Action statement No.266

Flora and Fauna Guarantee Act 1988

Soil erosion and vegetation damage and disturbance in the alpine regions of Victoria caused by cattle grazing

VICTORIA State Government | Environment, Land, Water and Planning

Cover photo: Mt Bogong area, Iris Curran (Parks Victoria)

Compiled by: Dr Arn Tolsma (Arthur Rylah Institute)

ISBN:978-1-74146-946-2 (pdf)

Accessibility

If you would like to receive this publication in an alternative format, please telephone the DELWP Customer Service Centre on 136 186, email customer.service@delwp.vic.gov.au, or via the National Relay Service on 133 677, email www.relayservice.com.au. This document is also available on the internet at www.delwp.vic.gov.au

Action Statement No. 266

Soil erosion and vegetation damage and disturbance in the alpine regions of Victoria caused by cattle grazing

Description

Geographically the term 'alpine' commonly refers to those areas above the physiological limit of tree growth, which on the Australian mainland occurs at approximately 1700 - 1900 m above sea level (Williams *et al.* 2014). However inverted treelines are common in Australia, where shallow, sub-alpine valleys are subjected to severe frosts from cold air drainage and the vegetation is more closely associated with alpine vegetation (McDougall 1982). In areas such as Bentley Plain, vegetation considered to be 'alpine' has been recorded down to nearly 1000 m, while bogs consistent with federally-listed 'alpine' bogs may occur below 1000 m (DE 2014). Grazing licences are defined as 'alpine' if any part of the licence area extends above 1220 m. Therefore, this action statement will extend the term 'alpine regions' to all areas at or above 1000 m elevation (including peaks, high plains, valleys, plateaux and snowgum woodlands) that are subject to seasonal snow cover and are dominated by vegetation characteristic of higher-elevation regions.

Grazing by domestic livestock in the alpine regions commenced in the mid-19th century (Cabena 1980, Lawrence 1995, DSE 2005), and by the late 1870s most suitable areas were seasonally grazed (DSE 2005). In the 1890s and early 1900s large numbers of livestock were brought to the alpine area for drought relief. During the severe drought of 1902/1903 there were an estimated 40 000 sheep in addition to cattle on the Bogong High Plains alone (Lawrence 1995). This intense stocking pressure, together with regular burning-off, initiated much of the land degradation that became apparent in the mid-20th century (Lawrence 1999).

Nunniong Plateau wetland (Arn Tolsma)

Alpine ecosystems have evolved with, and are relatively resilient to, their natural disturbance regimes, which include occasional fire (Williams *et al.* 2008). However, the evolution of Australia's alpine ecosystems has occurred in the total absence of ungulates (hoofed animals) such as sheep, horses, deer and cattle and, in the case of the highest altitudes, largely in the absence of grazing by larger vertebrates (Carr and Turner 1959a, Downes 1962, McDougall 1982, Costin 1983, Ashton and Williams 1989). As a result, the introduction of domestic stock to alpine ecosystems has resulted in profound changes to natural disturbance regimes and the mechanisms of recovery.

Cattle within the alpine environment are free-ranging, as there are few or no restrictive fences. They are also selective in the communities in which they graze, rest and drink (van Rees 1984). Some communities, such as grasslands, are utilised heavily; while others, such as closed heaths, are little-used. Cattle are also highly selective in the species upon which they graze. This means that the sensitivity of plant species and communities to the total impact of stock grazing is variable. Some are highly sensitive, and in such cases, the effective grazing pressure may be high, even where the nominal stocking rate is low. Moreover, because the cattle are free-ranging, it is impractical to keep them out of the most sensitive areas.

It has been well documented since the 1940s that grazing in alpine areas has the potential to initiate and exacerbate soil erosion, alter the composition and structure of the vegetation in preferentially-grazed and adjacent plant communities, and retard or prevent the recovery of alpine vegetation following major disturbances, with consequences for resident native fauna (McDonald and Stretton 1946, Williams *et al.* 2014). Grazing of livestock is incompatible with primary objectives of the *National Parks Act 1975*, and incompatible with national and international standards for a national park (DSE 2005). There is overwhelming evidence that alpine grazing has negligible, if any, ecological benefit in Australia's mainland alps and research suggests it has had little impact on the likelihood or severity of fire in the alpine region, either in treeless or forested areas (Williams *et al.* 2006, Williamson *et al.* 2014).

