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Restoration of mires of the Australian Alps following the 2003 wildfires

Roger Good

1178 Bungendore Road, Bungendore, Australia
rgo03227@bigpond.net.au

Genevieve Wright

NSW National Parks and Wildlife Service, Department of Environment and Climate Change, Queanbeyan, Australia

Jennie Whinam

Biodiversity Conservation Branch, Department of Primary Industries, Parks, Water and Environment, Hobart, Tasmania, Australia

Geoff Hope

Archaeology and Natural History, Australian National University, Canberra, Australia

Introduction

The alpine and subalpine bogs and fens formed some 3000 to 9000 years ago during periods of active growth of *Sphagnum spp.* and other mire plant species. The climate and the wet, acidic and anaerobic soil and environmental conditions during this period provided for the rapid accumulation of partially decomposed organic matter and the formation of deep peatbeds. The bogs and fens at the present time have an underlying peat depth of 50 cm to 150 cm, although the accumulation of organic matter and peat formation has been minimal over the past several thousand years.

Saturated peats of the bogs and fens can store between 100 and 300 litres of water per cubic metre of peat, and make a significant contribution to catchment hydrology in terms of water storage, water quality and stream flow regimes, as well as providing water to other adjacent or associated ecological communities (Ashton and Williams 1989; Good 1992; Grover and Mackenzie 2002).

At the time of European settlement, some 8500 ha of alpine, subalpine and montane mire existed across the Alps in NSW, Victoria and the Australian Capital Territory, but approximately half of this area was lost during the grazing era (early 1800s to the late 1900s) as a result of heavy grazing of the mire vegetation and physical destruction of the peatbeds by cattle and sheep trampling (Costin 1952; Academy of Science 1957).

During the 2003 wildfires, almost all the alpine, subalpine and montane bogs and fens were burnt over, with *Sphagnum* hummocks and other mire plants being severely damaged or destroyed. A further loss of about 15% of the functional bog and fen communities was recorded after the fires. The loss of these mires was the end result of the protracted pre-fire drought which led to drying of almost all surface water pools, desiccation of *Sphagnum* and other mire plant species and dehydration of the peats, providing the opportunity for the fires to burn into the peatbeds.

It was recognised that further bog and fen community losses would occur due to post-fire runoff, leading to peat tunnelling, flowline entrenchment and subsequently peat erosion, unless some remedial works were undertaken in the immediate post-fire months.

The mire restoration program began in March 2003 as a project under the Australian Alps National Parks cooperative management program, with special post-fire funding from the NSW, Victorian and Australian Capital Territory governments. Additional support was provided by research personnel from the Australian National University, the Tasmanian Department of Primary Industries and Water (Biodiversity Conservation Branch) and the Victorian Arthur Rylah Institute.

Restoration works were applied to approximately 130 bog and fen sites burnt by the fires, this number being about one 10th of the number of bogs and fens burnt over by the fires. All the restoration works were underpinned by earlier mire and catchment ecological research (CSIRO) and restoration experience accrued from the post-grazing, alpine-area restoration and revegetation program, carried out over a 15-year period between 1960 and 1974 by the NSW Soil Conservation Service (Good 1976, 2000).

Several mire recovery monitoring and research programs were also initiated immediately post-fire to guide the restoration work and quantify the benefits of the various restoration techniques and programs (Hope et al. 2006). Photo monitoring points were established at all bog and fen restoration sites. Several demonstration sites were also established to provide a visual comparative appreciation of the benefits of mire restoration and as ecological-restoration education and interpretation sites.

Impacts of the 2003 wildfires

At the time of the 2003 fires, many of the bog and fen areas were still recovering from the impacts of stock grazing, some 40 to 50 years after the cessation of grazing in the Alps. Due to the long 2000 to 2003 drought, the peat in many bogs and fens was extremely dry, predisposing the vegetative cover and the underlying peats to burning (Figure 1). Following the wildfires, it was observed that a number of these bogs and fens were so severely impacted that they were beyond restoration, while many others were subject to lesser impact and were identified as being in a condition that would benefit from the implementation of specific restoration works.

The impacts of the fires varied with the intensity and the rate of spread at the time the bogs and fens were burnt. The impacts ranged from minor burning of some *Sphagnum* (moss) hummocks (mainly *Sphagnum cristatum*), to complete destruction of the bog and fen vegetative cover, to partial burning of the underlying peatbeds. The latter resulted in the loss of the functional hydrological role of the peats and as a consequence, the loss of the ecosystem services the bogs and fens provide to catchment water storage, flow regulation and run-off filtering.

