Extended abstract No. 123

CONDITION ASSESSMENT AND RESTORATION OF THE PEATLANDS OF THE SNOWY MOUNTAINS, SOUTH-EASTERN AUSTRALIA

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SUMMARY

Extensive mires (topogenic shrublands and sedgelands) are found in the mountains of the southeastern highlands of Australia where they total 11,000 ha. The peatlands have been exposed to fires throughout the Holocene but are well adapted to recover with little loss of peat. The peatlands preserve significant regional carbon stores but the net long term carbon sequestration rate is probably only 0.6 tonnes C/ha/yr although *Sphagnum*-shrubland mires can reach 1.5 tonnes C/ha/yr. In the Snowy Mts of New South Wales, summer grazing after 1850 led to a marked retreat of the peatlands. Grazing stopped around 1950 but recovery has been slow. Extensive fires in 2003 set progress back many areas. Moss transplants, artificial shade, fertiliser and channel blocking have been trialled in burnt areas and promising results obtained.

KEYWORDS: Bog mapping, peat repair, carbon budget, long term sequestration, fire

INTRODUCTION

The Australian climate is marginal for peat preservation but numerous small topogenic peatlands occur above 750m in the wetter mountains of the southeast of the continent above 750m. As discussed in Whinam and Hope (2005), raised shrubland and *Sphagnum cristatum* hummock communities are termed bogs while simple graminoid mats , often dominated by *Carex gaudichaudiana,* are termed fens. The bogs and fens are all topogenic, occupying rain-colecting hollows or valley bases but chemical analyses show that the moss shrub bogs have similar nutrient availability to raised Dutch and Canadian moss bogs (Grover et al 2005), helping to maintain the distinction based on floristics, structure and watertable position. The wire rushes (Restionaceae) such as *Empodisma minus* are keystone species in this environment, maintaining a tough surface mat which readily resprouts after fire (Hodges and Rapson 2010). The bogs preserve around 1m of fibrous and humic peat while the sedge fens are up to 4m of peat over organic-rich silty clays.

The Snowy Mts of New South Wales (35° S, 750-2200m alt, 650-1500 mm rainfall, equal summer-winter precipitation) experienced 100 years of summer grazing by cattle and sheep before areas above 1000m were excised around 1950 and managed as nature reserves and water catchments. Damage to the peatlands was severe with the destruction of moss bolsters, peat loss from trampling, water courses incised and reduced water retention. The full extent of peat loss cannot be calculated but pollen analyses show that subalpine *Sphagnum* bogs were

