AUSTRALIAN ALPS NATIONAL PARKS

Australian Alps Climate Futures

Taking Action Now to Strengthen Resilience

Summary Report

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People in Nature

NCCARF National Climate Change Adaptation Research Facility
National Adaptation Network NATURAL ECOSYSTEMS

IUCN

WCPA WORLD COMMISSION ON PROTECTED AREAS

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Synopsis

The Australian Alps Climate Futures Forum was run as part of the Science Management Series under the auspices of the Australian Alps national parks Co-operative Management Program. The science management forums are supported and partnered with the IUCN/WCPA through the Mountains Specialist Group which has a focus on conservation, management and protection of mountain protected areas globally. Over 60 people attended from a wide range of backgrounds including protected area managers, researchers, agency experts and alpine ecologists.

The structure of the forum was based on:

- The climate science and the down scale data projections to 5 km grids for the Australian Alps with an outlook to 2100;
- The expected impact of climate futures on key biodiversity features of the Australian Alps;
- The key biodiversity programs the agencies currently run and why;
- Adaption pathways and the vison and challenges for biodiversity features and a consideration of the alignment of current biodiversity programs with climate futures thinking; and
- The future Institution/agency relationship in dealing with those challenges.

Climate change projections for the Australian Alps in 2100 indicate there will be an increase in mean annual temperature of 4 to 5°C with hottest summer days ~5°C warmer in the future, an increase in minimum daily temperature from 3 to 6°C and up to 20% decrease in annual precipitation with significantly decreased snowfall.

The impact on biodiversity features will vary significantly as some features will change and may be lost while others persist. The greatest changes that will impact more on ecosystems as a result of increased temperature and reduced water and snow availability may be expected to be on Alpine Peatlands and water recharge systems, Montane Forests and Alpine Fauna. Increased fire frequency will be a key vector of change.

There is significant and important investment across the Australian Alps in a range of biodiversity programs that are generally aligned to build resistance and resilience in the environment. These will support preparing for climate futures; however agencies may be accepting climate change and just working on the stressors rather than actively planning and adapting. Some new thinking is needed beyond that to determine what changes may be best allowed to happen and where interventions are more critical.

Two concepts may help consider future interventions and management actions:

- Adaption pathways: ability to accept change though multiple pathways, developing climate ready objectives; and
- Typology of change: assessing the rate and magnitude of change.

The future relationship and institutional partnerships between scientists, researchers and management agencies is critical and there are multiple pathways to develop this. A proposal for an Australian Research Centre for High Mountain Futures may consolidate the science and research network.

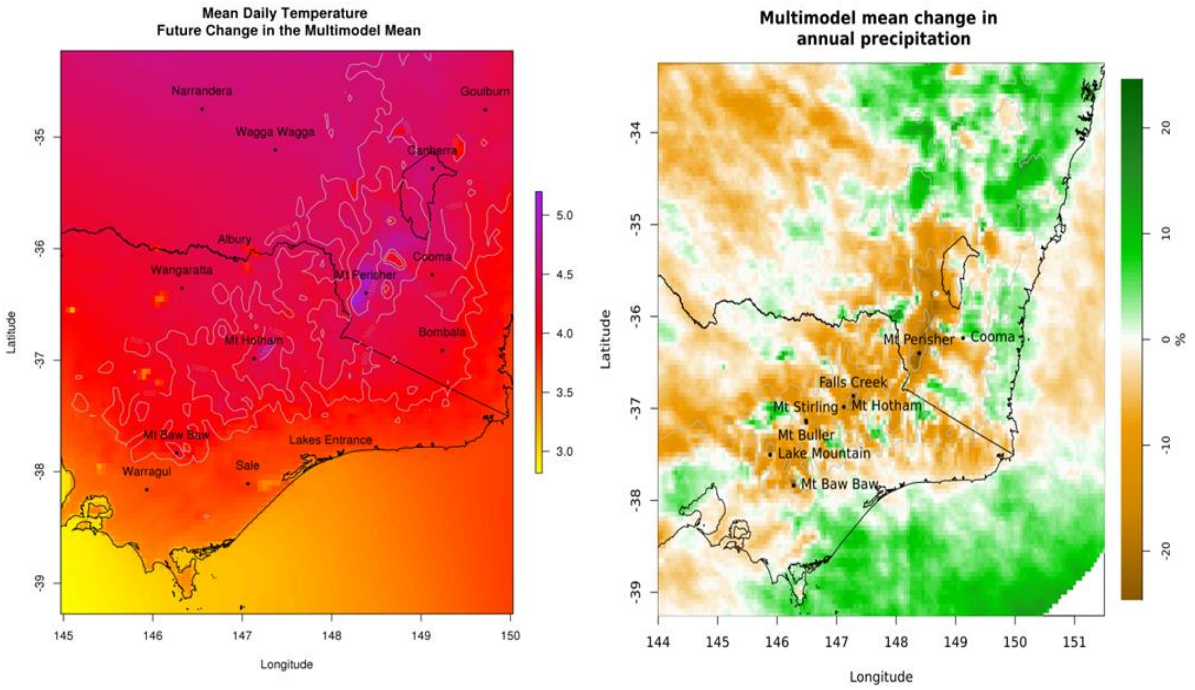
Understanding Climate Futures

Climate futures model outputs for the Australian Alps: Dr Nathan Bindoff

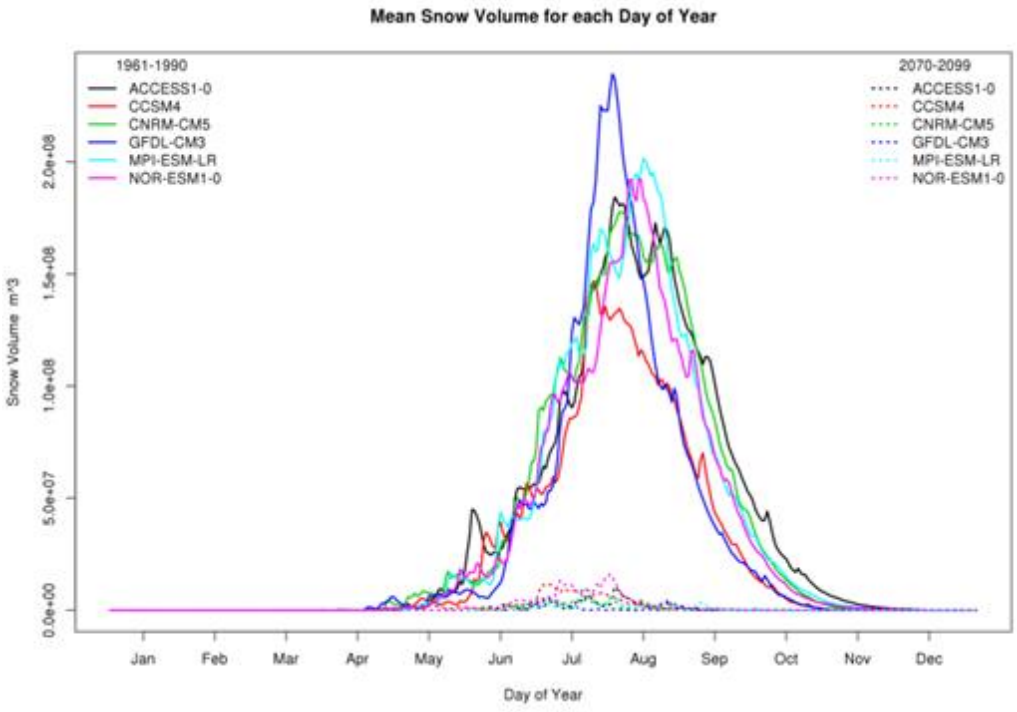
Dr Nathan Bindoff outlined his role with the IPCC 4th Climate Change report and the climate futures project prepared for the Australian Alps as part of the NERP Landscape and Policy Hub program.

The IPCC concluded that the warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased. It also concluded that human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system.

The Australian Alps Climate Futures project involved downscaling based on six climate models, providing high resolution data (spatially and temporally at 5 km grids) and captures regional climate processes. It allows variability (daily, seasonal, inter-annual) to be assessed. The data make projections for the period 2070-2100.



2100 projections for temperature and precipitation under high emissions scenario



2100 projections for snow cover based on 6 climate models.

Down scale regional projection show change as an understandable progression from the current climate. Across the Australian Alps region, under a high emissions scenario some outcomes of the projections to 2100 are:

Temperature:

- Increase in mean annual temperature 4 to 5°C; hottest summer days are ~5°C warmer in the future.
- Increase in minimum daily temperature 3 to 6°C coldest winter temperatures increase.

Precipitation:

- Drying out pattern with spring most variation; Up to 20% decreases in annual precipitation (rain + snow); Decreased winter precipitation and significantly decreased snowfall. Reduction in runoff with very large reductions in water recharge.
- Rainfall – intensity increasing by 40 – 100mm – extreme rainfall becoming more frequent but space between wet days will be dry spells
- Strong spatial and seasonal variability in changes.

