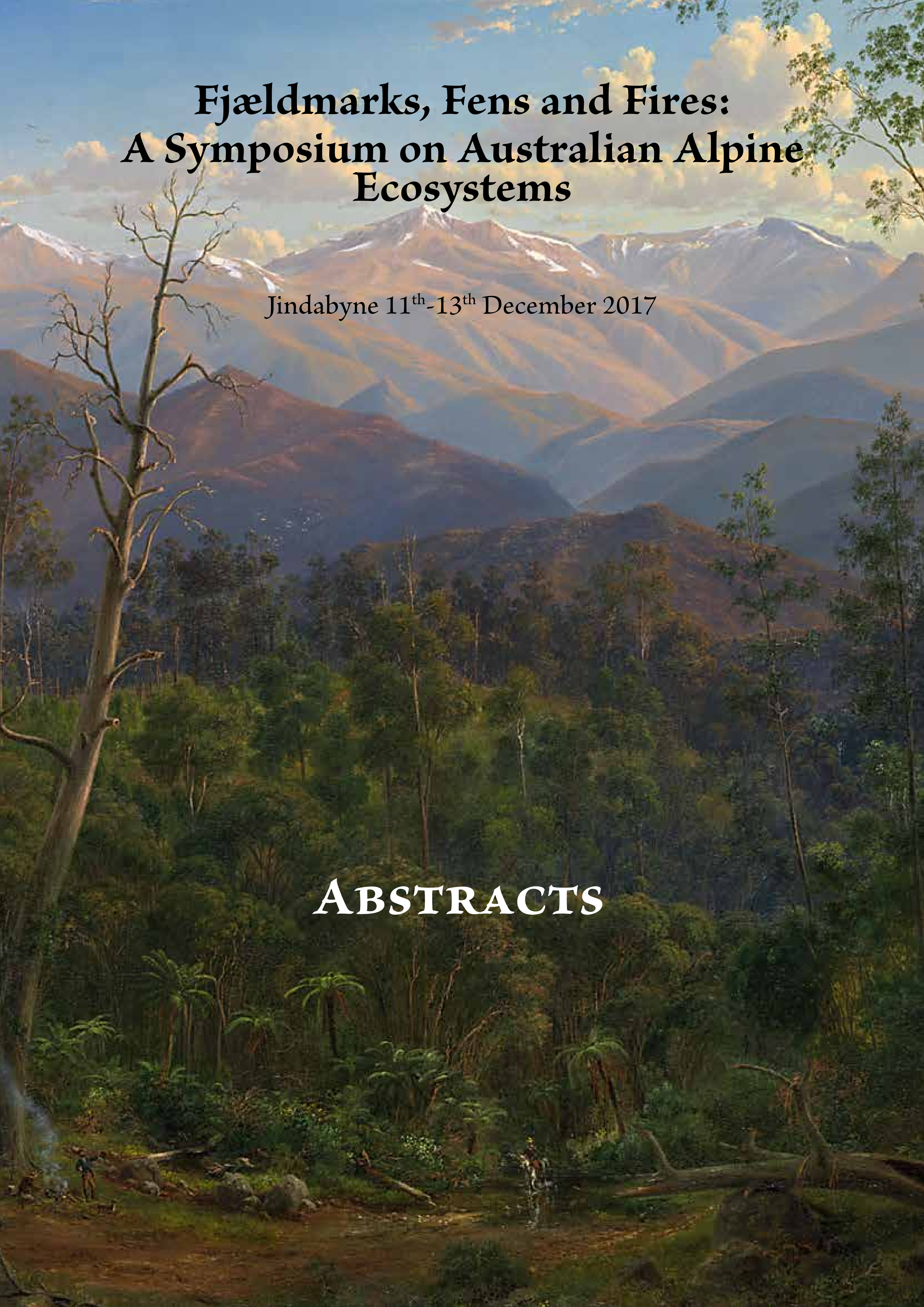
# Fjældmarks, Fens and Fires: A Symposium on Australian Alpine Ecosystems

Jindabyne 11th-13th December 2017

# Abstracts



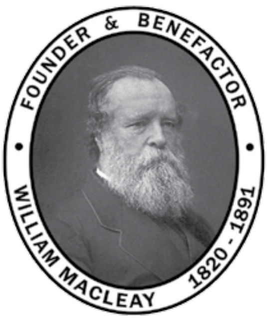
# Fjældmarks, Fens and Fires: A Symposium on Australian Alpine Ecosystems

Alpine ecosystems are among Australia's most remarkable, covering less than 1% of its land mass, and home to highly distinctive flora, fauna and landscapes with a long history and climatically varied since Tertiary uplift. Today, alpine ecosystems confront new pressures associated with human land use, invasions of alien plants, animals and diseases, altered bushfire regimes, recreational activities, and anthropogenic climate change. Maintaining Australia's alpine flora, fauna and landscapes under such pressures requires a co-operative effort.

This symposium aims to bring together new contributions on alpine environments across multiple disciplines:

- Evolution and systematics
- Plant and animal ecology
- Geology and geomorphology
- Hydrology
- Fire and Invasion ecology
- Biogeography and paleo-history
- Climatology and climate change
- Biodiversity and geodiversity conservation
- Restoration ecology
- Cultural heritage and history

The scope of the symposium encompasses alpine and subalpine ecosystems across New South Wales, the Australian Capital Territory, Victoria and Tasmania.

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**Front cover:** Detail from *Mount Kosciusko, seen from the Victorian border*, Eugene von Guerard, 1866. National Gallery of Victoria
**Back cover:** Detail from *North-east view from the northern top of Mount Kosciusko*, Eugene von Guerard, 1862. National Gallery of Australia

Fjældmarks, Fens and Fires: A Symposium on Australian Alpine Ecosystems
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| Monday 11th December 2017 | | |
|---|---|---|
| | **Time** | **Presentation** |
| | **9:00am** | **Registration** |
| **Session 1** Chair-David Keith | 9:55 | **Linnean Society Welcome- David Keith** |
| | 10:00 | **Dr Graeme L Worboys (ANU)-**Plenary Address: Caring for Kosciuszko. |
| | 10:40 | **Jorja Vernon (UOW)** -A ~3000 year record of palaeo-environmental change and human disturbance in Kosciuszko National Park. |
| | **11:00** | **Morning Tea** |
| **Session 2** Chair- Hayley Bates | 11:30 | **Craig Woodward (ANSTO)**-Towards a comprehensive record of Quaternary environmental change from the Snowy Mountains, Australia. |
| | 11:50 | **Ian Percival (Linnean Society of NSW)** -Overview of the geology of the Snowy Mountains Region of southern New South Wales. |
| | 12:10 | **Andy Spate (UTAS)-** What is the significance of the karsts of Kosciuszko National Park? |
| | 12:30 | **Nicola Stromsoe (CDU)-**Dust contribution to soil development in the Snowy Mountains. |
| | 12:50 | **Victoria McCartney (La Trobe)-** Bryophyte pools on the Bogong High Plains – threatened groundwater ecosystems. |
| | **1:10** | **Lunch** |
| **Session 3** Chair-TBC | 2:00 | **Susanna Venn (ANU, DU)-** Alpine shrubs as ecosystem engineers. |
| | 2:20 | **Catherine Pickering (GU)-**Conservation of the highest and potentially rarest grass in Australia: The Feldmark grass, *Rytidosperma pumilum*. |
| | 2:40 | **Barbara Briggs (RBG)-** Habitat disturbance and the breakdown of ecologically maintained species: *Ranunculus* revisited. |
| | 3:00 | **Sonya Geange (ANU)** -*Aciphylla glacialis* mortality, growth and frost resistance: A field warming experiment |
| | **3:20** | **Afternoon Tea** |
| **Session 4** Chair-TBC | 3:50 | **Emma Pearce (ANU)-** Dendroclimatological analysis of *Podocarpus lawrencei* reveals the impact of recent temperature and snow trends in the Australian Alps. |
| | 4:10 | **Casey Gibson (UNSW)-** Snow, frost and movement: assessing the future of Australia's alpine flora under climate change. |
| | 4:30 | **Lauren Szmalko (La Trobe)-** Seed dispersal in the Australian Alps. |
| | 4:45 | **Aviya Naccarella (La Trobe)-** The response of alpine and subalpine treelines to climate change and disturbance in the Falls Creek and Hotham region, Victoria. |