Occurrence

In the late 19th and early 20th centuries there were no controls over alpine grazing (DSE 2005). Stock levels were high, especially during droughts, and burning-off to promote new growth was common. Such overgrazing, associated with regular burning-off and the occasional bushfire, caused extensive damage to the fragile alpine environment, which had evolved in the absence of cattle grazing and under different fire regimes. In extreme cases, the soils and vegetation were damaged severely, to the extent that the soil mantle was stripped entirely, and stony erosion pavements were created (Costin 1957b, Wimbush and Costin 1979a, b, c).

During the 1940s concerns about damage to alpine ecosystems in Victoria led to the establishment of grazing research on the Bogong High Plains and the 'Royal Commission to Inquire Into Forest Grazing' (McDonald and Stretton 1946) and controls were gradually introduced. Sheep, horses and burning-off by graziers were banned in 1946 on the Bogong High Plains, and restrictions on the length of the grazing season were imposed (DSE 2005). Over the following decades, cattle were excluded incrementally from additional areas, including alpine resorts (DSE 2005, Stephenson 1980). With some temporary exceptions after the 1998 and 2003 fires, cattle continued to graze seasonally within large areas of the Victorian Alpine National Park until 2006, when the final national park grazing licences were withdrawn (most licences finished in 2005). In May 2015 the *National Parks Act 1975* was amended to re-affirm that cattle could not be introduced or used for any purpose in the Alpine National Park.

Current situation

Cattle continue to graze during the summer and autumn months in some areas of State Forest (Figure 1), including the sub-alpine Nunniong Plateau, and on private land such as Bennison Plains and the Dargo High Plains (DELWP unpublished data).

Alpine grazing can be seen largely as a seasonal extension of low-country farming activities. However, there have been reports over the years of wild or illegally-grazing cattle around the Baw Baw plateau (McDougall and Walsh 2007), Snowy River National Park (D. Burton, Parks Victoria, pers. comm.) and Alpine National Park (F. Brooke, Parks Victoria, pers. comm.). This action statement