The impact of bushfire conditions expect to be:

- 'Total Fire Ban' conditions are expected to increase by at least 75%.
- Spring: Very High Fire Danger is expected to increase 250%
- More days at the highest range of fire danger at some locations.
- Gradual and accelerating increase in (likely) frequency of fire.
- Four times as much fire suppression work required by 2100.
- Burning off weather: will decrease.

Implications for key Alpine Biodiversity Features

A number of ecologists discussed likely impacts of projections on framework/icon biodiversity features. (refer Appendix 2 for presenters)

Alpine Peatlands

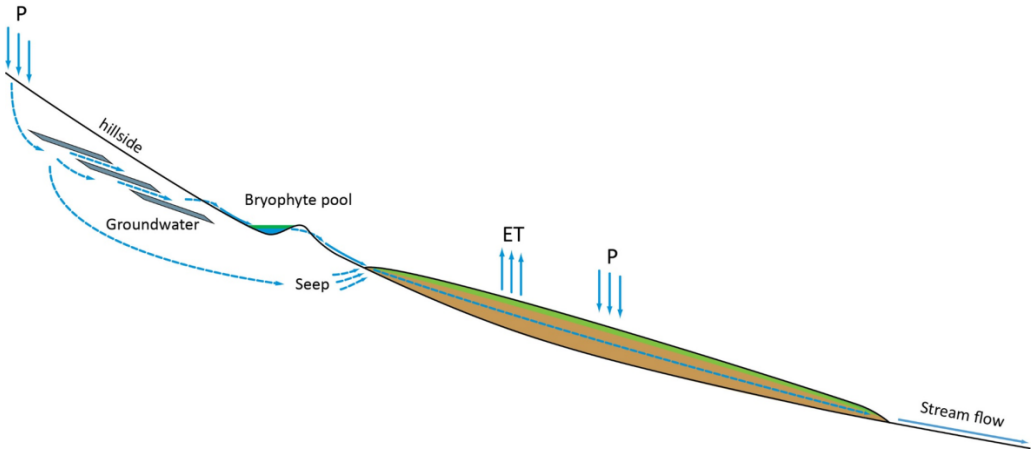
It is expected the response of alpine peatlands to climate change will be highly variable because the peatlands vary considerably. Direct changes could be expected to be drying out due to less water availability and indirect due to increased fire frequency. Bogs have nevertheless burnt over many years (6,000 y o) as shown from core analysis.

The affect will be greater on those already degraded and it is expected the marginal peatlands will shrink and potentially change state to different alpine vegetation on inorganic soils.

The positive may be that warmer temperatures may increase carbon capture and favour development of organic soils. If able to keep moist they will be more resistant to fire and more resilient to recover. Alpine Peatlands can naturally recover but this is a long process; Sphagnum takes up to 12 years to respond following being burnt.

Water availability and retention will be the key to their ability to resist change and recover. It could be expected that peatlands will become shrubbier as they dry out, which will in turn increase fire impact. Focus should be on protecting the Alpine Peatlands in best condition and high water availability and these will be most likely to persist.

Hydrology & Aquatic ecology



The Australian Alps ground water cycle

The nature of the alps means it has strong resilience to storm events due to high recharge efficiency into groundwater. High rainfall events have a relative high yield of water with very low ionic concentrations

Alps groundwater is relatively young; less than 50 years and is relatively quickly discharged.

Groundwater supports unique and restricted communities; bryophyte pools are a stable thermal environment and contain rare aquatic fauna. Some species in these pools, such as endemic mosses have no resistance to drying – need constantly wet environment. The groundwater system has an important role in chemical regulation. The alpine peatlands contribute importantly to composition of stream flow but they depend on reliable groundwater.

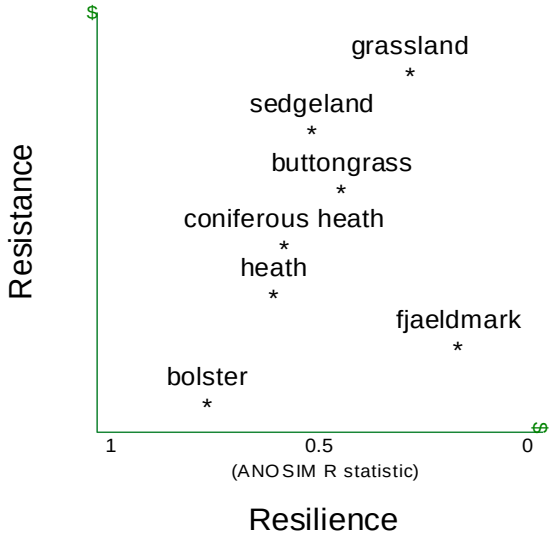
It is expected that climate futures will bring significantly reduced runoff & recharge of ground water but more intense storms. There will also be losses in soil organic carbon. These factors will have a significant impact of healthy groundwater systems.

Alpine Treeless and adaptive potential of alpine vegetation

Alpine herbfields and Grasslands

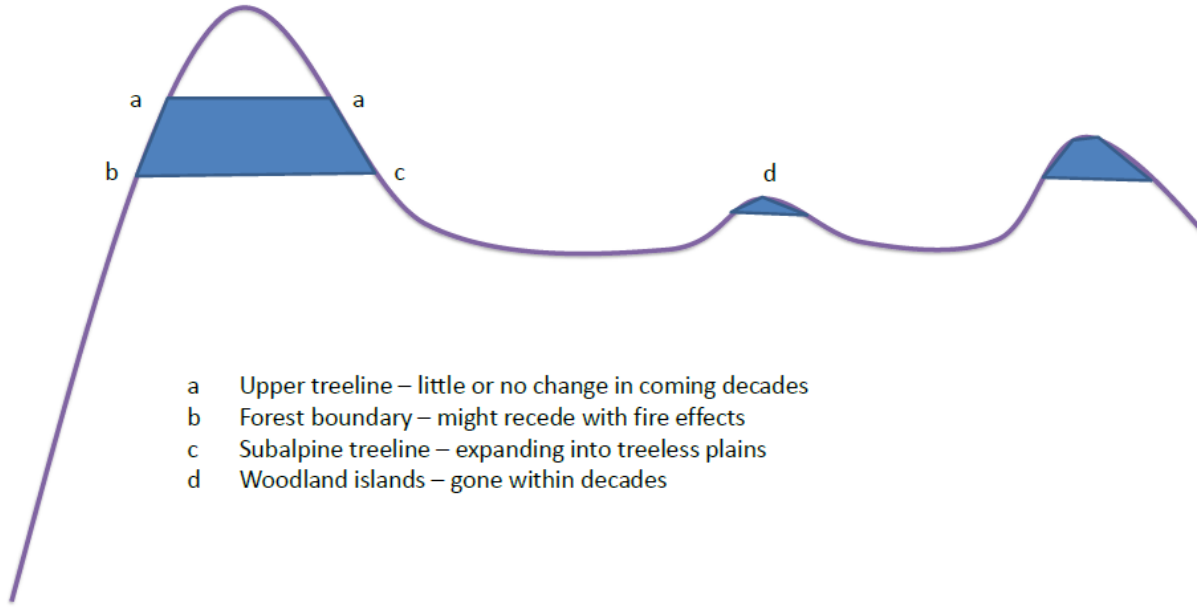
The species of the alpine treeless area tend to have significant genetic diversity and divergence meaning it is important to understand species genotypes to determine their ability to adapt to changing circumstances. Areas of genetic refugia in the treeless areas occur which are areas of biodiversity genetic 'hot spots'. They have been refugia for long periods of time. They can be identified and these should provide priorities for conservation in future. It is apparent that shrubs & forbs are increasing in treeless areas. It is expected there will be continued persistence of herbfield communities at higher altitudes, and in smaller exposed patches and hollows.

An understanding of resistance (ability to resist change) and resilience (ability to recover) is important and as their relationship suggests their susceptibility of Alpine Treeless species to climate change. Grasslands are least susceptible.



Future resistance stability can be determined by considering disturbances from invasive species, fire and hydrological disturbances, integrated with climate futures data such as projected changes in temperature, rainfall and radiation. This has been analysed (utilising the MCAS-S decision support tool) for Alpine Peatlands in Victoria and with other data such as societal and natural values data has provided some guidance on likely future condition and importance of protection of Alpine Peatland localities. This could be applied to other alpine treeless communities and could include genetic data.

Snow Gum Woodlands



Snow Gum woodland and open forest has been severely affected more recently by landscape scale fires, particularly in 2003 and 2006/07. Drought conditions meant that these forests which are normally too wet to burn at high intensity, freely burnt across the landscape. The result is very little old growth snow gum forest exists in the alps, although regrowth has been prolific.

The alpine treeline (a) in Australia has not moved upslope in past years. The montane forest boundary (b) is influenced by fire and snow gum may move into lower boundaries or montane species invade snow gum; both may occur.