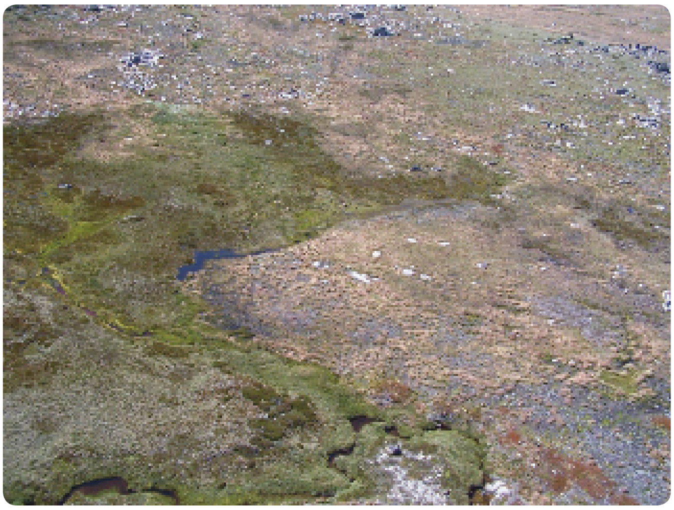

Figure 1. A valley bog extensively burnt during the 2003 bushfires

The science underpinning the restoration program

The restoration program has been underpinned by research and field trials commenced in the 1950s by CSIRO personnel (Costin 1952; Costin et al. 1959, 1960, 1964; Wimbush 1970), NSW Soil Conservation Service Alps field research staff (Good 1976, 2000), and several Victorian researchers (Wahren et al. 1996, 1999).

Wimbush (1970) carried out a detailed study of the water relationships and functional role of a bog in the upper Piper's Creek valley, this study being a baseline from which subsequent mire restoration and rehabilitation works were developed. Hahn (2004) revisited the site after the 2003 fires and re-established the hydrological studies before and after restoration works were implemented in the bog.

Mire survey work in the Alps catchments by Hope and Southern (1983), Clark (1980), Clark and Martin (1999), Whinam (1995), Whinam and Chilcott (2002), Whinam et al. (2001, 2003) and Hope (2003) has extended the ecological information base upon which the post-fire restoration works have been carried out. The research work of Hope, Wimbush and Costin also provided the background information for several recent post-graduate mire studies (S. Grover and C. Hahn), which have also contributed to an increased understanding of the ecology and hydrological functioning of bogs and fens and hence their restoration and rehabilitation.

A number of papers and reports have subsequently been published on the mire restoration and research program, (Grover and McKenzie 2002; Good 2004, 2006, 2008; Hahn 2004; Hope et al. 2005, 2006; Grover et al. 2005; Grover 2006; Growcock and Wright 2006; Hope 2006; Hope and Clark 2008). A project outline has also been placed on the Global Restoration Network website (GRN 2009).

Between 1964 and 1982, a number of mire restoration and rehabilitation techniques were trialled and applied to several domestic stock and fire-damaged bogs and fens along the main range of the Snowy Mountains, between Mount Kosciuszko and Mount Twynam, and in the Mount Jagungal area. Several fens were also 'constructed' to determine whether the techniques could be used to re-create 'mire' landscapes in sites where these ecosystems had previously existed but, due to grazing and burning impacts, had been lost from the landscape.

From these early investigations and field trials, it was identified that where the underlying peats of mires exhibited little or no physical damage from stock trampling and grazing, they could readily regenerate a vegetative cover, and their ecosystem function recovered without the implementation of any restoration works.

The recovery of the *Sphagnum spp*. component of the mire vegetation was identified as essential to this, as *Sphagnum* is the dominant contributor to the continuing accumulation of organic matter and peat formation. It was also observed and recognised that *Sphagnum* requires partial shading for its regeneration, this being provided naturally by mire shrubs (*Baeckea, Leptospermum* and *Callistemon spp.*) and taller restionaceous species (*Empodisma* and *Baloskian spp.*).

The many mire studies also identified the need to restore any surface mire pools as quickly as possible after damage or impact. These pools contribute to the rapid recovery of mire vegetation, particularly *Sphagnum, Empodisma* and *Baloskian* species, and are important in the rehydration of any dehydrated peatbeds.

The sharing of research and monitoring data has been maintained through the program of workshops and scientific forums coordinated by the Australian Alps Liaison Committee, which oversees the Alps Parks Cooperative Management Program. A number of workshops on rehabilitation principles and techniques have been conducted over the past six years for some of the above project participants, catchment management authorities, local-government personnel and community groups (Figure 2).