| Tuesday 12th December | | |
|---|---|---|
| | **Time** | **Presentation** |
| **Session 5** Chair-TBC | 9:00 | **Adrienne Nicotra (ANU)-** Expert elicitation: Predicting adaptive capacity in Australian mountain plant communities. |
| | 9:20 | **Keith McDougall (NSW OEH)-** Plant pests and pathogens of Kosciuszko National Park. |
| | 9:40 | **Kate Umbers (WSU)** -The startle display of the mountain katydid. |
| | 10:00 | **Zak Atkins (La Trobe)** -Allopatric divergence drives the genetic structuring of endangered alpine endemic lizard, *Liopholis guthega*. |
| | 10:20 | **Hayley Bates (CES UNSW)-**Back to the future: how an understanding of the past can help strengthen the future conservation efforts of the Mountain Pygmy-possum (*Burramys parvus*). |
| | **10:40** | **Morning Tea** |
| **Session 6** Chair-TBC | 11:00 | **Ken Green (NSW NPWS) -** Locomotion and foraging adaptations of large marsupials to survival in winter snow cover. |
| | 11:20 | **Mellesa Schroder (NSW NPWS)** -Establishing a balance between threatened species management and recreational use – Kosciuszko National Park. |
| | 11:40 | **Linda Broome (NSW OEH)-**Feral cats in alpine areas of Kosciuszko National Park: Quantifying distribution and threat to native fauna. |
| | 12:00 | **Scott Mooney (UNSW)-**Twentieth century changes in the fire regimes of high altitude ecosystems in eastern Australia: Evidence from long, multi-proxy records. |
| | **12:20** | **Lunch** |
| **Session 7** Chair-TBC | 1:20 | **Samuel Marx (SEES UOW)-** A record of landscape and industrial change reconstructed from peat mires in the Snowy Mountains. |
| | 1:40 | **David Keith (CES UNSW, OEH)-** Long term dynamics in alpine Sphagnum bogs: responses to livestock grazing, fire and cover. |
| | 2:00 | **Stephen Johnson (NSW DPI)** Protecting Fjældmarks and bogs: Eradicating hawkweeds from Kosciuszko National Park |
| | 2:20 | **Geoffrey Hope (ANU)-** Horses, Cows and Snowy Mountains peat Swamps |
| | 2:40 | **David Barnes (Linnean Society NSW)-** Historic photographs from the Snowy Mountains Region of southern New South Wales |
| | **3:00** | **Afternoon Tea** |
| **Session 8** Chair-TBC | 3:30 | **Genevieve Wright**-Archiving the scientific legacy of Alec Costin |
| | 3:50 | **Jodie Rutledge (UON)-** Reassessment of the age of the Yarrangobilly limestone. |
| | 4:10 | **Closing Statements - S**ummary of the symposium and a discussion on the future direction of research on Australian Alpine Ecosystems. |
| **Wednesday 13th December -Field Trip to Yarrangobilly Caves** | | |

# Abstracts

Plenary Address

## *"Caring for Kosciuszko"*

Dr Graeme L. Worboys
Honorary Associate Professor, Fenner School of Environment and Society, Australian National University

Kosciuszko National Park is a National Heritage Listed Property; an International Biosphere Reserve and one of the great national parks of the world. In 2019, it will be celebrating its 75th Anniversary and a leadership role it has played in the development of Australian professional protected area management. Many people of diverse backgrounds have cared for Kosciuszko and have influenced its conservation future at times when it could otherwise have been impacted. From the turn of 20th Century, famous geologist, Antarctic explorer and war veteran Sir Edgeworth David was deeply attached to Kosciuszko, published accounts of its glacial evidences with the Linnean Society and advocated for its conservation. His colleague, naturalist Richard Helms was of a like mind and despairing of the soil erosion impacts he was witnessing in the mountains. This desire to protect the high country was sustained by generations of scientists and like-minded people including artists, poets, bushwalkers and members of the community who simply loved the mountains. Their efforts and the intervention of visionary politicians like Sir William McKell helped to establish a State Park in 1944 while exceptional foresters Baldur Byles and Neville Gare introduced professional park management from 1959. Since then the Kosciuszko Park has witnessed the restoration of the mountain catchments; the prevention of engineering developments in the summit area; the prevention of tourism developments along the Main Range and it has responded to many other threats. The work is ongoing, with new threats challenging 21st Century managers of this great Park.

## A ~3000 year record of palaeo-environmental change and human disturbance in Kosciuszko National Park.

*Jorja Vernon[1], Samuel Marx[1], Craig Woodward[2] Krystyna Saunders[2] and Nicola Stromose[3]*
[1] GeoQuEST Research Centre, School of Earth and Environmental Sciences, University of Wollongong, Australia, NSW
[2]Australian Nuclear Science and Technology Organisation, Lucus Heights, NSW.
[3] Engineering Health Science & Environment, Charles Darwin University, NT

The aim of this study was to expand upon knowledge of the recent paleoclimate of the alpine region of Kosciuszko National Park, as well as evaluate its response to human impact. This was achieved by evaluating a series of sedimentary, geochemical and biological proxies that were extracted from a core obtained from the centre of Blue Lake in Kosiusko National Park (KNP). A number of palaeo-envionmental proxies were used to reconstruct past changes within the lake, including in erosion/sediment delivery, organic productivity, fire regimes and biological functioning of the lake over the 3,500-year history of the core. Results implied a transition from a cooler/wetter conditions between 3,500 and 3,000 cal. yr BP, to a comparatively drier/warmer conditions by 1,800 cal. yr BP. After this period it appears climate in the alpine region of KNP may have experienced a gradual return to wetter conditions. The upper section of the core records the most significant changes within its 3500 year history. These changes occur following European settlement in conjunction with the beginning of resource use in the Australian alpine region. Most significantly, an increase in the sedimentation rate occurs, while in addition, there is a change in the geochemical composition of sediment delivered to the lake. The change in sediment geochemical composition reflects the increasing delivery of eroded soil to the lake, this contrasts with the first 3300 years of the record where sediment derived from catchment rock was largely deposited in the lake. These same changes were also found in other alpine lakes within KNP, most notably Club Lake (Stromsoe, et al., 2013), implying European disturbance constituted a major disruption

  

within KNP.