The subalpine treeline (c) is the one where most change has been observed where *Eucalyptus stellulata* (which is more tolerant of frosts) in particular is noticeably moving into subalpine plains, particularly in Kosciuszko National Park. This may be related to drought, lack of heavy frosts or reduction of grazing pressure.

The understorey is variably under pressure from fungal and insect attack. The insect attack may be from native insect species (but may not be from Alps). This may be related to climate change but

more research is needed to determine cyclical or long term change related to climate as is the case globally in mountain and sub alpine forests.

Woodland islands (far right on diagram) appear to be under pressure & may disappear due to fire, damage from insects & fungus (native) placing pressure on trees.

Alpine Ash/Montane Forests

Obligate seeders (Alpine Ash) in fireground and sprouters (Mountain Gum & Peppermint) in background.

Fire in montane forests has increased in frequency in the last two decades with vast areas burnt in several fires, particularly the mega fires of 2003 & 2006/07. Although these large fires have been due to multiple lightening ignitions, people have had huge impact on fire frequency particularly since European settlement & later management influences.

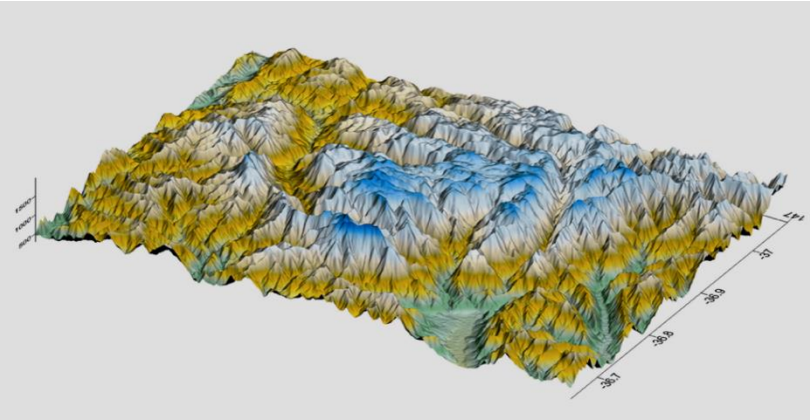
The Alpine Ash forests are particularly vulnerable to frequent fire as they are obligate seeders with a biological significant intervals between fires of about 20 years for seed to be produced, although recent observations in the ACT has shown some Alpine ash A stands produced some viable seed in 10 years.

The Montane Forest re-sprouters such as Mountain Gum, Candlebark and Peppermint eucalyptus species appear to have recovered well from these fires, however in places highly intense fires have killed re-sprouters as well. In Victoria, in the Alpine National Park near Mt Hotham, Alpine Ash burnt in 2013 resulted in double and triple burnt areas, burnt within the biological significant interval with little chance of natural regeneration. About 4800 hectares of the area was artificially re seeded. The question is whether this response is sustainable given the likely re-occurrence of this situation, or the seeded area being burnt again before it becomes seed bearing with climate change influences. A projected warmer drier climate may lead to a 50% reduction in intervals between fires. It may be more sustainable to regenerate what were traditionally Alpine ash forests with other species more likely to be sustainable with climate futures. The study of more robust genotypes

The unknown is whether intensity will increase with climate change, there is some uncertainty about this.

The study of montane forest species genotypes would be valuable to identify critical areas for conservation and reducing impact and to support thinking around revegetation of sustainable species and genotypes: An insurance policy to ensure genotypes can survive i.e. the best re-sprouters, Alpine ash re-sprouters.

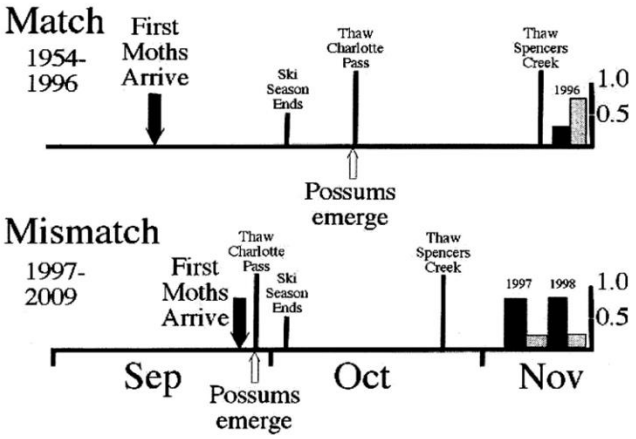
Alpine Fauna



The Australian Alps are cold climate islands (refugia) habitat for alpine fauna species.

The likely effects of climate change on alpine fauna are well documented in Snow: A Natural History; an uncertain future; (1998) Ken Green and Field Guide to Wildlife in the Australian Snow Country; Chapter 11 Climate Change and the Snow Country Fauna (2012). Ken Green and Will Osborne.

Native fauna will tend to move "up and early" with non-alpine species starting to compete with alpine species. Some consequences may be the predation of Laughing Kookaburras on rare alpine skinks, wallabies impacting on alpine herbfields and swamp rats displacing other small mammals such as Broad Toothed Rat.



Change to timing of association between Bogong Moth Arrival, Mountain Pygmy Possum emergence and thaw.

The cyclic and seasonal natural phenomena of the alps is becoming mismatched, for example the Bogong Moth is arriving 25 days later than previous years leaving little time before the Mountain Pygmy Possum emerges, thus changing the dietary pattern and movement of the Mountain Pygmy Possum leading to starvation and increased predation from foxes.

Gene pool mixing may be a more sustainable approach to robust alpine fauna populations. Recently the introduction of genetic diversity into the declining Mt Buller Mountain Pygmy Possum population is an attempt to increase the ability of the local population to resistant and resilient.

The campaign over the year to eliminate the Dingo to protect high country sheep herd has had the consequence of eliminating the natural the apex predator resulting in nothing to control wallaby, kangaroo and introduced animal populations. We need to change the way we think.

Overview: Alpine biodiversity futures under climate change

The Australian Alps bioregion is and contains many rare and restricted flora and fauna species with the alpine area being only 0.15% of the Australian continent. It is showing most change relative the other Australian terrestrial bioregions as a result of climate change.

There are risks and multiple biotic and abiotic (e.g. declining snow) stresses; the environment is getting warmer, drier and getting burnt, invasive species are having a big impact and community attitudes to some of these (e.g. feral horses and cattle grazing) are challenging. The challenge is dealing with 'shock of the new'; leading to uncertainty around when to intervene and what perverse outcomes may arise.

Of the key vegetation communities and features:

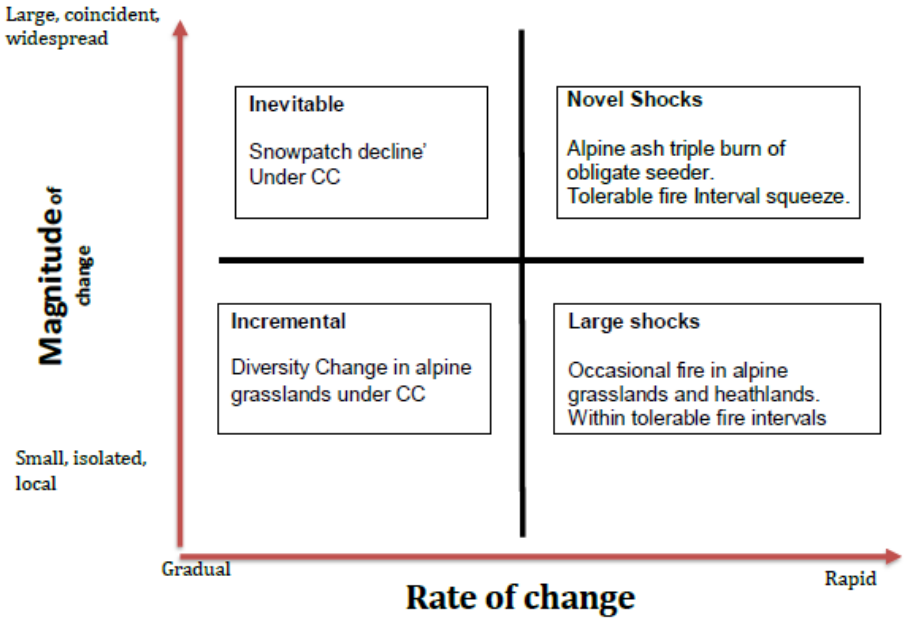
- Bogs & Peatlands need ground water to persist in landscape; there is capacity in the water to buffer against change but significant reduction in ground water recharge is big risk for the persistence of Alpine Peatlands and their ability to resist fire impacts.
- The treeless areas are expected to be quite resilient, however species will move around and the ITEX experiment indicates there will be increased shrub growth reaching maturity earlier. Heathlands are most flammable and as fire intervals contract more shrubiness can be expected. The thermal regime may mean change comes from around the mountain rather than up. The snow patch vegetation community is only 1% of 0.15% of alpine Australia and is at high risk of loss due to reduced snow pack, but the species will persist in other areas.
- The alpine treeline does not seem to be moving but encroachment into the sub alpine area in noticeable probably due to less severe frosts.
- Montane forests are at risk at local level from reduced fire intervals but across the landscape there may be enough buffer to maintain the Alpine Ash framework species.