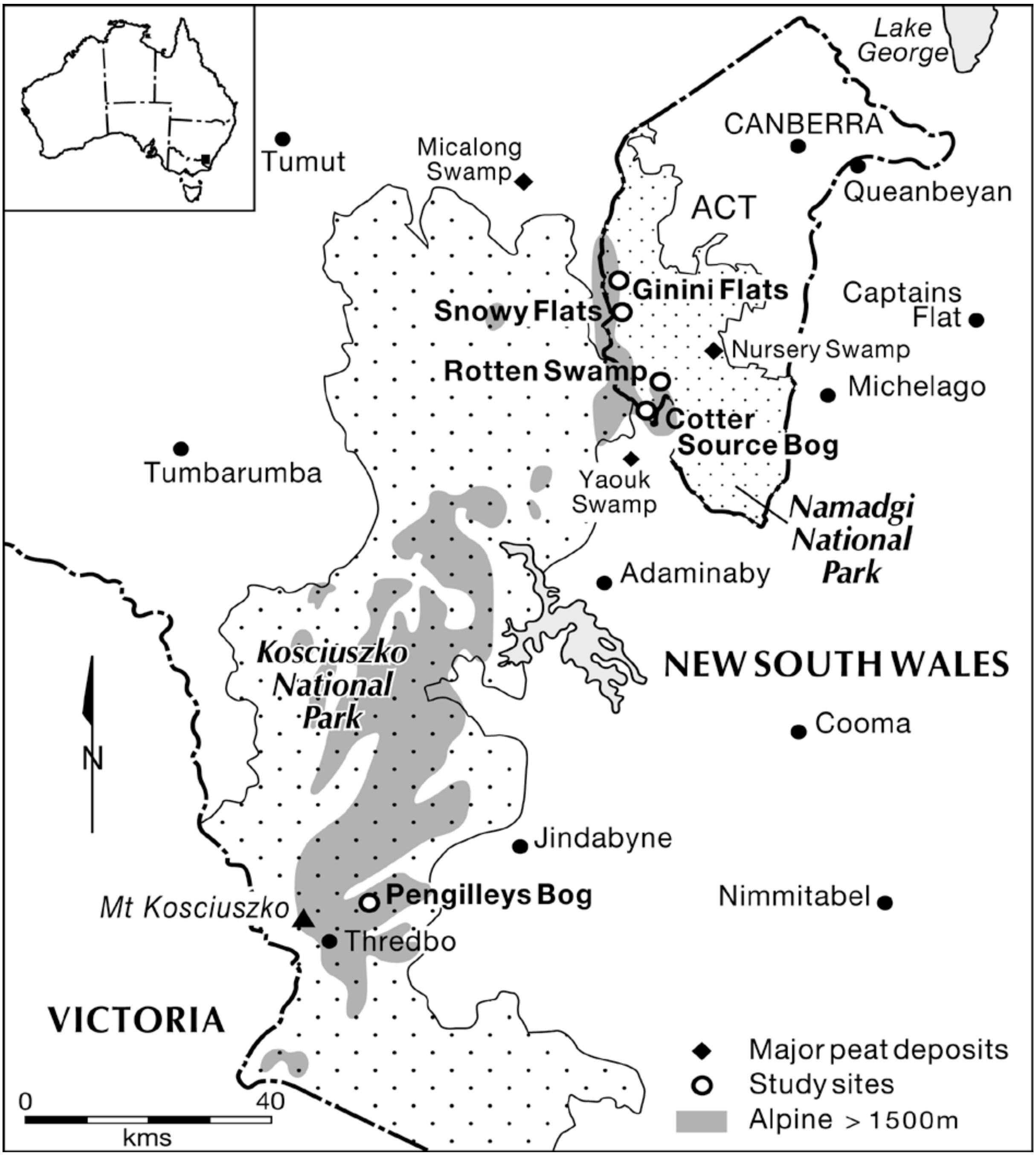

Fig. 1. Location diagram showing mires monitored for rehabilitation

converted to *Empodisma* moors in the montane and subalpine zones (Hope and Clark 2008). *Empodisma* moor is now very extensive.

EXTENT AND CARBON STORAGE

GIS mapping of the peatlands of the Snowy Mountains has located 8000 ha of peatland in the 1.2x106 ha mountain region or <0.7% of the area (Fig 1, Table 1). In the wettest high altitude areas the peatlands form up to 3% of the landscape and humus forms in the alpine soils. While shrub bog and sedge fens occur at all altitudes, the largest peatlands are sedge mires around 1000m in altitude.

Table 1. Extent of five peatland types in the Snowy Mountains region of NSW, Australia. SSB is *Sphagnum* shrub bog.

Alt Zone	Alpine SSB	Sub-alpine SSB	Montane SSB	*Empodisma* Moor	All bogs and moor	*Carex* Fen
m	Area ha	Area ha	Area ha	Area ha	Area ha	Area ha
700-1000	0	0	0.9	1.3	2.2	225.7
1000-1300	0	173.2	139.1	202.1	514.7	1136.2
1300-1600	41.9	1590.3	15.9	1263.3	2911.4	493.0
1600-1900	981.5	597.2	0	166.2	1744.9	4.0
>1900	393.9	0	0	14.3	408.2	12.4
All	**1417.6**	**2360.8**	**155.9**	**1620.2**	**5554.5**	**1871.3**

The carbon content of the peatlands was calculated by estimating average peat depths for characteristic peatlands in a range of altitudes, based on detailed stratigraphy. The GIS area data could then be used to generate estimated peat volumes for each type of peatland. The carbon content was estimated from a series of carbon analyses down selected profiles cross-correlated with Loss on Ignition values (Fig. 2). These show that some humified peats in shrub bogs have the highest carbon density. The total carbon store was calculated by summing the carbon bulk densities for each peat type and multiplying this by volume (Table 2).