Figure 2. Peat coring during a mire-restoration workshop program

Objectives

The general objectives of the restoration program, drawn from past and current research and restoration programs, have been to:

1. Assist and promote the regrowth of *Sphagnum*, *Empodisma*, *Carex* and other bog and fen vegetation species;
2. Slow the rate of water movements both into and within the bogs and fens to reduce the potential for peat incision channel entrenchment;
3. Restore, where possible, the functional hydrological role of the bog and fen communities in the catchment;
4. Implement sound ecologically based techniques that will ensure sustainability of the restored sites;
5. Implement a research and monitoring program as an integral part of the rehabilitation works such that the success of the program can be assessed;
6. Ensure knowledge transfer between the research personnel, restoration specialists, national-park staff and non-government organisation volunteers involved in the program.

Implementation

There are two main tenets for this ecological restoration work. One is that peats should be prevented from becoming hydrophobic and, as a response, shedding water from the site, as well as ensuring the peats recover their capacity to take up surface and subsurface flows and regain their saturated state. The second is the recovery and restoration of a natural shade cover to provide for widespread recovery of mire plants, particularly *Sphagnum spp*. regeneration.

The most important steps in the restoration and rehabilitation program are, therefore, to slow surface flows to prevent flowline entrenchment; to create pools of surface water where *Sphagnum spp.* can regenerate; and to ensure that the pooled and subsurface water saturates the peats and spreads laterally through the peat profile and adjoining organic soils.

The ultimate objective is to restore the hydrologic regime of the bogs and fens and their functional role in catchment water storage, flow regimes and water quality.

The basic techniques for the restoration of bog and fen ecosystems are relatively simple. They involve the shading and protection of the remnant bog and fen plant populations, particularly *Sphagnum* species from high ultraviolet light levels and desiccation; the construction of straw-bale 'dams' in flowlines to create/restore surface pools; the construction of subsurface organic-matter dams to slow the flow of water from the peats; and the placement of coir and straw-filled jute mesh 'logs' as surface water-spreaders and sediment traps.

Following the placement of straw bales as flow-control structures, sods of *Sphagnum* and *Carex* species have generally been planted into them to hasten the recovery of the species and to assist the integration of the organic materials into the peat complex. In most pools, silt deposition has occurred and *Carex* sods have been planted into the sediment fans. The rehabilitation techniques and materials used in this project and outlined below are only several of a number of techniques and approaches that could be used in bog and fen rehabilitation programs.

1. Spreading and diversion of inflows to the bogs and fens

The initial work at each site has been to identify any entrenched flowlines entering the bogs and fens and to implement water-spreading structures such that flows into the bogs are slowed and spread across the entrant slope. This reduces the potential for flowline incision through the bogs and fens and reduces the rate of flow through any bogs that had already been incised, providing for slow rewetting of the dried or drying peats.Where water-spreading was required, it was achieved through the placement of coir logs and straw bales across the slopes above the bogs.

2. Pool creation and flow-control structures

The fires and a number of post-fire storm flows resulted in destruction and loss of many natural bog and fen pools. To reconstruct the organic-matter dams that naturally provide for the bog and fen pools, sterilised straw bales, some wrapped in jute mesh fabric, were placed in outflow channels to re-create surface ponding and to slow flows from the sites. The ponding provided the opportunity for regeneration of a fringing water-edge *Sphagnum* community and re-saturation of the underlying peatbeds (Figures 3a, 3b). It had previously been noted that *Sphagnum* regenerated quickest where free-standing water existed and shading was provided by other associated pool-fringing bog plants such as *Carex* and *Empodisma* species (Good 1976, 2004, 2006).

Figure 3a. Haybales inserted into a low-flow area to spread water into the surrounding peats and to form a stable pool for the re-establishment of fringing *Sphagnum* hummocks

Figure 3b. Regeneration of *Sphagnum* around the edge of the stable water pool, three years after restoration works

In sites where high flows occurred and substantial vertical incision of the peat had developed, channel depths of 1 m or more were evident. In many places, incision to the underlying gravels and bedrock had occurred, with lateral erosion at the gravel/peat interface up to 2 m either side of the incised flowline. Flows were reduced in these areas through packing straw bales into the incised flowlines, and inserting hessian bags filled with straw into the undermined peatbeds, to provide support for the peat, preventing collapse into the flowlines and subsequent loss from the system.