The presence of high impact invasive species such as Feral Horses, Deer, Willows etc puts the inevitable change "on steroids".

Nature is in flux, change is inevitable; the challenge is to develop adaptation pathways for an uncertain future to understand when to intervene and what to do about it? The change will not be all doom and gloom ecologically, there is considerable room to move and some change will be of little concern ("so what"). Other change may be highly harmful and worth intervention. Monitoring is crucial but must be targeted (e.g. don't monitor the dead canary).

Management decisions about when to intervene may be guided by an assessment of the typology of change; i.e. the rate of change (is it within or outside range historical variability) versus magnitude of change; see below.

Typology of change



Incremental change may fall into the "so what" category but Novel Shocks and Large Shocks are worth considering intervention and what would we do differently.

Current major biodiversity Programs in the Alps

Agencies presented and discussed key biodiversity investment programs in the Alps: Why invest and what are the gaps in knowledge?

Factors for determining priorities for pest management

(based on NSW OEH Regional Pest Management Strategy):

Critical

- Threatened Species Conservation – are, or are likely to be, significantly impacting on threatened species, populations or communities
- Health and Disease – impact significantly on human health or a part of a declared national emergency
- Economic – impact significantly on economic enterprises
- New and Emerging - new or suppressed population of highly invasive species

High

- International Heritage – impact significantly on world heritage or international heritage values
- High – Cultural Heritage – impact significantly on important cultural heritage values

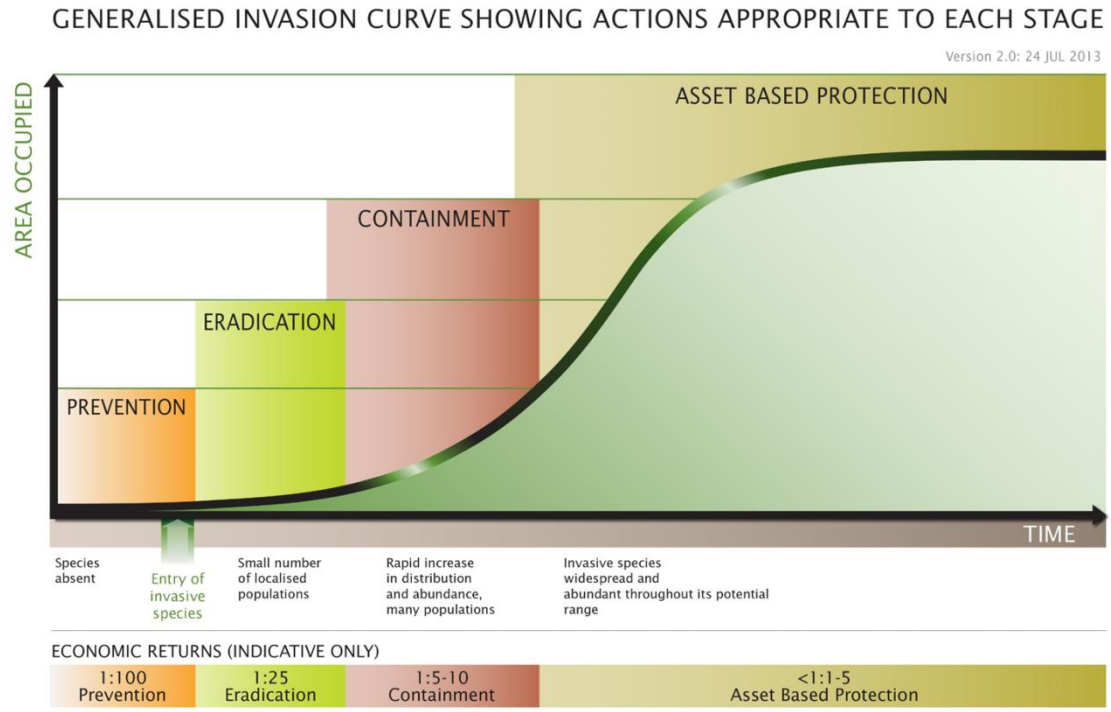
Medium

- Wilderness and National Heritage – impact significantly on wilderness, wild rivers, national heritage values or other important listed values
- Recreation and Aesthetic Values – impact significantly on recreation, landscape or aesthetic values
- Cooperative Programs – cooperative programs targeting pests that impact significantly on park values or agricultural production
- Isolated Infestations – isolated infestations of highly invasive pests, widely distributed, with high potential for future impacts on park values

Low

- Localised Programs – localised impacts on natural ecosystems or agricultural lands that promote community skills, awareness and involvement with parks
- Previous Programs – localised impacts on native species and ecosystems, and that can be efficiently implemented to maintain benefits

Stages for responding to pests
(based on Victoria Biosecurity Framework)



Program Response to Climate Change

The NSW OEH Manage Benefits map incorporates the impacts of climate change with the conservation significance of the community (due to past and projected future loss). Areas range in value between strongly deserving investment or unlikely to have significant biodiversity values in the future. Kosciusko National Park is defined an area that will become significant areas of conservation significance into the future. This could be due to loss of other areas containing those communities or the vegetation community has changed into a significant community. Therefore this park is likely to need the retention of its current management practices, with the consideration of how climate change will impact current threats.

Invasive Animals

The Invasive Animals CRC and the Australian Bureau of Agricultural and Resource Economics and Sciences were commissioned by OEH to model the distribution of vertebrate pests in New South Wales under climate change.
(http://www.environment.nsw.gov.au/pestsweeds/PestAnimalsClimateChange.htm).

There was no consistent trend for the ranges of vertebrate pest species in the study to either expand or contract as a direct result of forecast climate change. Among the vertebrate pest species of most concern (feral goat, feral cat, fox, rabbit and feral pig), only the feral pig is predicted to increase its range substantially.

Key Alps wide invasive animal programs include:

Feral Horses: High populations of feral horses occur in the Cobberas and Bogong sections of the Alpine National Park and southern and northern Kosciuszko National Park. In the ACT, there are no feral horses however there is a watch and act program due to potential migration or release. The removal of feral horses is a very contentious and divided one in the community. NSW NPWS have just released a new draft Kosciuszko Horse Management Plan for comment and Victoria has the intention to developing one. In Victoria, capture is by roping and trapping, in Kosciuszko, by trapping only. In NSW future horse control techniques will be determined as the Draft plan is finalised.

The particular concern for feral horse presence is the impact on Alpine wetlands.

Deer: Deer occur right throughout the alps, with distribution and presence widening significantly over the last 20 years. The species are mainly Sambar Deer which occurs in all environments, but Fallow and Red Deer are also present in places. In Victoria, Targeted deer control is being carried out in 4 'treatment areas' using ground shooting by contractors and volunteers from the ADA and SSAA. In NSW, ground and aerial shooting includes night shooting with the use of thermal scope; a bait feeder technique under development. Legislative constraints and differences provide challenges for control programs.

Feral Pigs and Goats: Feral Pigs and Goats occurrences are isolated but concerning. Control includes ground baiting, trapping and ground and in NSW aerial shooting. Pigs have a major localised impacts on a range of environments but particular concern for the alpine and sub alpine treeless areas.

Foxes: Focus on impact on threatened species such as Long Footed Potoroo and Mountain Pygmy Possum. Current control: ground and aerial baiting, canid pest ejectors and trapping.

Wild Dogs: ground and aerial baiting, canid pest ejectors and trapping and opportunistic ground and aerial shooting. Operations focus on private land interface particularly where dogs impact on sheep, not a biodiversity program. Core areas of park are considered dingo conservation areas.

Invasive Plants

Key Alps wide invasive plant programs include:

Eradication Programs: Strict criteria must be met for eradication to be feasible, offers to remove the problem for good, prevents potential weed impacts e.g.

- Hawkweed

Containment Programs: Prevents spread into new areas, Good weed mapping, surveillance and planning required. A sustained and ongoing effort is required e.g.

- Ox eye Daisy

Asset Protection Programs: Generally well established 'intractable' weeds, focus on protecting priority assets from weed impacts. control must be sustained long-term e.g.

- Broom
- Willow
- Blackberry

Rehabilitation Restoration & Intervention

Key Alps wide Rehabilitation Restoration & Intervention programs include:

Restoring natural landscapes through traditional rehabilitation techniques e.g.

- Riparian restoration and restore habitat connectivity e.g. Rock Creek – Kosciuszko NP

Intervention following a landscape scale event e.g.

