Water Adelaide, Steve Szarvas, Ron Smernik and Simon Chamberlain; from the Australian Nuclear Science and Technology Organisation, Geraldine Jacobsen, Henk van der Gaast, Atun Zawadski, Jennifer Harrison and Henk Heijnis.

Assistance has also been provided by many people outside their work roles. Blair McKenzie made helpful comments on a draft of chapter 5. Peter Kershaw and Robert van de Graaff kindly lent peat corers to me, without which the secrets of the bog would have remained in the ground. Tineke Adolphus provided a home away from home during my visits to CSIRO in Adelaide. Heather Keith and Jane Mullet guided my design and construction of the chambers with which I measured CO<sub>2</sub> emissions. The aerial photograph of Wellington Plain peatland was taken by Henrik Wahren, and James Shannon ‘photoshopped’ it for my purposes. Nathan Wong taught me how to use ARCVIEW.

Elve Lode and the other organisers of “Ecohydrological Processes in Northern Wetlands: an international conference and educational workshop, Estonia, 2003” warmly welcomed a southerner. Tramping over both pristine bogs and drained cutover peatlands in the company of some of the northern hemisphere’s most esteemed peat scientists set my research on the right track, inspired me and gave me first hand experience of the techniques and theories of peat ecohydrology. Lisa Belyea and Andy Baird both took a chance on an unknown Australian and generously allowed me to be involved with their field work on bogs in the United Kingdom.

While such a community of peat scientists does not exist in Australia, I have been fortunate to be a part of the CRC for Greenhouse Accounting. Janette Lindesay and Robyn Harris have particularly looked after me and their dedication to the wellbeing of CRC students has added greatly to my enjoyment and skill development.

My field work in the Alps has been made more enjoyable by the assistance of many of my friends and family. Repeat offenders include Rebecca Sharkey, Domenica Settle, Liz Hobday and Zoe Loh. Jodie Matire and Susanna Venn even helped me in the laboratory, as well as in the field.

My family, Anne Marie Power, Joe Bolza and Will Power, have always supported my education- thanks guys, I think it may be over now! More recently, Susanna Venn has supported me enormously during the completion of my PhD- thank-you. My housemates at 72 Thomson St have encouraged and entertained me over the past four years- particular thanks to Camille Heisler, who has seen me through the whole thing. The Brunswick Women's Choir and Luna Yoga School helped me to withstand, both physically and mentally, the pressures of completing a PhD.

Funding for this research was provided by grants from the CRC for Greenhouse Accounting and Parks Victoria, an Australian Postgraduate Award and an Australian Institute of Nuclear Science and Engineering Postgraduate Research Award.

Finally, I think it is appropriate to thank the inanimate beings who have made this research possible. Thanks to Wellington Plain peatland and Darebin Creek. The former provided both the physical basis for this research, and endless inspiration and joy. The later kept me sane and in touch while in town.

## Definitions and abbreviations

**Acrotelm:** the upper layer of a bog, rapid exchange of matter and energy with the environment, see Table 1.3 for details

**Alkyl carbon:** a carbon atom bound to only hydrogen atoms or other carbon atoms

**ANSTO:** Australian Nuclear Science and Technology Organisation

**Aromatic carbon:** a carbon atom with a double bond to another carbon atom

**Bog:** a peatland with the watertable permanently above the surrounding groundwatertable, usually *Sphagnum*-based and actively accumulating peat, has a characteristic hummock and hollow topography, also known locally as a mossbed

**Bog peat:** the peat in a bog

**Capitula:** the top of the *Sphagna*, a headlike cluster of branches at the apex of the stem

**Carbonyl carbon:** a carbon atom with a double bond to one oxygen atom and a single bond to another oxygen atom

**Catotelm:** the lower layer of a bog, slow exchange of matter and energy with the environment, see Table 1.3 for details

**Dried peat:** a drained remnant of bog peat, without a permanent watertable, also known locally as humified peat

**EOD:** extent of decomposition

**Fibric peat:** undecomposed or weakly decomposed organic material; plant material remains are distinct and identifiable; yields clear to weakly turbid water; no peat escapes through the fingers when squeezed in the hand

**Groundwater:** water which has passed through soil or rock material

**Hemic peat:** moderately to well-decomposed organic material; plant remains recognisable but may be rather indistinct and difficult to identify; yields strongly turbid to muddy water, amount of peat escaping through the fingers ranges from none to up to one third; residue is pasty

**Mesotrophic:** water high in nutrients, generally groundwater

**Minerotrophic:** water high in nutrients, generally groundwater

**NMR:** nuclear magnetic resonance

**O-alkyl carbon:** a carbon atom bound to an oxygen atom

**Ombrotrophic:** water low in nutrients, generally rainfall

**Peat:** the organic soil of a peatland, including all material below the close surface of the *Sphagnum capitulum*

**Peatland:** an ecosystem with a peat soil

**Permanent storage:** storage of water for years

**Sapric peat:** strongly to completely decomposed organic material; plant remains indistinct to unrecognisable; amounts ranging from about half to all escape between fingers; any residue is almost entirely resistant remains such as root fibres and wood

**Temporary storage:** storage of water for hours or days