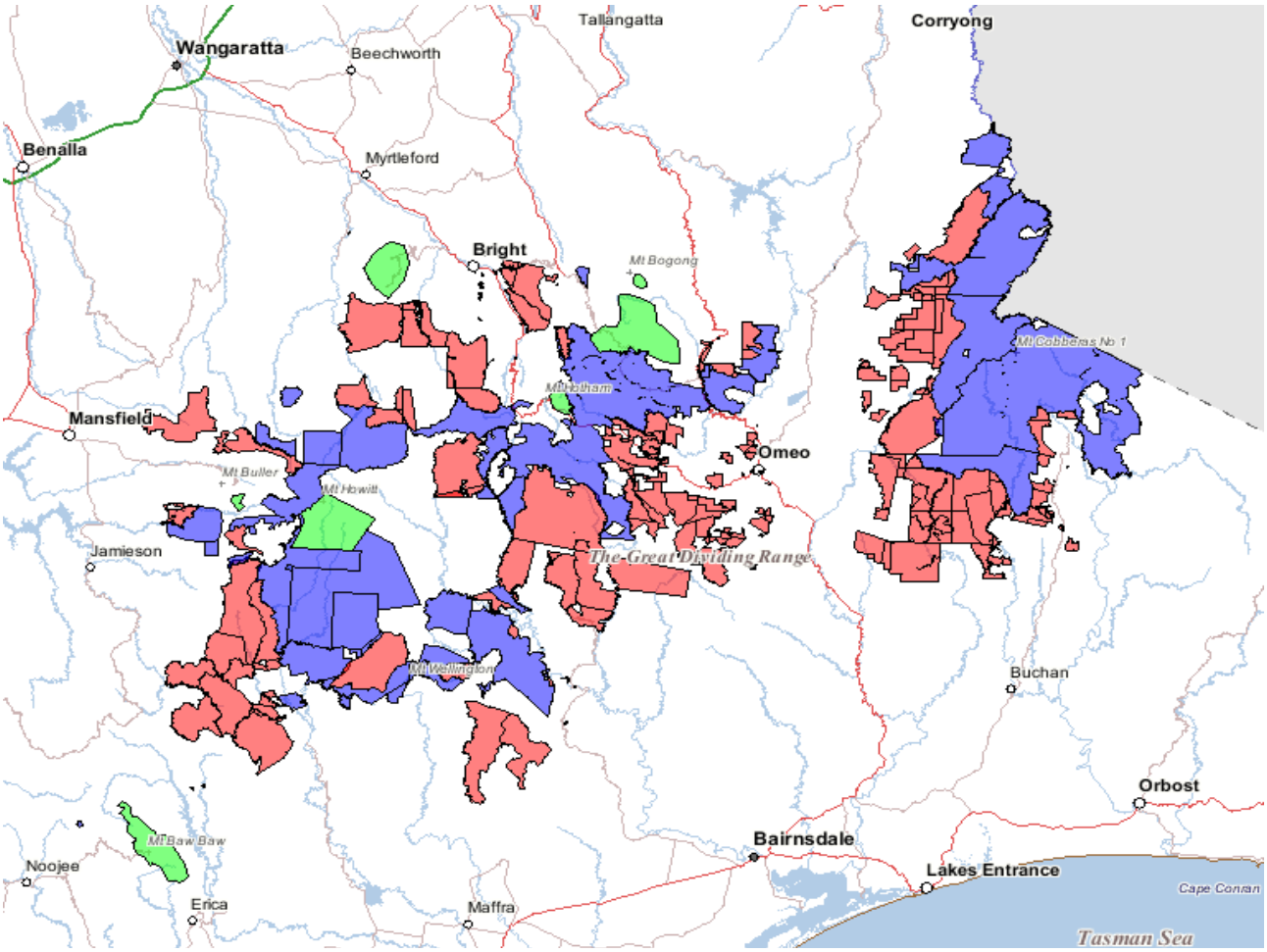

Figure 1. Grazing licence areas by tenure. Pink = existing state forest licence; Blue = national park licence, withdrawn prior to 2005; Grey = national park licence, withdrawn 2005.

therefore considers the issue of wild cattle as well as those grazing legitimately.

Nature of threat

Taxa and/or communities of flora and fauna affected

Of the species at risk from grazing in alpine regions, 34 plants (Table 1), 13 animals (Table 2) and at least four floristic communities (Table 3) are listed as threatened under Victoria's *Flora and Fauna Guarantee Act 1988* (FFG Act) and/or the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (DSE 2009, 2013, DEPI 2014, DE 2015a, b). An additional 90 plant species at risk are on DELWP's advisory list of rare or threatened plants (DEPI 2014), and a further 3 animal species at risk are considered threatened in the advisory list of threatened vertebrate fauna in Victoria (DSE 2013).

Table 1: Listed plant species potentially affected by cattle grazing in the alpine regions of Victoria (Source: National Herbarium of Victoria and DELWP unpublished data). EPBC – Status as listed under the Commonwealth EPBC Act. (VU = vulnerable in Australia, EN = endangered in Australia). FFG – Status as listed under the FFG Act. (L = listed).