- Direct seeding of Alpine Ash in Alpine National Park following 2013 fires
- Bog Restoration Post 2003 Fires Namadgi National Park, ACT Parks
- Rehabilitation of tracks and trails following wildfire suppression

Stabilisation and revegetation of severely degraded sites e.g.

- Snowy Hydro sites, quarries, adits etc.

Rehabilitation/landscaping as part of recreational development activities e.g.

- Restoring old ski infrastructure localities and developing strategies to minimise new construction impacts.

Restoring habitat connectivity for threatened species – artificial construction of habitat and restoring native vegetation linkages in disturbed areas e.g.

- Wildlife crossings across ski runs under roads to connect habitat
- Restoring habitat for Mountain Pygmy-possum – Happy Jacks, KNP

Endangered Species

Over the last 20 years or so there has been a paradigm shift from species based conservation approaches to ecosystem and community conservation strategies. Managing for resilient systems should benefit endangered species, but we need to consider the opportunities lost if not attentive to species as well.

Key Alps wide specific endangered species programs include:

- Mountain Pygmy Possum
- Long Footed Potoroo
- Smoky Mouse
- Brush Tailed Rock Wallaby
- Leafy Anchor Plant
- Southern and northern Corroboree Frog
- Alpine Peatlands

Most activity is around removing threats from introduced predators and invasive plants and fire recovery. Many species are often only considered closely when assessing impacts of developments.

Fire Ecology

The last 15 years has seen increased focus on understanding fire ecology in the alps and applying that knowledge to burning programs and prioritising protection of fire sensitive vegetation communities.

Key Alps wide specific fire ecology programs include:

- Fire regime modelling using tolerable fire intervals (TFI) to inform prescribed burning programs
- Determining burn units that are highest risk to ecosystem resilience to future fire through 'Burn Unit' modelled fire impact analysis of ecological fire regime sensitive values.
- Landscape analysis of fire regime sensitive communities and species currently vulnerable to future fire.
- Prioritising investment in a fire sensitive community vulnerable to future fire; e.g. Alpine Peatlands.

The approach and techniques vary somewhat between agencies, however outcomes sought align.

Aligning Science and Management

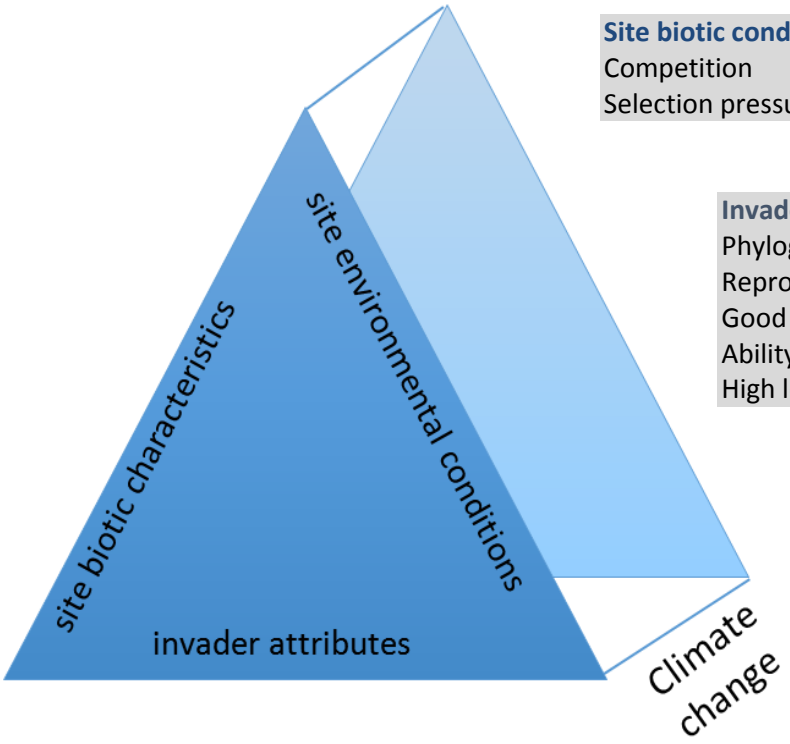
Predicting impact of key invasive species under climate futures

Dr Rebecca Harris presented the Climate Change and Invasive species in the Australian Alps Project which started as part of the NERP landscape and Policy Hub Project. Dr Keith MacDougal discussed three papers currently published or in progress around predicting invasive species movements.

The aim is to:

- To model the future climate suitability for high priority species in the Alps
- To develop a framework for identifying future invasive plant species under climate change

How to predict future invasives? The **Invasives triangle:**



Site biotic conditions
Competition
Selection pressures

Invader attributes
Phylogeny (related to invasive species)
Reproductive strategies (asexual/sexual);
Good dispersal;
Ability to hybridise;
High levels of phenotypic plasticity/genetic adaptation

Site environmental conditions
Climate
Soil
Aspect, Slope
Disturbance

Biogeography – native and introduced ranges
Broad latitudinal range?
Is the species' range strongly determined by climate?
Known distribution helps infer thermal tolerances

The model has been applied to a number of species, particularly Hawkweed and Broom species and is ready to apply to other key invasive species.

In summary:

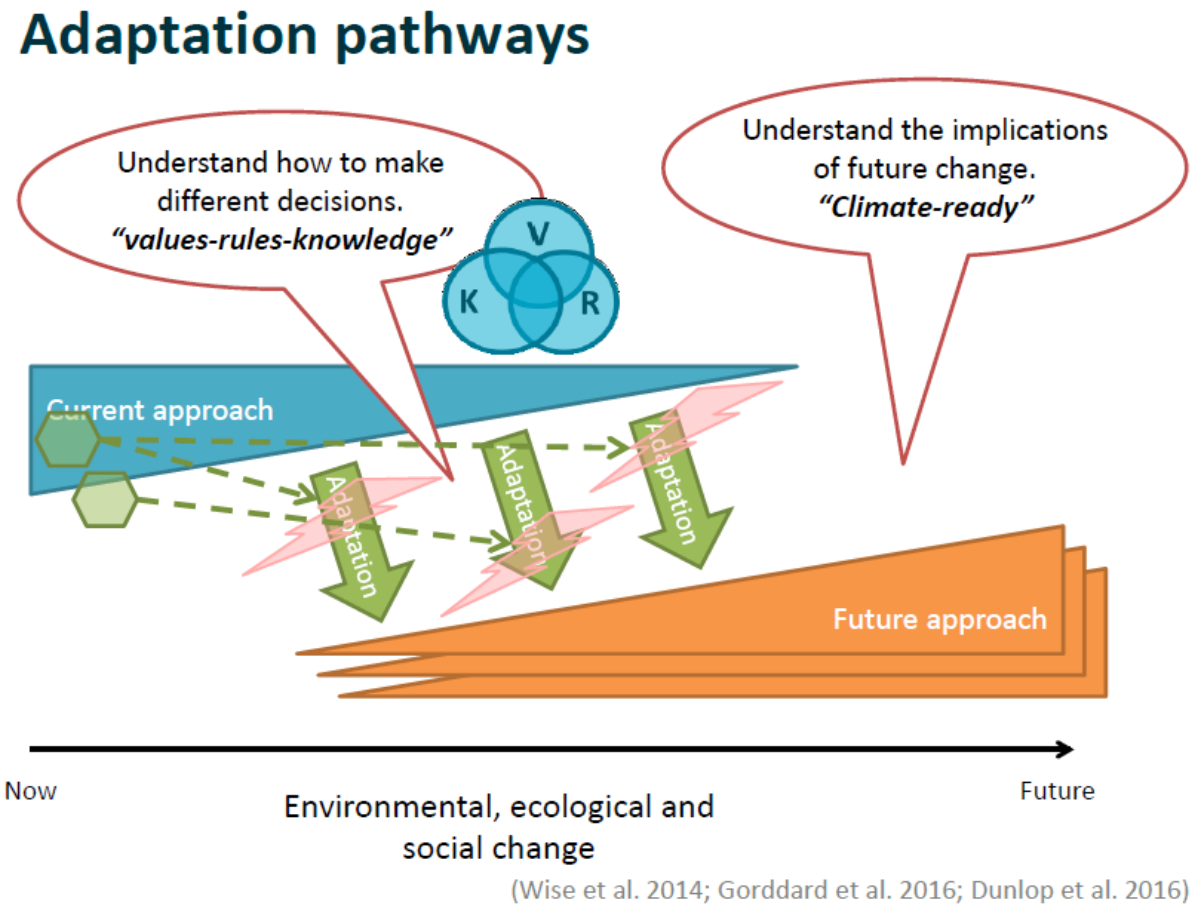
- Changing climatic conditions will reduce suitability for current invasive species and improve it for others. Fine scale climate projections improve the ability to identify suitable areas.
- This will provide opportunities as well as risks for management –targeted eradication of current species, early intervention to prevent spread of future invasives into the Alps.
- Knowledge of future climate suitability for particular species can help prioritise these management responses. The Framework also helps identify when climate modelling might not be useful; not all species will respond to the same climate variables, and all movement will not just be up-slope.
- Decisions will still be made under high levels of uncertainty however, SDMs can be used to define the range of possible trajectories a species may be on. Monitoring and adaptive management are essential to support and adjust predictions.
- In general, future movements of non-native species will be driven more by moisture availability than by temperature; range contractions may occur.
- Likely alpine invaders under current and future conditions (based on modelling at local and global scales): Anthoxanthum odoratum, Echium vulgare, Hedera helix, Holcus lanatus, Hypericum perforatum, Leucanthemum vulgare, Lotus corniculatus, Mimulus moschatus, Poa pratensis.
- Not all invading species will have an impact. Predicting impacts of non-native species is often possible: if they have an impact in one mountain area they are likely to have an impact in others – communication is therefore important.