**References:** Stromsoe, N., Callow, J.N., McGowan, H.A. and Marx, S.K. (2013) Attribution of sources to metal accumulation in an alpine tarn, the Snowy Mountains, Australia. Environmental Pollution 181, 133-143.

## Towards a comprehensive record of Quaternary environmental change from the Snowy Mountains, Australia

*Craig Woodward [1,2], Jie Chang [2,3] Doug Clark [4], Patricia Gadd [1], Ken Green [5], , Adrian McCallum [6] , Sam Marx [7], Krystyna Saunders [1], James Shulmeister [2], Jorja Vernon [7], Atun Zawadzki [1]*
[1] Australian Nuclear Science & Technology Organisation, Australia
[2] University of Queensland, Australia
[3] Chinese Academy of Sciences, China
[4] Western Washington University, USA
[5] NSW National Parks and Wildlife Service, Australia
[6] University of the Sunshine Coast, Australia
[7] University of Wollongong, Australia

Kosciuszko National Park in the Snowy Mountains, Australia is an international Biosphere Reserve containing a Ramsar wetland, and is a key catchment for the Snowy Mountains hydro-electric scheme. There have been several paleoenvironmental studies that have examined late Quaternary climate variability in this area and investigated the effects of human impacts on the landscape. However, much is still to be learnt about how this area has changed in the past, and how it might be managed in the future. We present results from an ongoing project exploring human induced and natural environmental change in the Snowy Mountains. The long-term aim is to develop a comprehensive regional record of environmental change that utilizes the different responses of the four main alpine lakes to external drivers. We cored Blue Lake in the winter of 2016 and retrieved 8.5 m of core. This has now been scanned using high resolution x-ray fluorescence and shows strong potential for a high resolution record going back to the Last Glacial- Interglacial Transition (~ 16,000 years ago). We have also taken short cores from Cootapatamba, Albina and Blue Lake to examine human impacts since the 19th century and climate change in the Late Holocene (the last 4000 years). These cores indicate a major increase in catchment erosion and change in fire regime due to European impacts which began in the 1800s.

## Overview of the Geology of the Snowy Mountains Region of southern New South Wales

*Ian G. Percival*
Senior Principal Research Scientist (Palaeontologist), Geological Survey of NSW, Londonderry NSW 2753.

Geological studies in the Snowy Mountains region from the late 1940s into the 1960s primarily focussed on reconnaissance-scale mapping and engineering geology investigations associated with the Snowy Mountains Scheme. Extensive research on granitic igneous rocks, which underlie a large swathe of southeastern New South Wales, followed in the 1960s and 1970s. Detailed mapping in the 1980s, by Bureau of Mineral Resources geologists Mike Owen, Doone Wyborn, Lesley Wyborn and colleagues, of the area extending from Tumut to the Brindabella Range in the north to the Victorian Alps in the south, culminated in compilation and publication (1990) of the *Geology of Kosciusko National Park*. This map at 1:250,000 scale remains the best depiction of the complicated geology of the region. Ordovician sedimentary rocks of deep water turbidite origin are interspersed with volcanic rocks interpreted to have formed in an island arc setting, with minor mafic intrusives. Silurian sedimentary rocks that unconformably overlie, or are faulted against, the Ordovician succession initially include deeper water clastic deposits that generally shallow upwards into massive fossiliferous limestone exposed at Yarrangobilly, Cooleman Plains and Quidong, before becoming covered by mud-dominated sediments. Volcanic and intrusive igneous rocks, initially of ‘S-type’ and subsequently changing to ‘I-type’, become widespread in middle to late Silurian time and extend into the lower Devonian, when shallow water limestone deposits (now restricted to the Ravine–Lobbs Hole area) developed around emergent islands. Uplift of the region and subsequent erosion extended over approximately 350 million years before volcanism in the Eocene and Miocene buried the old dissected land surface. Two relatively brief episodes of Pleistocene glaciation created the characteristic moraines and glacial lakes of the high country. Recent research has contributed a reinterpretation of interrelationships between the Ordovician successions, while a new geophysical model supports a two-stage uplift of Eastern Australia to form the Australian Alps.

## What is the significance of the karsts of Kosciuszko National Park

Andy Spate[1] and Andrew Baker[2]
[1] Optimal Karst Management, PO Box 5099, UTAS Sandy Bay, Tasmania, 7005
[2] Landforms and Rehabilitation Unit, National Parks and Wildlife Service, PO Box 2267, Bathurst, NSW, 2795

There are eight areas within Kosciuszko National Park ranging from the sub-alpine to montane forest conditions. Two, at least, Yarrangobilly and Cooleman Plains, are of national – perhaps international - significance.
This paper amplifies earlier discussions of the heritage significance of the Kosciuszko karsts but does not meaningfully alter the earlier assessments. The highest levels of significance result from cultural values relating to use by indigenous people and to modern scientific research.
Cooleman Plains, Yarrangobilly and perhaps Indi were used by Indigenous people for dispositional burials, occupation and perhaps parietal art, for over 10,000 years. The caves in the headwaters of Jounama Creek to the north of Black Perry Mountain have not been rigorously studied for their indigenous or other values because of their extreme inaccessibility within the Bogong Wilderness but their proximity to the Bogong bora rings and many Bogong moth sites makes them a likely site.
Cooleman Plains and Yarrangobilly have been the subject of internationally published research in the fields of karst processes with publications of the late Joe Jennings being cited in texts more than four decades later. Micro-erosion meter sites established in 1984 are still being monitored. More recently the world's first studies of the impacts of fire on karst processes in and above caves is being undertaken at Yarrangobilly (and on other NSW karsts) with a number of publications arising.
One area of particularly unstudied, but subdued, karst is found on a west-bank tributary of Pilot Creek several kilometres north of Cowombat Flat in the Pilot Wilderness. It deserves further study. There may be other karst in this region.

## Dust contribution to soil development in the Snowy Mountains

*Nicola Stromsoe[1], Sam Marx[2]*
[1]School of Environment, Charles Darwin University, Darwin, Northern Territory, 0815, Australia
[2]School of Earth and Environmental Sciences, University of Wollongong, Wollongong, New South Wales, 2522

Wind blown dust has long been acknowledged as an important component of soils in the Snowy Mountains and elsewhere. However previous attempts to identify dust within soil profiles have been hampered by the lack of definitive indicator to distinguish dust from locally sourced material. This study uses geochemical proxies to provenance dust within soils in the alpine zone of the New South Wales Snowy Mountains. Trace elements are used to determine the importance of dust accession relative to weathering of local bedrock. Results imply substantial proportions of dust in soil in addition to post-depositional translocation of aeolian material within soils.

## Bryophyte pools on the Bogong High Plains – threatened groundwater ecosystems.

*Victoria A McCartney[1], Ewen Silvester[1] and John Morgan[1]*
[1] Department of Ecology, Environment & Evolution, La Trobe University

Groundwater source pools are a poorly studied ecosystem on the Bogong High Plains. We have identified that *Blindia robusta,* an aquatic moss, is dependent on such permanent pools where temperature is almost always at 6 °C and pH is 5.3 pH.