The estimated store, of 3.5 m tonnes of carbon, is unusually high in the Australian context. The average carbon store in *Sphagnum* bogs in the subalpine and alpine is 200 tonnes C ha

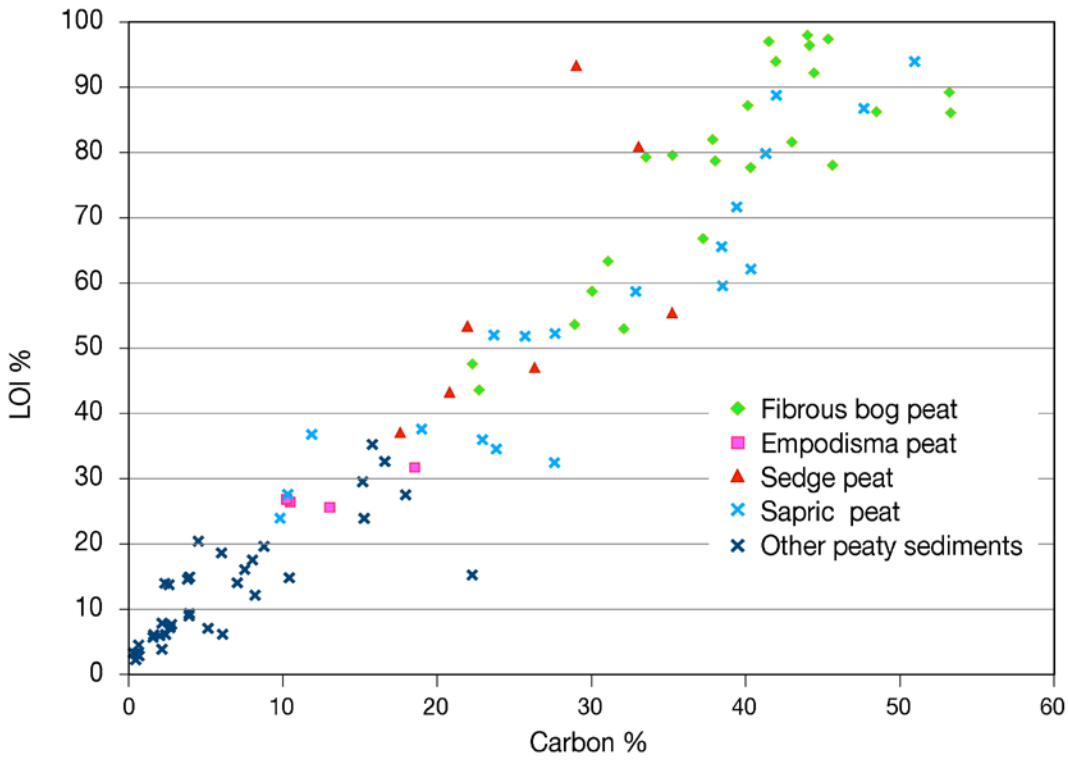

Fig. 2. Relationship of Loss on Ignition (LOI) to C determined by infrared gas chromatography for peat and sediments from the Snowy Mountains.

Table 2. Estimated peat volumes (m^3) and carbon weight (kilotonnes) in the Snowy Mts mires

	Mire Area (ha)	*Sphagnum* peat (m^3)	*Empodisma* peat (m^3)	*Carex* peat (m^3)	Sapric peat (m^3)	Organic clays (m^3)
alpine	1528	3 518 234	139 139	40 979	2 454 229	2 085 770
subalpine	4026	7 380 306	2 680 262	2 227 157	9 298 939	9 016 966
montane	1879	1 079 895	304 386	14 746 799	5 148 084	11 618 401
Total peat	**7432**	**11 978 436**	**3 123 888**	**17 014 936**	**16 901 329**	**22 721 238**

Carbon	kt	kt	kt	kt	kt	kt
Alpine		258.7	6.4	2.4	150.3	58.6
subalpine		408.1	122.7	131.1	588.3	245.4
montane		59.7	13.9	868.1	334.9	304.5
Total C	**3553.3**	**726.5**	**143.0**	**1001.7**	**1073.5**	**608.6**

and for montane and subalpine *Carex* fen is about 750 tonnes C ha. However individual mires may preserve much higher stores. The 4 m peat column at Micalong Swamp represents around 2600 tonnes C ha while a 1.5 m hemic-sapric profile in the subalpine represents 950 C tonnes ha. This supports the case for managing the peatlands to increase stability, water holding and resilience to fire and disturbance.