Adaptation Pathways approach to addressing future ecological changes

Dr Mike Dunlop introduced the notion of adaption pathways and attributes that will change and those that could persist for valued aspects of the Australian Alps. Climate ready objectives for values and features prepare and adapt for what may change or persist as a result of climate change.

Strategies must accommodate:

- Large magnitude of ecological change, and significant loss.
- Considerable uncertainty in the detail of ecological changes.
- Different impacts on multiple valued aspects of biodiversity.



(Wise et al. 2014; Gorddard et al. 2016; Dunlop et al. 2016)

The adaption pathway for values and features of the alps is summarised in the table below, prepared by Mike Dunlop, based substantially on presentations and discussions from Sessions 2 in the program.

Valued aspect of the Alps	Attributes that will change *(inevitable change, loss)*	Attributes that could persist *(feasible to maintain**)*
Alpine peatlands	Lose lots. Many will shrink.	Lots of peat bogs. Ephemeral wetlands?
Alpine herbfields	Loss of many to shrubs and grazing.	Many (restricted) herbfields** Healthy native ecosystem.
Snow patch communities	Will eventually disappear. Some species extinct.	Healthy native ecosystem: snowgrass, shrubs
Alpine (treeless) ecosystems	Gradual and persistent elevation in the treeline, more shrubs.	Large areas remain for many decades. Healthy native ecosystem.
Snow Gum woodlands	Expand up & down. No old ones. Invaded from below. Thicken.	Lots of snow gum woodlands.
Montane and wet forests	Widespread loss, in all but fire protected areas	Some restricted populations in refuges. Re-sprouter eucalypt forests**
Alpine fauna	Some species crash. Expansion of lowland natives. More ferals.	Some persist. Large diversity of natives. Contained ferals**. Small mammals**
Unique alpine flora and fauna	Abundance & location of populations will change. Declines; extinctions.	Very high diversity of uniquely alpine species
Diversity of native species	Fewer old species. Many new species, including refugees. Many aliens.	Very high diversity of Australian native species
Visual amenity	Reduction in classic treeless vistas	Distinctive geographic features; extensive alpine vistas. Great for tourists.
"Wilderness" (natural, remote)	Anthropogenic ecological change. Increase in alien plants and animals.	Overall remoteness and sense of naturalness retained
Water supply	Changes in rain, water storage (snow and bogs); changes in flow regimes.	Alps will remain sources of plentiful and clean water

Scoping future visions and challenges

Groups discussed six key features of the Australian Alps addressing 4 questions:

1. **The Vision**: what is the likely change trajectory of this feature: how much might it adapt, persist or be harmed?
2. **The Challenges:** what challenges will this feature have in resisting or adapting to harmful change?
3. **Current programs:** Are management agencies adapting programs to build resilience and meet the challenges?
4. **Knowledge:** What knowledge is needed to meet the challenges?

The table below summarises the feedback from the groups

	The Vision	The Challenges	Current programs	Knowledge
Alpine Peatlands	**Persist:** Alpine Peatlands will be supported to continue to retain and process water, build peat, be healthy habitat for native species and support downsteam ecological processes. **Loss:** Total area of Alpine Peatlands will shrink with reduction in water, marginal peatlands will dry out, change ecological state and lose peatland characteristics. **Expansion:** Non peatland species expand into previous peatlands as they change state on inorganic soils.	**Marketing and communication:** Community understanding, appreciation and support for protecting Alpine Peatlands and their downstream values so social licence can be gained for controlling feral horses and other impacts. **Introduced Species:** Controlling impacts of feral horses, deer, pigs, willows and other wetland weeds. **Fire:** Increased frequency and intensity/impact of fire as alpine peatlands dry out. **Water:** Water retention is critical for survival **Infrastructure:** Impact of aqueducts where water is redirected from entering alpine peatlands and impact of roads, tracks and skifields.	**Current approaches:** Peatland Programs are quite active and have generally been well funded. **Continue:** Programs that are aiming to map and understand the risks to peatlands, their condition and reduce impacts to build resistance and resilience to climate change. Programs include feral horses, pigs, deer, willows, rehabilitation of peatlands and bushfire mitigation strategies. **Issues:** Lack of social support/licence and politics make managing horse and deer impacts difficult and legislation effects deer management. **Future approaches:** Prioritise peatlands for management activity to maintain in the best condition those most likely to persist under climate futures.	**Climate:** Climate projections relevant to alpine peatlands and likely species and structural changes due to climate change and the effect on their ecological function. **Pest programs:** Potential weeds, pathogens and disease likely to impact under climate futures and the best management techniques and combinations for peatland amelioration. **Prioritising Alpine Peatlands**: What characteristics will influence which peatlands are most likely to survive in climate futures and most important for the ecological system and therefore important to protect (guided by work already done in Victoria re bushfire fire mitigation).

	The Vision	The Challenges	Current programs	Knowledge
Alpine Treeless/herbfields/ heathlands	**Persist:** Typical high alpine factors and species will persist but will have patchiness of systems. Alpine treeline not expected to move substantially into the alpine treeless areas. Catchment and landscape scale biological function and health should remain intact. Genetic refugia will also remain. **Loss:** Loss some communities i.e. Snowpatch **Expansion:** Heathland may expand with increase in shrubiness.	**Snow cover:** Less snow; effecting of snow blanket that limits temperature fluctuations and supports some vegetation communities such as snowpatch. **Moisture:** Less moisture will effect recharge to sustain alpine wetlands. **Native animals:** Movement of native animals outside their historical ranges may lead to over abundant native animal issues: i.e. grazing by wallabies effecting alpine herbfields. **Phenology:** Change in phenology leading to mismatches. **Introduced species:** Invasive introduced animals and plants that will persist and potentially increase with climate change. **Fire:** Increased fire frequency that squeezes tolerable biological fire intervals.	**Current approaches:** Programs are well targeted but largely re-active rather than adaptive to Climate Change. **Continue:** Manage to reduce/eliminate existing invasive species threats such as Feral Horses, Deer, Pigs, Willows, Hawkweeds, Ox eye Daisy & Broom spp. Continue rehabilitation and restoration of damaged sites. Continue to manage fire to mitigate impacts. **Issues:** Lack of social support/licence and politics make managing horse and deer impacts difficult and legislation effects deer management. **Future approaches:** Identify and recognise priority refugia including genetic hot spots and those areas in best condition with low threats. Protect these as a priority. Set up some trial plots.	**Baseline information:** Although well studies there is still a lack of baseline data and research on inventory of values, genetics and genotypes, refugia, fine scale models of catchment scale function; snow and hydrology function. **What's changing:** Understanding changing such as vegetation structure and habitat. Need to effectively monitor change (e.g. don't monitor the "dead canary"). **Refugia** Understanding and characterising refugia, identifying locations and protecting.

	The Vision	The Challenges	Current programs	Knowledge
Snow Gum woodlands	**Persist**: Snow Gum is generally persistent in its ability to respond to impacts of fire, drought and higher temperatures. Extensive snow gum woodlands and open forest will persist as will the Alpine treeline. **Loss:** Old growth snow gum presence has been reduced substantially by fire over last 15 years and increase the scrubbiness and multi stem nature of regrowth snow gum forests. Snow gum woodland islands appear to be declining in condition and may not withstand climate change impacts. **Expansion:** Invasion of snow gum woodland (particularly *Eucalyptus Stellulata*) into sub alpine treeless areas is noticeable already and likely to increase with temperature changes and less severe frosts. Snow gum may also expand into Montane Forest.	**Invasion of other areas:** Should Snow Gums be considered weeds if they invade other areas such as sub alpine treeless areas? **Insect invasion:** Noticeable increase in insect attack is Snow Gum understories. **Fire:** Under climate futures, Snow Gum forests will become more flammable, as shown by large fires extensively burning snow gums during the millennium drought years (1998, 2003 & 2006/07 fires). Increasing fire frequency is turning snow gum forests into multi stemmed, scrubby forests and more flammable and frequent and intense burning below tolerable fire intervals may affect their ability to keep re-sprouting and further reduce old growth snow gum.	**Current approaches:** Snow Gum woodlands Programs are largely re-active to invasive species rather than adaptive to Climate Change. **Invasive species:** Weeds such as Chilean Needle Grass (ACT) and Broom species are controlled as part of wider weed programs. Feral horses are also present where they abut sub alpine treeless areas and are part of these control programs. **Fire:** Agencies tend to zone snow gum forests as non treatable for prescribed burning, although there are exceptions of strategic importance. **Grazing:** Once grazed by cattle, this impact has been removed. Deer inhabit these forests seasonally but there is little control. **Future approaches:** Identify impacts likely to increase with climate change such as insect attack and disease and take control measures. Reduce impacts of bush fire. Protection of old growth forest.	**Fire:** Research the impact of frequent and intense fire and tolerable fire intervals for Snow Gum woodlands. **Invasion:** Determine significance of Snow Gum invading sub alpine areas. **Pests:** Understand insect and disease attacks to the understorey species **Genetics:** Understand the genetic diversity of Snow Gum Woodland and Open Forest tree species to inform future management decisions.