Scientific name	Common name	EPBC	FFG
Almaleea capitata	Slender Parrot-pea		L
Argyrotegium nitidulum	Shining Cudweed	VU	
Bartramia subsymmetrica	Bogong Apple-moss		L
Botrychium australe	Austral Moonwort		L
Brachyscome sp. 3 (aff. tenuiscapa)	Mountain Daisy		L
Calotis pubescens	Mountain Burr-daisy		L
Cardamine franklinensis	Franklin Bitter-cress		L
Carex cephalotes	Wire-head Sedge		L
Carex pauper	Dwarf Sedge		L
Celmisia sericophylla	Silky Snow-daisy		L
Climacium dendroides	Marsh Tree-moss		L
Deyeuxia affinis	Allied Bent-grass		L
Discaria nitida	Shining Anchor Plant		L
Discaria pubescens	Australian Anchor Plant		L
Diuris ochroma	Pale Golden Moths	VU	L

Scientific name	Common name	EPBC	FFG
Drabastrum alpestre	Mountain Cress		L
Epilobium willisii	Carpet Willow-herb		L
Euphrasia eichleri	Bogong Eyebright	VU	L
Euphrasia scabra	Rough Eyebright		L
Juncus antarcticus	Cushion Rush		L
Kelleria laxa	Snow Daphne	VU	L
Lobelia gelida	Snow Pratia	VU	L
Myoporum floribundum	Slender Myoporum		L
Persoonia asperula	Mountain Geebung		L
Prasophyllum frenchii	Maroon Leek-orchid	EN	L
Prasophyllum morganii	Mignonette Leek-orchid	VU	L
Prasophyllum niphopedium	Marsh Leek-orchid		L
Prasophyllum suttonii	Buffalo leek-orchid		L
Pterostylis cucullata subsp. sylvicola	Tall leafy Greenhood	VU	L
Pterostylis X aenigma	Enigmatic Greenhood	EN	L
Saxipoa saxicola	Rock Poa		L
Thesium austral	Austral Toad-flax	VU	L
Utricularia monanthos	Tasmanian Bladderwort		L
Wahlenbergia densifolia	Fairy Bluebell		L

Table 2: Listed fauna species potentially affected by cattle grazing in the alpine regions of Victoria. EPBC – Status as listed under the Commonwealth EPBC Act. (VU = vulnerable in Australia; EN = endangered in Australia). FFG – Status as listed under the FFG Act. (L = listed; N = nominated and supported).

Scientific name	Common name	EPBC	FFG
Eustacus crassus	Alpine Spiny Cray		L
Thaumatoperla alpina	Alpine Stonefly		L
Thaumatoperla flaveola	Mount Stirling Stonefly		L
Cyclodomorphus praealtus	Alpine She-oak Skink	EN	L
Eulamprus kosciuskoi	Alpine Water Skink		L
Liopholis Guthega	Guthega Skink	EN	L*
Galaxias fuscus	Barred Galaxias	EN	L
Galaxias gunaikurnai	Shaw Galaxias		N
Galaxias mungadhan	Dargo Galaxias		N
Litoria spenceri	Spotted Tree Frog	EN	L
Litoria verreauxii alpina	Alpine Tree Frog	VU	L
Mastacomys fuscus mordicus	Broad-toothed Rat		L
Philoria frosti	Baw Baw Frog	EN	L
Pseudomoia cryodroma	Alpine Bog Skink		L
Pseudomys fumeus	Smoky Mouse	EN	L

** originally FFG Act listing as Alpine Egernia (Egernia guthega)*

Table 3: Listed floristic communities potentially affected by cattle grazing in the alpine regions of Victoria. EPBC – Status as listed under the Commonwealth EPBC Act. (EN* = endangered in Australia, Victorian communities combined under a single federal listing). FFG – Status as listed under the FFG Act. (L = listed).

Floristic community	EPBC	FFG
Alpine Bog Community	EN*	L
Fen (Bog Pool) Community	EN*	L
Alpine Snowpatch Community		L
Caltha (now *Psychrophila*) *introloba* Herbland Community		L

Change in vegetation composition and structure

Australian alpine landscapes are extremely limited in area and distribution, both at a state and national level, and contain plant communities and flora and fauna species that are found nowhere else in the world. These alpine taxa or plant communities can be affected by the selective nature of grazing, by physical damage to habitat and the underlying substrata, and by subsequent processes such as weed invasion. Grazing also acts on other aspects of the alpine ecosystem, including:

- Reductions in grazing-sensitive plant species and wildflower displays
- Increases in unpalatable plant species, especially woody taxa
- Reductions in vegetation cover and increases in bare ground
- Changes to peatland vegetation structure
- Introduction and proliferation of weeds