  

We investigated the desiccation tolerance of *Blindia robusta,* to quantify its sensitivity to desiccation, i.e. groundwater pools drying out. We predicted that *Blindia robusta* have low tolerance to drying relative to species at the margins of water bodies. Cell wall chemical composition and nutrient analyses of *Blindia robusta* were also quantified and compared to the widespread wetland moss *Sphagnum cristatum* to compare physiological functioning of the plants.

We quantified photosynthesis efficiency of *Blindia robusta* using a range of five minute desiccation durations at increasing temperatures before rehydration. Fourier-transform infrared was used to identify stem cell wall chemical composition and nutrient analyses quantified to identify the main nutrient contents of stem and leaf material. *Blindia robusta* was not tolerant to desiccation or the combination of desiccation with the raising of temperatures over short periods of time. With predicted changes in precipitation and temperature in the Australian alpine likely to change landscape patterns of wetness, and evidence that groundwater pools are already drying out, *Blindia robusta* can be expected to decline from marginal groundwater pools. It may be amongst the first to be threatened with extinction by changes in the frequency and severity of drought in the alpine. Protection of all groundwater source pools is vital to this species persistence.

## Alpine shrubs as ecosystem engineers

*Susanna Venn*[1,2]
[1] Research School of Biology, Australian National University
[2] School of Life and Environmental Sciences, Deakin University

Research conducted in the arctic has revealed many relationships between snow accumulation and shrub cover; shrubs can create snow drifts in their lee, interact with wind blown snow to increase local snow depths and snow water equivalents (SWE), affect snow density at different depths and affect the patterns of melting snow; all of which can lead to changes in local ecosystem processes.

In south-eastern Australia, initial observations have revealed that snowdrifts in the lee of the largest shrubs remain for weeks while snow has melted elsewhere. Shrub architecture traits such as height, clump size, specific leaf area and leaf area index are expected to be important drivers of snowdrifts and snow density in and around alpine shrubs. However, snow sampling over three winters has revealed that early-season snow-depths around target shrubs tends not to be related to shrub height. In addition, shrub height does not appear to affect snow density on side of shrubs, with mean SWE of approximately 10.5 cm on both sides. Although, later in the season, approximately 70 percent of target shrubs produced a snowdrift on the leeward side that was deeper than that on the windward side, indicating that snow density on the leeward side of shrubs may also be higher as snow continues to compact during the season. Snow accumulating around shrubs provides more suitable conditions for microbial activity and nutrient release, as well as additional meltwater in spring, thus potentially promoting shrub expansion in alpine areas.

## Conservation of the highest and potentially rarest grass in Australia: The Feldmark grass, *Rytidosperma pumilum*

*Catherine Pickering*[1]
[1] School of Environment, Griffith University, Gold Coast

The Feldmark grass, *Rytidosperma pumilum* (formerly *Erythranthera pumila*), is listed as vulnerable species both by the Australian Government and the NSW Government, in part because of its very limited distribution to roughly 3 ha of Windswept Feldmark along the highest ridges of the Australian Alps. To further clarify the current distribution of the grass and its ecology, surveys of potential and know habitats were undertaken in January 2017. They confirmed that *R. pumilum* has a very limited distribution appearing to be restricted to only 2-3 areas of Windswept Feldmark that are traversed in part by a walking track. The surveys established for the first time, that distribution of the grass in the Feldmark is positively associated with the canopy of the dominant shrub *Epacris gunnii*. This prostrate shrub tends to grow slowly towards the lee/eastern side of the ridge line due to the damaging effects of the icy winds. It has previously been found to facilitate the occurrence of several other small alpine plants contributing to the diversity of the Feldmark community. As both fire and trampling have been shown to adversely affect the cover of the *E. gunnii* shrub, they are also likely to threaten *R. pumilum*. This research adds further support to relocating the walking track away from the Windswept Feldmark, which is itself listed as a critically endangered ecological community by the NSW Government. With fire having already affected other areas of Feldmark, and as *E. gunnii* is slow to recover from fire, the risk of extreme fire conditions leading to the few areas of Feldmark containing the grass, burning is only likely to increase as conditions continue to warm and become dryer in the Australian Alps with climate change.

## Habitat disturbance and the breakdown of ecologically maintained species: *Ranunculus* revisited.

Barbara G. Briggs[1]
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Kosciuszko is a hotspot of *Ranunculus* speciation. The 17 species recorded in the National Park include five limited to this region: *R. productus*, *R. dissectifolius*, *R. millanii, R. acrophilus* and *R. anemoneus*.
An early study, together with somewhat more recent observations, showed that nine are interfertile but occur in different habitats: *R. graniticola* in the drier montane and subalpine, *R. pimpinellifolius* in montane and subalpine swamps and wet grassland, *R. productus* at lake or creek edges in the subalpine, *R. dissectifolius* in subalpine bogs, *R. millanii* in fens subject to flooding, *R. clivicola* on seepages on subalpine Thredbo slopes, *R. niphophilus* in seepages below alpine snowpatches, *R. muelleri* in alpine herbfields and grassland, and *R. acrophilus* in the highest fjældmark. Habitat selection was shown to maintain the distinctness of these species, since interspecific hybrids are largely confined to ecotones where their habitats adjoin. In the 1950s, before the area was gazetted as a National Park, summer grazing by cattle had caused extensive damage to the alpine and subalpine grasslands and herbfields, leaving a considerable proportion of the soil surface bare and readily colonised by forbs. Under these conditions, *Ranunculus* species became more abundant than now and formed extensive hybrid swarms. It is likely that, in some cases, species integrity would have been lost had disturbance continued. Cessation of grazing and restoration of habitats has allowed the diversity of the species to be maintained.

In addition to this group of interfertile diploid species are four aquatic species and two terrestrial hexaploids of the alpine and subalpine: *R. anemoneus* and *R. gunnianus*. These are related to New Zealand alpine species. The handsome *R. anemoneus* is a symbol of the Kosciuszko area but alpine grazing reduced it to a rarity. Its regeneration since the cessation of grazing has been spectacular.

## *Aciphylla glacialis* mortality, growth and frost resistance: A field warming experiment

*Sonya R. Geange[1,], Meisha-Marika Holloway-Phillips[1], Veronica F. Briceno[2] and Adrienne B. Nicotra[1]*
[1] Division of Ecology and Evolution, Research School of Biology, Australian National University, Canberra, Australia
[2] Instituto de Ciencias, Ambientalies y Evolutivas, Facultad de Ciencias, Universidad Austral de Chile, Valdivia, Chile

Background
Climate change projections of decreasing snow depth and earlier snowmelt in alpine regions is expected to expose plants to a greater frequency of extreme temperature events than previously. Thus, paradoxically, despite increasing temperatures, we expect frost to emerge as a major factor in determining plant survival and development under a warming climate.

Here we assess the effects of simulated warming on seedlings grown from seed sourced from early and late snow-melt sites. We established a field transplant experiment using the Australian alpine herb, *Aciphylla glacialis*, in which seedlings were planted in the field under either warmed (open top chambers, OTC), or ambient conditions. We hypothesized that seedlings grown under OTC's would have reduced levels of survival and growth and would be less freezing tolerant. Further, we predicted that seedlings from early snow-melt sites would exhibit less evidence of detrimental effects of warming conditions than those from late snow melt sites.