	The Vision	The Challenges	Current programs	Knowledge
Unique alpine fauna	**Persist:** Fauna is the Alpine zone will persist but species present may change and it may become 'crowded at the top' as other non-alpine specialist species move in. **Loss:** Alpine specialists species (e.g. Mountain Pygmy Possum) may decline (or become more specialist) due to increased competition from non-alpine specialists species, habitat decline (due effect of fire, increased temperature and decreased snow cover and moisture), increased predation and changes to phenology. Some invertebrate species may already be lost. **Expansion:** Warming might benefit some alpine species such as Corroboree Frog	**Anthropogenic:** the ability of the community to understand & accept the inevitable changes to habitats and species composition. Do we allow species to disappear while others persist? How much do we triage species as opposed to managing landscapes and allowing change to species to happen. **Ecological:** being ready for unforeseen changes and impacts i.e. insects, pollinators, new species moving in, changing grazing profile. **Policy:** current policy constraints limit intervention options. **Introduced species:** managing pressures from invasive species and developments to sustain resistance and resilience to change.	**Current approaches:** Tends to be species focussed and reactionary rather than systems focussed. Management programs are currently focussed on introduced predator control and weeds affecting habitat condition which need to be sustained. **Future approaches:** Ideological shift needed to deal with change and uncertainty.–Multiple pathways needed with both species and systems focus and willingness to take risks; this is fundamental to dealing with climate change.	**Inventory**: knowledge of invertebrate elements in particular is incomplete – where is it & what is it? Adaption: new and novel options and approaches **Trajectories:** where will climate change push species to? How quickly might hey adapt, how will they resist competition. **Community:** achieving an informed, engaged and supportive community to align with inevitable changes and give social license to management decisions. (interaction between knowledge, values & rules) **Nutrient cycling:** impacts on biological processes.

	The Vision	The Challenges	Current programs	Knowledge
Montane and wet forests	**Persist:** Montane forests will persist throughout the Australian Alps landscape however the composition of tree species is likely to change. There may be a range of outcomes. **Loss:** The occurrence of stands of obligate seeder species such Alpine Ash will reduce, possibly substantially, if frequent fire continues to squeeze the tolerable biological fire intervals, as they have in the last 15 years and are likely to under climate futures. At lower elevations, foothill forest species may reduce the stands of historical montane forest species. **Expansion:** Montane forests may expand further into snow Gum forests as warming increases their potential range.	**Community education & support:** Acceptance by the community of radical change and approach where Alpine Ash forests are considered no longer viable or radical approached to fire protection. Support at every stage of process. **Fire:** Radical approaches to protecting vulnerable immature Alpine Ash stands from fire. **Interventions:** how should agencies respond and intervene in the future to extensively burnt immature Alpine Ash forests. Should seed stores be kept for intervention and if so what species? Should more climate change robust species replace historic Alpine Ash forests.	**Current approaches:** Reactive approaches to dealing with fire. Large Alpine Ash reseeding program in Victoria following the 2013 fires where extensive immature forests were burnt, but was debate on the run and no long term approach in place. Currently have open ended management documents that aren't helpful. **Future approaches:** Shift is needed in thinking to deal with change and uncertainty. Develop climate ready objectives, deliberate strategies and a range of options to deal with Alpine Ash forests based on an adaptive management approach. Develop fire protection and response strategies to protect Alpine Ash old growth stands, genetic refugia and vulnerable immature areas for protection from fire. Monitoring & evaluation is critical to support adaptive management and how manage into future.	**Revegetation:** What species mixes may be able to be used to restore burnt immature Alpine Ash Forests that have little chance of regeneration and what forest practice techniques can be utilised and successful. (*This may involve building alternative seed stores that are a mix of montane forest species and develop restoration techniques.)* **Genetics:** what genetic diversity within Montane Forests may exist that could be utilised to promote more climate ready forests (e.g. Alpine Ash re-sprouters). **Interventions:** what are the biotic and abiotic consequences of not intervening into extensive burnt immature Alpine Ash Forests. **Refugia and Vulnerability:** where are the genetic refugia, long unburnt stands and vulnerable immature stands that require special protection from fire and other impacts.

	The Vision	The Challenges	Current programs	Knowledge
Water: Hydrology; quality and quantity, aquatic ecology	**Persist:** Water will persist but there will be less and delivered differently. Some biological systems will change & adapt. **Loss:** There will be less water (20%) (and less manifested as snow and ice) with more demand downstream. There will be changes in yields, seasonal flows, stream flows & quality. Less water will affect the condition of highly water dependant alps vegetation communities such as peatlands and bryophyte pools, some will adapt, others more marginal will be lost. Storms will lead to increased erosion. **Expansion:** there will be more extreme rainfall events, but longer drier periods between.	**Water awareness:** $8 billion worth of water is derived from the Australian alps, used for power production, irrigation and domestic water supplies as well as for environmental flows. This value of water needs to be marketed to community so they value the change & processes the alps are going to go through as there will be greater demand for water from the Alps but less to supply. The community needs to understand and appreciate the problem.	**Current approaches:** Some water programs are managed well with agencies actively dealing with stresses on water including climate change but are not actively climate ready. Peatlands protection programs are at least partly targeting water quality and flow, along with biodiversity. Water management is a priority for post bushfire rehabilitation programs. Big players in water are Snowy Hydro and AGL for power productions and Catchment Management Agencies. **Future approaches:** There is a need to adapt & introduce new water programs and strategic plans to be climate ready which reflect accurate water projections. Manage water more optimally for ecological, social & economic needs. Change must reflect how water is allocated to protect aquatic ecosystems. Streamflow monitoring should be a KPI for management and develop an Alps water account.	**Climate and water projections:** Build on existing data to prepare detailed climate and water projections and models. **Ecosystems:** how will various vegetation communities respond to less water to help understand when & how to intervene. **Groundwater:** Better understanding of processes and how water moves through the environment and what are the stressors on that. **Optimisation:** how can water be most efficiently managed.

Alps Science Community- what does it look like?

A Panel chaired by Dr Adrienne Nicotra explored the future relationship and institutional partnerships between scientists, researchers and agencies.

Science and management is somewhat disconnected in meeting the challenges of Climate Futures. The way forward may be through achieved through building relationships, which is paramount and acting timely as we prepare ourselves and society for rapid change, a paradigm shift and coping with novelty. The current foci and future challenges often quite detached and we need to build capacity at many levels with integration across state jurisdictions and tenures.

An overview of some of Australian alpine research initiatives included:

- Australian Institute of Alpine Studies (AIAS) (Ken Green) to promote research in alpine & sub alpine areas in Australia & O/S.
- Research Centre for Applied Alpine Ecology (Ewan Silvester) virtual research centre – Melb, Latrobe & CSIRO – delivers the Alpine Ecology Course; and
- A proposal for an Australian Research Centre for High Mountain Futures: an Expression of Interest to the Australian Research Council for a Centre of Excellence in 2017.

The Australian Research Centre for High Mountain Futures is committed to bring stakeholders, managers, regulators and leading researchers together to solve multiple challenges and deliver adaptation pathways to maintain diverse values in the High Mountains. An option may be a centralised purpose built and located facility.
Some comments from experts were:

- What is the objective – is it long term strategic research or applied?
- Need values clarification plans across alps: where are the blockages in messaging & communication. Social research needed around transformational change.
- Importance of involving managers and community with researchers.
- Need to consider a range of models: COE – can be on & off after 3 years: Virtual Research Centre versus other models.
- Australian Alps Program facilitates relationships now (e.g. Landscape and Policy Hub over last 3 years); needs to articulate its needs & communicate to researchers and working together not just relying on one model. Need to share & update information.
- Field Station: Discussion on merits: determine objectives and long term liabilities maintenance of such a facility.

A working group was formed to include Brett McNamara of the AALC to further discussions on support for the Centre of Excellence, the notion of a research centre located in the mountains and other science/management partnerships.