Grasslands

Grasslands contain a high occurrence of species preferred by cattle (van Rees 1984) and selective grazing alters the proportions of occurrence of species. Palatable forb genera that increase significantly after stock removal include *Celmisia*, *Craspedia, Helichrysum, Leptorhynchos, Microseris*, *Aciphylla, Euphrasia* and *Podolepis* (Wimbush and Costin 1979c, a, Williams and Ashton 1987b, Wahren *et al.* 1994). Forb species within the grassland constitute the wildflower component of the alpine landscape, and cattle grazing is an obvious threat to the abundance and diversity of these wildflowers.

Heathland

In open heathland, changes in shrub species composition reflect both the palatability of species and their mode of regeneration. Palatable, obligate re-seeder shrubs such as *Asterolasia* and *Grevillea* initially increase when cattle grazing is removed, then begin to reduce through senescence, but unpalatable shrubs such as *Prostanthera, Hovea, Orites* and *Bossiaea* continue to expand (Wahren *et al.* 1994). This is a well-documented process of gap dynamics, whereby grazing may inhibit palatable shrubs in some areas, but facilitates persistence of non-palatable shrubs in other areas (Williams and Ashton 1987b, Williams 1990a, 1992).

Herbfields and snowpatches

Alpine herbfields are sensitive to cattle activity due to the high concentrations of palatable species that comprise the vegetation (McDougall 1982). Snowpatch herbfields that occur on steep slopes where snow persists well into the growing season are especially susceptible to degradation because of the slope, the short growing season, and the soils remaining moist, and therefore easily damaged, until well into summer Snowpatch vegetation is utilised preferentially by cattle (Wahren *et al.* 2001a, Williams *et al.* 2015 in press), with resulting impacts on bare ground and vegetation cover.

Peatlands

Alpine peatlands (EPBC-listed bogs) play a major role in water catchment protection, soil conservation and maintenance of nature conservation values. They contain organic, peaty soils which are particularly susceptible to trampling because of their structure and the fact that they remain wet year-round (Costin 1954, 1957a, Wimbush and Costin 1983, Ashton and Williams 1989, McDougall 1989, Wahren *et al.* 1999a, Wahren *et al.* 2001c, Whinam *et al.* 2001). Peatlands as a whole are not generally grazed by cattle, although cattle regularly enter them to drink, especially late in the growing season, and some fens rich in *Carex* spp. (that are contained within peatlands) may be grazed heavily (van Rees 1984). The major peatland species *Sphagnum cristatum* and *Psychrophila introloba* have been shown to increase significantly in cover in ungrazed research plots, but are dislodged in grazed plots (Wahren *et al.* 2001c).

Weed invasion

Weeds are another major consequence of cattle grazing in alpine regions, and a comprehensive survey in the 1980s showed that the largest numbers of weeds were in grazed areas, in particular the areas where cattle were loaded and unloaded (Walsh *et al.* 1984). Livestock are considered important vectors of weed dispersal in the alpine regions of Australia (McDougall *et al.* 2005). For example, cattle are implicated in the spread of the highly invasive Scotch Broom (*Cytisus scoparius*) – a weed of national significance (Hosking *et al.* 1998, Sheppard *et al.* 2000). Bare ground created by cattle in and around alpine bogs can also potentially provide microsites for the germination of Grey Sallow Willow (*Salix cinerea*), one of the most invasive woody weeds in the alpine area (NHT 2003, McMahon *et al.* 2009). The maintenance of a thick sward of native alpine vegetation may restrict the establishment or persistence of some introduced plant species (Wimbush and Costin 1979c), but this can only occur in the absence of major disturbances such as grazing.