3. Subsurface straw-bale 'dams'

In several large drained and drying bog areas, narrow trenches were machine cut through the peats down to the underlying gravels or bedrock (1 to 2.5 m) and then filled with one to three levels of straw bales. This was done to provide a subsurface, semi-impervious organic 'dam' to assist the retention of subsurface inflows and the subsequent re-saturation of the peats. After placement, the straw bales were covered with soil and planted with sods of bog vegetation (*Sphagnum, Carex* and *Empodisma spp.*). Eventually, the straw bales will decompose and be incorporated into the peat mass.

This was initially considered to be an extreme measure to impose on several bog areas but was deemed essential if the bogs were to regain their water-holding capacity and have their hydrological role restored. This technique has been very successful, with no identifiable detrimental impact on the structure, function or vegetation of the mires, where these structures were implemented.

4. Vegetation shading

Not all vegetation of the bogs and fens was destroyed by the fire, with some live *Sphagnum* moss hummocks remaining in a number of bogs, post-fire. In other bogs, the *Sphagnum* exhibited small patches of regeneration from within the core of the burnt *Sphagnum* hummocks, with growth being assisted by some shading from overhanging dead shrub material and other dead herbaceous organic matter.

In order to further increase the potential for *Sphagnum* recovery, sterilised straw mulch was initially spread over remnant *Sphagnum* hummocks that exhibited some post-fire recovery. The straw was spread at a rate of approximately two tonnes per hectare, loosely spread to a depth of 3-5 cm. This rate of application provided approximately 70% shading for the underlying vegetation; a level of shading previously identified as optimal for initiating and enhancing *Sphagnum* regeneration (Good 2000; Whinam et al. 2003).

Due to the difficulty of transporting heavy and bulky straw bales to remote sites and the very variable results that accrued, commercial shade cloth was trialled and was found to be a suitable alternative, being easier to apply and longer lasting than the straw shading material (see Whinam et al. in this volume). Some 6000 sq. m of shade cloth have been placed over *Sphagnum* hummocks in bog and fen sites in Kosciuszko and Namadgi National Parks, with noticeable benefits to plant growth and health being evident after only two years (Figure 4).

Figure 4. Shade cloth partly removed to show the benefits of shading to post-fire regeneration of *Empodisma* and *Sphagnum spp.* Photograph by D. Whitfield

Summary

A total of 130 bogs and fens across the Alps have had some restoration works applied to them. Approximately 300 ha of bog and fen ecosystem have been restored to functional and stable mires, with large areas of adjacent organic soils and associated shrub and grassland ecosystems benefiting from the improved soil moisture regime accruing from the mire restoration works. All bogs and fens to which restoration works have been applied/implemented have recovered from a desiccated state to a saturated state, although the full recovery of this condition has taken between 15 months and six years. The full recovery of the functional role of the ecosystem and a complete bog and fen vegetation complex will still take many years to achieve.

The current restoration and rehabilitation work is nearing completion (2010/11) but the associated mire mapping and monitoring programs will continue for at least a further two-to-three years and 15 years respectively.

Important lessons have been learned during the program in terms of the techniques implemented to assist the rewetting of peatlands through peat trenching and damming, peat tunnel blocking, pooling of incised flowlines through the bogs, reconstruction and restoration of permanent bog and fen pools and the re-establishment of *Sphagnum* mossbeds by artificial shading, as well as the development of new rehabilitation/restoration materials (now commercially available).

Importantly, several of the techniques developed, trialled and implemented have been considered suitable and have already been implemented in a number of stable undisturbed bogs and fens, as part of an associated program to enhance mire survival capacity and resilience under predicted climate-change regimes (Good 2008).

New techniques for the mapping and monitoring of mires have also been developed in association with research personnel from the Australian National University, La Trobe

University, Tasmanian DPIWE, ACT Environment and ACTEWAGL research personnel, and NSW Department of Environment and Climate Change (National Parks).

The techniques and approaches to ecosystem restoration have also been taken up by several other management agencies in other bioregions and environments and interest in the program has been expressed by European mire-management personnel.

Acknowledgements

Much of the early bog and fen restoration work in the ACT was planned and coordinated by Amanda Carey. The area now known as Carey's mire will forever remind us of her contribution to bog and fen ecosystem conservation in the Australian Alps. Her work has been continued over the past three years with the same determination and enthusiasm by Dave Whitfield and other Namadgi National Park staff.

This project has been judged one of Australasia's top 25 restoration projects by the *Ecological Management & Restoration Journal*, in partnership with the Global Restoration Network (2009).

See http://www.globalrestorationnetwork.org/countries/australianew-zealand/

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