Results and Conclusions

Seedling mortality was significantly higher under the warmed than ambient conditions. However, higher mortality did not appear to detrimentally affect freezing resistance, subsequent leaf production, or photosynthetic efficiency. Rather, surviving seedlings grown under warmed conditions were slightly taller at the conclusion of the experiment when compared to ambient grown counterparts. Contrary to our predictions, there was little evidence of within-species variation. Based on this, we suggest future summertime heat events may pose risks for alpine seedling establishment and survival. However, relatively rapid acclimation processes may mitigate further impact on surviving seedlings.

## Dendroclimatological analysis of *Podocarpus lawrencei* reveals the impact of recent temperature and snow trends in the Australian Alps

*Emma Pearce*[1], *Matthew Brookhouse*[1,2] *and Ceridwen Fraser*[1]
[1] Fenner School of Environment and Society, The Australian National University
[2] Research School of Biology, The Australian National University

Alpine and sub-alpine ecosystems are particularly vulnerable to the impacts of climate change. Consequently, understanding the impact of current temperature trends in these areas is vital in predicting the longer-term impacts of climate change. The Australian Alps contain a diverse array of ecosystems and species, which are especially susceptible to climate change due to the low elevation of the mountain range in comparison to alpine areas elsewhere. The main aims of this study were to use dendrochronological methods to identify the sensitivity of *Podocarpus lawrencei* (mountain plum pine) growth to variability in air temperature and snow depth throughout the Australian Alps and to determine whether recent temperature and snow depth trends are impacting long-term growth of the species. We obtained tree-ring width data from full stem cross-sections from Mt Bimberi and Mt Murray in the ACT, Mt Jagungal in NSW as well as Falls Creek and Mt Buller in Victoria. These tree-ring width series were then objectively crossdated and standardised to create site-level ring width chronologies. We used multiple dendrochronological standardisation methods to create chronologies that emphasised short-term and long-term tree-ring width variability. These chronologies were then integrated using principal component analysis to generate regional chronologies that emphasised common variability trends. The chronologies comprising the first and second principal components revealed correlations with temperature and snow depth. More importantly, correlation between the first principal component chronologies and averaged air temperature across the Australian Alps weakened significantly over the latter part of the twentieth century. In addition, a significant positive temporal trend is evident in tree-ring width during the same period. This trend suggests that recent trends in temperature that are potentially linked to climate change, may be impacting upon *P. lawrencei* throughout the Australian Alps.

## Snow, frost and movement: assessing the future of Australia's alpine flora under climate change

*Casey Gibson*[1,2] *David Keith*[1,3] *Will Cornwell*[2]
[1] Centre for Ecosystem Science, Biological, Earth and Environmental Sciences, University of New South Wales, Kensington, NSW
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Australia's alpine flora faces an uncertain future under a warming climate. In this research project we aim to determine the sensitivities and resilience of Australia's alpine plants to some of the threats associated with climate change likely to occur in alpine ecosystems. We have initiated an experiment to investigate how the standing vegetation responds to loss of snow cover to determine whether plants will shift their phenology following reduced winter snowfalls and earlier spring snowmelt. Earlier snow melt and reduced snow cover will likely expose alpine plants to more severe late winter and spring frosts. This may have implications for reproduction, as the onset of flowering in many alpine species is closely tied in with snowmelt timing. If the flowering phenology of plants is occurring earlier, delicate reproductive structures may be damaged or killed by frost events. We will examine floral frost sensitivity in the field and laboratory, and determine if frost damage influences regeneration strategies in alpine plants. Damage to flowers and fruits is likely to have important population-scale consequences, as the reduction in mobile propagules ultimately limits potential dispersal events. While dispersal capacity is generally restricted among much of the alpine flora, long distance dispersal events, although rare, are likely to be ecologically important for species persistence. We will investigate whether there is an asymmetry in upslope and downslope seed dispersal, and determine the capacity of migration into potential warm-period mountain microrefugial sites such as granite tors and mesic cold-air pooling valleys. This study is unique in considering how alpine plants might respond to different threats at each stage in the life cycle. It is imperative to assess how the alpine flora will respond to these future threats, and quantify their capacity to regenerate and move through the topographically complex landscape towards microrefugia.

## Seed dispersal in the Australian Alps

*Lauren Szmalko[1], John Morgan[1] and Susanna Venn[1]*
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Seed dispersal is the main way plants will migrate in response to climate change. Within alpine ecosystems, many species will need to migrate upslope and then establish new populations to remain within their current climate envelopes. The majority of alpine plant species are known to be wind-dispersal or simply rely on gravity to disperse seed. From measuring seed traits, I will create an alpine seed database for identification purposes and analysing dispersal capacity based on seed morphology. Seed traps will be used in the field to quantify how far alpine seeds are dispersing. A germination study will be conducted to examine the functional trade-offs in seed morphology, specifically between seeds with enhanced dispersing characteristics and those without. This component of my study will focus on comparing seeds of species within the Asteraceae and whether seeds with reduced or no dispersal appendages have an increased competitive ability. A greater comprehension of seed dispersal and potential trade-offs in germination strategies will help produce effective conservation management for alpine species against the threat of climate change.

## The Response of alpine and subalpine treelines to climate change and disturbance in the Falls Creek and Hotham region, Victoria.

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Treelines are an indicator of climate change. At a global scale treeline positions are driven by temperature and are therefore highly sensitive to changes in climatic conditions. With rising global temperatures, alpine treelines are expected to advance uphill, and trees surrounding frost hollows are expected to invade the subalpine grasslands. Rising temperatures may improve conditions for tree establishment beyond the current treeline, and there is evidence of treeline advance across the globe since 1900. However, the current state of Australian alpine and subalpine treelines is largely unknown. The Australian Alps have warmed over the last century and therefore climatic conditions at the treeline have altered and treeline advance is predicted. This study provides a rare opportunity to utilise historic data from a network of alpine and subalpine treeline sites surveyed during honours research and long term monitoring. The project aims to explore how treeline dynamics have altered over the last 20 years. The project will firstly investigate if and to what extent Australian treelines have responded to warming climates. By comparing seedling numbers and the location of seedlings beyond the treeline between surveys we can quantify treeline dynamics and map advance. Secondly, the atypical occurrence of three landscape-scale bushfires over this period enables comparison of the effect of fire history and frequency on treeline dynamics. Through this comparison we will explore how fire affects resprouting capacity and recruitment of *Eucalyptus pauciflora*, the main treeline forming species. Changing treeline positions will have widespread implications for alpine and subalpine ecosystems and land management across the Australian Alps. Increasing woodland area will effect vegetation compositions, landscape flammability, landscape hydrology and water management throughout alpine catchments. Overall this project will uncover how climate change has affected alpine and subalpine treelines across the Victorian Alps and will continue to alter alpine ecosystems in the future.