The calculation of long term carbon sequestration rates in bogs and fens is possible using late Holocene net accumulation rates of carbon for bogs and fens. The appearance of the pollen of European introductions, particularly pine, also provides a marker which allows the late Holocene and post-grazing sequestration rates to be compared. Additionally, by comparing results from both damaged and undamaged mires the overall carbon losses caused by widespread humification associated with grazing can be broadly assessed. These values, while imprecise, have the value of measuring the actual carbon store maintained through decades or centuries. Characteristic peat accumulation rates were estimated using available radiometric and marker chronologies covering the past 3000 years. These rates were then converted to net carbon sequestration figures (Table 3).

Table 3. Estimates of long term carbon sequestration rates in the Snowy Mts mires. PAR is peat accumulation rate, SR is sequestration rate

	Fresh *Sphagnum* peat	**Hemic *Sphagnum* peat**	**Hemic *Em podisma* peat**	**Fibric-hemic *Carex* peat**	**Sapric peat**	**Organic clays**
Max PAR cm/100year	35	3.2	?0.9	9.2	1.5	3.3
Min PAR cm/100year	12	1.5	0.7	3.6	0.9	0.8
Carbon g/ml	.04530	.06502	.04579	.05887	.06326	.02722
Max SR kg ha /year	1585.5	208.1	41.2	541.6	94.9	89.8
Min SR kg ha /year	543.6	97.5	32.1	211.9	56.9	21.8
Mean Annual SR	**1064**	**153**	**37**	**377**	**76**	**56**

The modern (ie since ca 1900) annual net sequestration rate is 4950 ± 2350 tonnes per year,being the sum of the three fresh peat categories, *Sphagnum, Empodisma* and *Carex*. The range of 0.55-1.5 tonnes ha per year for fresh *Sphagnum* peat is comparable to New Zealand eddy carbon flux values of 1.8-2.1 tonnes ha per year for restiad peat (Nieveen and Schipper 2005). The estimate of a sequestration rate of ca 5000 tonnes per year over the last few decades can be compared to the long term rate of 2345 ± 925 tonnes per year, a reduction of 53%. It is assumed that the bulk of this difference is due to compression and loss of easily degraded components. However the long-term rates also reflect the impact of past drought and fire events that may have led to periods of negative sequestration. Thus the range of sequestration rates reflect both the range of productivity in different mires and the conditions of storage of peat once formed.

FIRE DAMAGE AND PEATLAND RESTORATION

Charcoal can be found throughout peat profiles in the Snowy Mountains, showing that they have proven resilient to fire throughout the Holocene. Wild fires in 2003 burnt 2.1 million ha of the southeaster mountains including a high proportion of the peatlands. *Sphagnum* and some shrub species were killed but *Carex* and *Empodisma* sprouted soon after the fire event. Some experimental approaches have been trialled to encourage Sphagnum shrub bog recovery from fire and from earlier disturbance. Measures include blocking incised channels, shade cloth and transplants (Whinam et al 2010). *Sphagnum* requires shade in this environment, and shade cloth resulted in better regeneration of both moss and associated shrubs (Fig 3). Transplanted *Sphagnum* was particularly supported by up to three years of shading. Water-spreading has also proven effective though burrowing crustaceans have undermined barriers in some cases.

CONCLUSIONS

The mountain mires of south-eastern Australia are biodiverse and valuable as resource areas for fauna during drought periods. Management guidelines are being developed because we can show that the mires most resistant to damage are those which have the most advanced peat structure for retaining water. The most serious impact on parts of the peatland is renewed trampling by an expanding population of horses and deer (Hope et al 2012).

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