Final summary and comments

The alps are on a journey; change is inevitable and things will be different: Are we climate ready?

Some biodiversity features will persist and some will change: What changes do we accept and what require intervention? There are no magic solutions but discussions such as these stimulate new thinking which may need an ideological shift in thinking in the face of uncertainty.

Two concepts that may help consider interventions and management actions:

- **Adaption pathways:** ability to accept change though multiple pathways, developing climate ready objectives; and
- **Typology of change:** the rate and magnitude of change.

For Managers:

Current programs appear to generally be aligned to build resistance and resilience to climate futures; however it was suggested that agencies are accepting climate futures and just working on the stressors rather than actively adapting. Some new thinking is needed beyond that to determine what changes may be best allowed to happen and where interventions are more critical. As an example, it will be important to identify and prioritise for conservation and protection areas of refugia that are most likely to persist under climate futures, including identifying genetic refugia, to build resistance to change. It is also important to understand the likely impact of insects and diseases which are occurring of which little is known about. Developing climate ready objectives for key features will support and inform futures thinking.

A taste of the work and resources that can be drawn on and collaborated on were presented: from ecologists, down scale climate data for the alps, invasive species projections models, and decision support tools (e.g. MCAS-S). There was encouragement to continue to build relationships with scientists and institutions and make use of the science and resources available to aim for climate ready thinking and be nimble and innovative in the landscape.

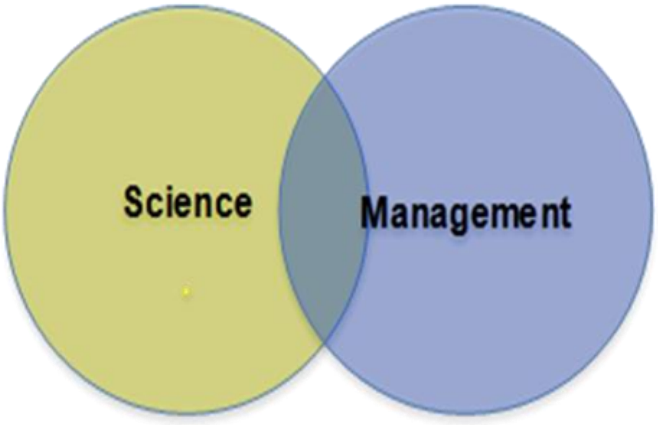
The issue of "social license" needed to take on some more controversial programs to reduce stressors was consistently raised. The need to have good science to support the journey to achieve an informed community with acceptance and collaboration in programs was expressed.

For Scientists:

Continue to explore the future relationship and institutional partnerships between scientists, researchers and management agencies. Consolidate support for the ongoing agency relationships and the potential for an Australian Research Centre for High Mountain Futures.

Next steps:

1. Share the learning with colleagues: convene local discussions in regions/workgroups. Evaluate the “climate readiness” of programs.
2. Stay on the journey: learning and adapting. Consider following up with practitioners and ecologists on areas of interest.
3. Appropriate presentations will be posted on the Australian Alps national parks website;
4. AALC will be considering outcomes and actions, including being on a working group to determine support for the science/management relationship and Australian Research Centre for High Mountain Futures.
5. Keep the science/management relationship in the alps alive and active.



Appendix 1 The Program

Taking Action Now to Strengthen Resilience:
Australian Alps climate futures: Program
University House, ANU, Canberra – 26 & 27 July 2016

Tuesday 26 July Day 1

Time		Topic	Presenter
0945 - 1015		Registration – tea and coffee on arrival	
1015	5 min	Acknowledgement of Country Welcome	Brett McNamara (AALC)
1020	10 min	Why are we here?	Peter Jacobs & Graeme Worboys IUCN WCPA Mountains Specialist Group
Session 1: Understanding Climate Futures			
1030	1 hour	Climate futures model outputs for the Australian alps	Climate futures expert Nathan Bindoff
Session 2: Implications for Alpine Biodiversity			
1130	1 hour	**Panel:** Ecologists discuss likely impacts of projections on framework/icon biodiversity features. 15 minute presentations followed by questions. Topics include: alpine peatlands, alpine fauna, hydrology and aquatic ecology, adaptive potential of alpine treeless vegetation & montane and Snow Gum forests.	**Panel:** Arn Tolsma, Ken Green, Ewan Silvester, Ary Hoffman, Keith McDougall Geoff Carey, David Bowman, Dick Williams. **Support:** Geoff Hope, Matt Riley, Anita Wild, Ian Mansergh.
1230	**1 hour**	**Lunch**	
1330	1 hour	Continue panel on likely implications for alpine biodiversity.	Alpine Ecologists/Researchers
1430	30 min	Overview: what are these projections likely to mean for biodiversity in the Alps landscape?	Dick Williams
1500	**30 min**	**Afternoon Tea**	
Session 3: Current major biodiversity Programs in the Alps			
1530	1 ¾ hours	**Panel:** Agencies discuss key biodiversity investment programs in the Alps: Why invest and what are the gaps in knowledge? 15 minute presentations followed by questions. Topics include: Pest Animals, Pest Plants, Rehabilitation and Intervention, Endangered Species & Fire Ecology.	**Panel:** F Muir, D Brown, M Schroder, T Corrigan & D Jamieson. **Support:** D Shawcross, O Orgill, E Thomas, B Stevenson, A Evans, M Keatley, G Wright, D Whitfield, M Holland, A Grant, J Seddon.
1715		Synopsis of the day	Facilitator
1730 Session Finish			

1800		Pre-dinner drinks 'Fellows Bar'	
1900		Dinner & 'tribute'	Andrew Nixon & Graeme Worboys
2100		Opportunity for specialist group discussions	Alpine Ecologists

Wednesday 27 July Day 2

0815		Tea and coffee on arrival	
Session 4: Aligning Science and Management			
0830	15 min	Introduction to Day 2	Facilitator
0845	30 min	Predicting impact of key invasive species under climate futures	Rebecca Harris (Keith McDougall)
0915	15 min	Adaptation Pathways approach to addressing future ecological changes	Mike Dunlop
0930	1 hour	Scoping future visions and challenges (small group discussions – 6) Reflecting on day one and Adaption Pathways: Each group is given a specific biodiversity feature to consider: 1. The Vision: how much might it adapt, persist or be harmed? 2. The Challenges: threats to resisting or adapting to harmful change? 3. Current programs: Are programs adapting to build resilience and meet the challenges? 4. Knowledge: What knowledge is needed to meet the challenges?	Agency Head Scientists Managers/Ecologists facilitate each session Mark Norman Kate Wilson John Wright Graeme Worboys Julian Seddon Jeremy Groves
1030	**15 min**	**Morning Tea**	
1045	45 min	Panel : Feedback and general discussion from small groups	As above with Mike Dunlop
Session 5: Alps Science Community- what does it look like?			
1130	1 hour	Panel: Exploring the future relationship between scientists, researchers and agencies Institutional Partnerships and future Alps Science Community	Agency Head Scientists Adrienne Nicotra – Geoff Carey & other Research Institutions
1230	15 min	Conclusion and next steps	Facilitator & AALC
1245		**Lunch and depart**	

Appendix 2 Session topics and contributors

Session 2: Implications for Alpine Biodiversity Day 1 26th 11.30 – 3pm

Topic	Lead	Support
Alpine Peatlands	Arn Tolsma	Geoff Hope
Hydrology & Aquatic ecology	Ewan Silvester	Matt Riley
Alpine Treeless and adaptive potential of alpine vegetation	Ary Hoffman	Anita Wild
Snow Gum Woodlands	Keith McDougall	
Alpine Ash/Montane Forests	Geoff Carey	
Alpine Fauna	Ken Green	Ian Mansergh
Overview	Dick Williams	David Bowman

Session 3: Current major biodiversity Programs in the Alps: Day 1 26th 3.30 – 5.15

Topic	Lead	NSW	ACT	Victoria
Invasive Animals • Horses • Deer • Pigs & Foxes	Frazer Muir	Duane Shawcross	Ollie Orgill	Elaine Thomas
Invasive Plants • Hawkweed • Willows • Broom • Blackberry • Ox eye Daisy	Dan Brown	Anthony Evans	Steve Taylor	
Rehabilitation Restoration & Intervention	Mel Schroder		David Whitfield	Marie Keatley
Endangered Species	Tony Corrigan	Genevieve Wright		Matt Holland
Fire Ecology	Dan Jamieson	Andrew Grant	Julian Seddon	

Session 4 Scoping future visions and Challenges; Day 2, 27th 9.30 – 11.00pm (small groups discussions)

Topic	Lead
Alpine Peatlands	Kate Wilson
Alpine Treeless/herbfields/heathlands	Mark Norman
Snow Gum woodlands	Jeremy Groves
Unique alpine fauna	John Wright
Montane and wet forests	Julian Seddon
Water: Hydrology; quality and quantity, aquatic ecology	Graeme Worboys

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