## Expert elicitation: Predicting adaptive capacity in Australian mountain plant communities

*Adrienne Nicotra, Research School of Biology, and the NCCARF Alpine Adaptive Capacity working gorup*

Increasingly conservation and management practitioners are required to make decisions about allocation of resources based on vulnerability assessments that incorporate exposure risk and adaptive capacity of species. But there is little agreement on how to quantify that capacity efficiently or rigourously. Further, resource allocation decisions cannot be based on adaptive capacity alone; the relative importance of the organism to ecosystem function must also be considered for conservation resources to be effectively allocated. A species with high functional importance and low adaptive capacity requires urgent management attention, whereas one with both low adaptive capacity and functional importance most likely not. But where is the science to enable to such decisions to be made objectively? Expert opinion is emerging as a way to augment empirical resources in a time of rapid change. We explored the potential for expert elicitation techniques to reveal areas of consensus and uncertainty about adaptive capacity and functional importance of species with Australia's critically threatened alpine and mountain biomes as a test case. We will report on the outcomes of this working group involving botanists, ecologists and land managers with extensive experience of mountain flora that aimed to infer performance of mountain plant species over the next 25 – 50 years.

## Plant pests and pathogens of Kosciuszko National Park

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In New South Wales, Kosciuszko National Park is the largest reserve and the only protected area containing alpine vegetation. Apart from periodic infestations of leaf-eating insects on *Eucalyptus pauciflora* and *E. delegatensis*, pests and diseases are poorly known there. Indeed, well known pathogens such as *Phytophthora cinnamomi* are thought to be unsuited to such cold environments and certainly the alpine area. Observations of shrub and tree decline, especially following the fires of 2003, have led to the identification of many insects and pathogens, some of which appear to be having an impact on native flora. A range of insects are exerting pressure on several rare species. Many deaths have been observed in *E. lacrimans* and the endangered species, *E. saxatilis,* associated with beetles, skeletonising larvae and a eucalypt weevil. Shrubs in treeless vegetation (especially in the family Asteraceae) are experiencing slow regeneration after the fire because of pressure from a range of insects. *Armillaria luteobubalina* has been isolated from dying keystone shrubs in sub-alpine heathland. *Phytophthora* species are implicated in the death and poor health of the alpine shrub *Nematolepis ovatifolia* and the rare subalpine shrub *Pimelea bracteata*. Many *Phytophthora* species have recently been identified in KNP using new detection techniques. Some may not persist but their impact is likely to increase with rising temperatures. Suitable climatic habitat for *P. cinnamomi,* for instance, may rise by 400 m in elevation by 2070 under conservative species distribution modelling to encompass all of Kosciuszko National Park apart from the alpine zone. A key problem for managing pests and pathogens in KNP is knowing which are naturally sporadic and which are new and likely to have lasting effects. The collection of baseline information about pests and pathogens is critical to effective management.

 

## The startle display of the mountain katydid

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Arms races between prey and predators are a central theme in evolutionary biology, yet some of the most striking prey defences have been consistently overlooked. Traditionally, studies on prey defences focus on static defensive signals involving conspicuous colours, cryptic patterns and noxious chemicals. Focus has rarely fallen on dynamic signals in which, when under attack, prey attempt to frighten their predators by suddenly unleashing an unanticipated secondary defence, e.g. suddenly revealing a brightly coloured body part. Such defensive suites, known as startle or deimatic displays (Gk. 'to frighten',) are expected to pause predator attack allowing the prey a chance to escape. However, this definition is largely untested and even from the empirical evidence available it is incomplete. For example, it fails to account for counter-intuitive circumstances where prey must receive tactile stimulation before they reveal their defence. This presentation will summarise what is currently known about startle displays and introduce the mountain katydid as a model organism for understanding the evolution of these complex multimodal signals.

## Allopatric divergence drives the genetic structuring of the endangered alpine endemic lizard, *Liopholis guthega*

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The restriction to sky-islands and subsequent modern-day allopatry of many alpine species leaves them particularly vulnerable to the retraction of alpine habitats with global warming. Attaining genetic understanding of these populations provides key insight into a species' diversity, dispersal capacity and vulnerability to disturbance. The Guthega skink, *Liopholis guthega*, is an endangered species that is restricted to the alpine regions of Australia. We analysed data from mitochondrial DNA and an unprecedented number of genome-wide SNPs to determine the population structure and phylogeny of this species in order to better understand species relatedness, dispersal and viability. We identified significant genetic structure within *L. guthega*, with the split between the New South Wales (NSW) and Victorian populations consistent with Plio-Pleistocene divergence. However, we detected evidence for admixture between populations from NSW (south-west Koscuiszko National Park) and Victoria (Bogong High Plains). Marked within-site population structure, and significant population differentiation among sites within each state, confirmed the limited dispersal capacity of Guthega skink which is likely the result of habitat specialisation and natural barriers to dispersal. Higher levels of genetic diversity identified within the NSW lineage support the correlation between elevation and diversity, and implicates the region as refugial site. Low contemporary habitat availability, capacity for elevational progression and genetic diversity, particularly on the BHP, leaves *L. guthega* highly vulnerable to threatening processes associated with climate change. Despite the significant structure and divergence between the allopatric *L. guthega* populations, conservation management should consider genetic rescue as a potential method to enhance genetic diversity across this species' range. Additional strategies should focus on maintaining viable representatives from genetic clusters to ensure diversity is retained, while maintaining and enhancing existing *L. guthega* habitat and maximising connectivity will best ensure this species' continued persistence in Australia's alpine zone.

  

## Back to the future: how an understanding of the past can help strengthen the future conservation efforts of the Mountain Pygmy-possum (*Burramys parvus*).

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Effective conservation management strategies depend on accurate predictions about how environments will change and how species within them will respond to those changes. A historical approach to ecological interpretation can add dimensions not available by other means and strengthen our understanding of a species adaptive capacity and ability to respond to change. It is therefore important that natural history plays a key role in the interdisciplinary conservation and management process. For example, palaeoecological data and observations made on extant species in captivity can provide platforms on which to observe a species response to changing environments both past and present. In Australia, the Mountain Pygmy-possum (*Burramys parvus*) is currently ranked as the species most vulnerable to the impacts of climate change. Restricted in distribution to small populations on isolated mountaintops and surrounded by hard limit dispersal barriers in Victoria and New South Wales, *B. parvus* cannot escape the debilitating changes anticipated to result from a warming climate. This talk will review the palaeoecological history of the lineage *Burramys,* recount the discovery of *B. parvus* in Kosciuszko National Park, present unusual observations made on early captive colonies of this species and discuss recent discoveries made on *B. parvus* Kosciuszko populations. We will then outline the implications these findings may have on the future conservation management of this species.

## Locomotion and foraging adaptations of large marsupials to survival in winter snow cover

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Many mammalian species frequently found in Tasmanian mountains are absent from Australian mainland high elevations. This is regardless of the extent of the Tasmanian alpine that is ten times as large, elevational range, or its growing season temperature that is nearly one degree lower. The defining selective factor is the extent and depth of winter snow cover.

Small mammals that use snow cover to avoid predators require deeper snow and conditions that allow mammalian activity beneath the snow. Numbers of mammals may be reduced by lack of snow cover or by ingress of water in winter snow such as the loss of broad-toothed rats in winter 2016.

Large winter active mammals are more affected by deep snow cover. This reduces their ability to access plant growth, which is reduced at higher elevations and is virtually absent above the snow in alpine areas. Deep snowfall makes activity difficult for large mammals particularly wallabies whilst kangaroos are virtually excluded.

Wombats and wallabies are poorly adapted to soft snow. Whilst wombats survive in the subalpine zone throughout winter, often by bulldozing, wallabies have no such ability and do not have burrows to survive periods of heavy snow. In soft snow hopping is relatively unaffected by a depth of about 15 cm. Deeper than this wallabies have trouble with snow. By changing to a pentapedal gait they can possibly travel on 50 cm of soft snow. However, once a wallaby falls through the snow it has great difficult in extricating itself.

On the mainland snow cover is expected to decline with climate change. Large mammals will therefore be able to move to higher elevations. However variable weather conditions will produce either years with low snow cover which will impact small mammals or years of heavy snow which will result in high mortality of wallabies.

## Establishing a balance between threatened species management and recreational use - Kosciuszko National Park

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The Australian Alps are important for their high biological endemism and the ecosystem services they provide. They also offer unique recreational opportunities for bushwalking, cycling and snow sports activities. Establishing a balance between conservation and recreational management is a challenging task. The NSW Ski Resorts are located within Kosciuszko National Park and despite historical disturbance continue to provide important habitat for threatened flora and fauna species. Maintaining lifecycle requirements for a range of threatened species while meeting demand for recreational pursuits is a challenge being addressed in these areas. Revegetation programs are replacing exotic plant species and restoring habitat connectivity to ameliorate infrastructure development impacts on native vegetation communities. Artificial habitat and wildlife crossings are being constructed to link patches of habitat and allow safe movement of threatened small mammals across disturbed areas. Monitoring of artificial crossings has provided a greater understanding of specific movement requirements of animals. Research focussed on alpine skinks has delivered simple methods to maintain linkages across disturbed ski slopes and an increased understanding of habitat requirements to reduce future impact. Monitoring and controlling predators, such as feral cats and foxes, has assisted recovery of Mountain Pygmy-possum populations. Finally, transplanting threatened plant species has assessed the potential for this technique to conserve species including the Anemone Buttercup. In conclusion, research and monitoring programs in NSW Ski Resorts has led to advances in knowledge that support the implementation of on-ground actions that better balance the dual objectives of biodiversity conservation and recreational use in Kosciuszko National Park.

## Feral cats in alpine areas of Kosciuszko National Park: Quantifying distribution and threat to native fauna

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Feral cats are likely to have been introduced to the high elevation regions of Kosciuszko National Park during the construction of the Snowy Mountains Scheme and early ski resort development. However, efforts to reduce numbers of feral cats did not occur until 2002, in response to declines of monitored populations of the endangered Mountain pygmy-possum in two ski resorts. To quantify the distribution, relative abundance of feral cats throughout the alpine and subalpine areas of Kosciuszko National Park surveys were commenced in 2009 using camera traps and scat searches. In 2015 a cat detection dog was trained to locate cat scent. The highest numbers of cat detections with camera traps has been in the ski resorts and other sites where there are defined tracks which the cats utilise. Camera traps have been less successful at detecting cats where there are no obvious tracks. However, visual location of cats, cat scats and location of cat scent by the detection dog indicate that cats are present throughout the alpine area. Examination of the gut contents of trapped cats indicate they are a predator of all the alpine small mammals, as well as skinks and some birds. Camera footage also shows they can predate bats.

  

## Twentieth Century changes in the fire regimes of high altitude ecosystems in eastern Australia: Evidence from long, multi-proxy records.

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We describe the results of a multi-proxy study, combining sedimentary charcoal and tree-ring analyses from multiple sites across the Snowy Mountains region of south-eastern Australia region. Our aim was to assess how fire regimes have changed over long time scales. We found little evidence of high-intensity fires during the Holocene; however, in the mid-20th Century there is a sudden and dramatic shift from low-intensity fires with minimal charcoal signatures to high-intensity fires with substantial charcoal inputs. The dendro-analyses showed a complex pattern of moderate intensity fires with substantial spatial variability across the study landscapes. We also use an analysis of high resolution charcoal accumulation at six sites in Kosciuszko National Park to consider the recurrence interval of fire over the last 500 years, a long composite record of charcoal accumulation across this region and the insights from the dendro- component to discuss the potential drivers of fire in these high altitude ecosystems. The clear shift in the fire regime of the mid-20th Century alludes to an important interaction between fire management practices and changing climatic conditions. The relative importance of climate variability and fire management practices on contemporary fire regimes are vigorously debated in Australia and are directly relevant to land management policies and their implementation.

## A record of landscape and industrial change reconstructed from peat mires in the Snowy Mountains.

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Palaeo-environmental records reconstructed for the Snowy Mountains not only reflect changes with the alpine region itself, but also record broad environmental changes occurring across southeastern Australia. Located directly downwind (east) of the Murray-Darling Basin and within the mid-latitude westerlies, the Snowy Mountains experience significant dust deposition. Records of dust deposition through time reconstructed from ombrogenous peat mires contain reflect both natural variability and human impact in upwind regions. Rates of dust deposition in the studied peat were found to accurately map the expansion of agriculture in the Murray-Darling Basin, with rates of dust deposition increasing by approximately 5 to 10 times after 1880 CE, while dust deposition pulses in the peat mire matching known land degradation events. In addition, the peat mires also recorded increasing accumulation of industrial metals (e.g. Pb and Zn) which are transported alongside dust. Their accumulation in Snowy Mountains peats reflects metal production trends in eastern Australia over the last 160 years. For example the onset of significant Pb contamination in the peat mires coincided with discovery of the Broken Hill ore body. As consequence of its position downwind of the World's major historic mining region these industrial metals are found widely throughout the environment of the Snowy Mountains. Collectively these results show changes to Australia's geochemical and sedimentary systems have left a profound in print in the Snowy Mountains environment.

 

## Long term dynamics in alpine Sphagnum bogs: responses to livestock grazing, fire and climate change

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Sphagnum bogs are among the more restricted of plant communities in the Australian alpine zone and have been accumulating peat since the end of the last glaciation. They are protected as Endangered Ecological Communities under Australian biodiversity legislation. We used long term vegetation monitoring to assess ecological responses of alpine bogs to three potential threats: livestock grazing; wildfire; and climate change. The series of 11 monitoring sites were established in the early 1960s, just after cessation of livestock grazing, along an altitudinal gradient from 1500 m to 2000 m above sea level. Plant species composition recorded in the 1960s, 1991, 2205, 2007 and 2013. Livestock grazing is likely to favour mineralisation of bogs because trampling increases mortality of slow-growing and structurally sensitive plants, and destabilises erodible, spongy soils, promoting oxidation of peat. We examined temporal trends in individual species and found that some trends since the 1960s were consistent with recovery of an open mineral-substrate system to dense Sphagnum-dominated vegetation on a peaty substrate. Sphagnum bogs may be sensitive to wildfires because of their flammable organic substrates and potentially slow post-fire regrowth and recolonisation. We compared compositional trajectories of vegetation in sites that were burnt in 2003 with those that escaped the fire using data from before and after the event. We found minimal cyclical patterns of change in burnt vegetation, which almost returned to their initial composition 10 years after fire, while change in unburnt plots was minimal and not directional. Alpine bogs are potentially sensitive to climate change because of their dependence on water availability surplus and low rates of decomposition. If plant species are migrating to higher elevations, we expect temporal trends in species composition to coincide with the altitudinal gradient in composition. We found evidence of compositional trends over the 50-year period of observation, but these were not coincident with the altitudinal gradient. We concluded that bogs have undergone protracted recovery from livestock grazing, cyclical post-fire succession and are so-far resilient to climate warming.

## Protecting fjaeldmarks and bogs: Eradicating hawkweeds from Kosciuszko National Park

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Alpine ecosystems (fjaeldmarks, bogs/fens, herbfields and heaths) are susceptible to weed invasions. Two hawkweed (*Hieracium*) species are one such threat in Kosciuszko National Park (KNP). Hawkweed species are global weeds, for example mouse-ear hawkweed (MEHW, *H. pilosella*) dominates over 6 million ha of tussock grassland in New Zealand. Infestations have reduced stocking rates up to 30%, and in extreme cases infestations have led to farm abandonment. In contrast, a total of 480,000 ha across 33 states of the USA are infested orange hawkweed (OHW, *H. aurantiacum* subsp. *carpathicola*). The species continues to spread with control costs exceeding US$58 million per annum.
A review examining the progress, effectiveness, resourcing and feasibility of an eradication program targeting these species was conducted in 2017. It found that orange hawkweed occurs in ten distinct locations in KNP (including in one Australian government listed alpine bog), and in one off-park (grazing) location. Eradication efforts have resulted in a reduction from 8.37 ha infested to only 96 m$^2$ of the species treated in the 2016-17 season. In contrast, mouse ear hawkweed has invaded two sites, a fjaeldmark, and a herbfield/fen site both in KNP, with a 99.96% reduction at the latter site achieved.
The eradication of hawkweeds from alpine ecosystems in Australia is highly feasible: detection and eradication efforts have commenced early and the weeds have not become widespread. An area of 5,000+ ha, much of it rugged and difficult to access, is susceptible to invasion but, until late 2016, was all single tenure land (KNP). This allowed centralised coordination of resources and management and a rapid strategic response. The deployment of innovative technologies has also contributed to the current eradication successes including remote detection (using drones and satellite imaging), canine detection and dispersal modelling, as well as considerable staff and volunteer engagement for on-ground search efforts.

## Horses, cows and Snowy Mountains peat swamps

*Geoffrey Hope*[1] [1] Archaeology and Natural History, College Asia and Pacific, Australian National University

There are about 8000 hectares of peatlands throughout the Snowy Mountains and these can be divided between *Carex* fens and *Sphagnum* –shrub bogs. These communities were formerly more extensive but an unknown proportion, perhaps 30-50%, were wrecked during the period of transhumance grazing from 1860 until the 1950's. Some areas of wet tussock and *Empodisma* (twig rush) moor were probably functioning peat-forming communities. The introduced mammals mashed up the soft organic soils and congregated along stream lines to eat green herbs. This created straight channels from the sinuous streams and ponded areas of the bogs, so the systems eroded, drained and dried. Although the peatlands have built up over the past 12000 years with frequent fires, once dry the peat burnt. In other cases the peat oxidised and shrank to humic silts and clays.

With the removal of grazing the peatlands have started on the road to recovery, developing complex drainage patterns and three dimensional vegetation structure. This restricted the damage caused by the extensive 2003 fires and recovery after 14 years has been impressive in some cases, though far from complete. The organic soils will take centuries to build up. Unfortunately this long term recovery is threatened by a burgeoning wild horse population, notably in the south and north of Kosciuszko NP and east of Tumbarumba. Attempts to keep horses out of the alpine are failing. Current recommendations (http://www.environment.nsw.gov.au/resources/protectsnowies/knp-wild-horse-plan-draft-160271.pdf) call for a substantial reduction in wild horse numbers and complete exclusion from central KNP and the alpine. There has been a marked reluctance to act on this plan but the reversal of peatland recovery makes action increasingly urgent before another large fire sweeps in.

## Historic Photographs from the Snowy Mountains Region of southern New South Wales

*David Barnes* Photographer and Image Librarian (Retired), formerly Geological Survey of NSW.

Since the late 19th century the Geological Survey of NSW has been documenting and promoting the geology and mining history of NSW in its reports, publications and through its former Geological & Mining Museum. The majority of these illustrations derive from a large and historically-significant collection of photographic images, many of which were taken by the field geologists of the day. These early photographs provide a fascinating snapshot of geological exposures, mines, people and scenery in the vicinity. The oldest of the images in this State Heritage-listed collection, in the form of glass negatives, prints and glass lantern slides, have been digitised and are stored in the Geological Survey of NSW's Maitland headquarters in addition to the State Records repository at Kingswood in western Sydney.

Part of the value of this collection involves permanent historic documentation of the flora of an area as well as focussing on the rocks in the landscape. It is surprising how much scenery can change in some places over the past 150 years, whereas in other localities it is possible to stand in the same place that the historic photo was taken and reproduce a view with relatively little change. The Snowy Mountains is one region where this collection of images can be used to observe the extent of historic variations, particularly the Kiandra region during the gold mining period.

Selected images will be shown of this region as well as the Yarrangobilly area and other images of interest from the collection.

## Archiving the scientific legacy of Alec Costin

*Genevieve Wright*
NSW Office of Environment and Heritage

Alec Costin is regarded as a father of alpine ecology, a widely respected scientist, and a mentor and inspiration to many contemporary ecologists. He did ground-breaking research in the Australian Alps on soils, hydrology and vegetation, and was the sole author of one of the first landscape scale accounts of biogeography in Australia (Ecosystems of the Monaro). Although most of his work focused on mountains of Kosciuszko National Park, he worked briefly with Maisie Fawcett and John Turner in Victoria, and on early conservation efforts in the ACT.

Alec's field notes and data sheets are important historically as are his large number of Kodachrome slides which are a record of the Alps in the 1950s and 60s. These slides provide an important resource which may be used to interpret change in vegetation and landscapes in the Australian Alps.

The Australian Alps National Parks has funded a project to catalogue these materials with the help of Alec, and archive them so future generations of scientists and historians can easily gain access to them. The University of Melbourne has been engaged to conduct the project, having been responsible for cataloguing material from many key Australian scientists in the past.

## Reassessment of the age of the Yarrangobilly Limestone

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The Yarrangobilly Limestone is a massive-bedded limestone estimated at 840 m thick, prominently exposed in the vicinity of Yarrangobilly Caves in the northern sector of Kosciusko National Park. As the most extensive carbonate unit in the National Park, it is important in containing fossils that provide good age control to the regional stratigraphy. The identification of conodont microfossils found within acid-insoluble residues of the limestone is of particular significance. Cooper (1974 & 1977) assigned a Ludlow age (within the upper Silurian) to the Yarrangobilly Limestone on the basis of his conodont studies. Additional conodont faunas (over 400 specimens from 25 samples) have been found in the course of my Honours research, with some faunas indicating a widening of this current date range.

Significantly, this research also records for the first time carbon and oxygen isotope results through the Yarrangobilly sequence. Excursions in oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotopes have been well documented throughout the Silurian globally and can be utilised by researchers to correlate marine rocks world-wide. These isotopic excursions reflect geochemical changes in the oceans signalling significant changes in climate and extinction events. Locally, studies by palaeoclimate workers (Jeppsson et al., 2007; Trotter et al., 2016) have recorded significant excursions in oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotopes coinciding with Silurian extinction events, including the time of the Lau bio-event event during the late Ludlow. Once all isotope results have been analysed, it is hoped that the Lau event, and possibly the earlier Mulde event, will be recognised within the Yarrangobilly Limestone.

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