Impacts on ecosystem processes

The physical damage caused by cattle grazing leads to detrimental impacts on a wide range of ecosystem processes, including:

- Increased soil compaction
- Increased soil erosion
- Interference with post-fire vegetation recovery
- Destruction of peatlands (and reductions in carbon storage)
- Damage to riparian vegetation and streams

Soil compaction

Grazed areas exhibit increased soil compaction that leads to a decrease in water infiltration and an increase in run-off, especially during storm events (Lawrence 1995). Most of the detrimental impacts on soil physical properties resulting from compaction occur with initial treading, but are nonetheless cumulative over time, and soils in pastures that are lightly grazed will eventually reach the same compacted state as heavily grazed pastures (Greenwood and McKenzie 2001). This suggests that a simple reduction in stock numbers might slow down the rate of damage in grazed areas but is unlikely to lead to substantial improvements in soil and vegetation condition in the long-term. With removal of grazing, bulk density of alpine soils will reduce, while soil porosity and water availability increase (Carr and Turner 1959b). Long-term hydrological data from Watchbed Creek on the Bogong High Plains indicate that run-off volumes declined after grazing controls were introduced in the 1940s, consistent with an improvement in catchment condition (Lawrence 1995).

Soil erosion

Physical damage to the vegetation and the erodible organic alpine humus soils leads to increases in the amount of bare ground (McDougall 1982, Gibson and Kirkpatrick 1989, Wahren *et al.* 1994). As little as 5% bare ground in alpine areas can cause substantial increases in surface run-off and soil loss (Costin *et al.* 1960), particularly where frost heave and wind ablation are active. The risk of land degradation increases as bare ground increases and vegetation cover declines (Costin *et al.* 1959, Williams *et al.* 2003), and for effective soil conservation the cover of vegetation should be maximal (Costin *et al.* 1960, Wahren *et al.* 1994, Williams and Costin 1994). This is not possible in grazed areas.

Post-fire recovery

Cattle grazing also impedes post-fire recovery. In alpine heathlands for example, protective cover was mostly restored by 10 years after fire in the absence of cattle, but had not recovered after 15 years in the presence of cattle (Wahren *et al.* 1999b).

Peatlands

Ecosystem processes in alpine peatlands can be severely interrupted by cattle grazing. Trampling and pugging leads to exposure of bare ground, destruction of *Sphagnum* hummocks, entrenchment of drainage lines, drying out of the peatland and ultimately the conversion of peatland to heathland or grassland (Costin 1954, 1957a, McDougall 1982, Wimbush and Costin 1983, Ashton and Williams 1989, McDougall 1989, Wahren *et al.* 1999a, Wahren *et al.* 2001c, Whinam and Chilcott 2002). Australia's alpine peatlands store tens of millions of cubic metres of highly organic peat, and preliminary data suggest that many now have positive carbon budgets and could play some part in the sequestration of atmospheric carbon dioxide (Hope *et al.* 2012). However, grazing, leading to the removal of peat, reduces the carbon storage capacity of peatlands (Hope *et al.* 2012). A direct link between peatland state and cattle activity was demonstrated by research on the Wellington Plain (Grover *et al.* 2005, Grover 2006). This showed that dried peat began forming 131–139 years earlier, coinciding with the introduction of livestock to the area in the 1850s, and that the subsequent loss of peat was caused by physical processes, not accelerated decomposition (Grover *et al.* 2005, Grover 2006).

Water quality

Riparian strips, wetlands and associated buffer zones that maintain the integrity of their vegetation cover and structure have the potential to filter suspended solids, nutrients and pollutants from water (Castelle *et al.* 1994, Davies and Nelson 1994). Filtering is particularly important in areas grazed by cattle, due to deposition of large amounts of urine and manure. A study on the Bogong High Plains prior to cattle being removed estimated that in one small 13½ square kilometre area there were around 1,770,000 cowpats (Meagher 2004), which take up to five years to decompose.

In grazed areas as the number of cattle increases so does the importance of buffer vegetation, which is critical to maintenance of water quality. At the same time, this increased grazing pressure also results in the destruction of the buffering capacity of vegetation. Also see discussion of impacts of water

quality on human health under *Wider conservation issues*.

Grazing may also impact on local streamflow characteristics, as peatlands in good condition have the capacity to store and release excess water for a few days after rain (Hope *et al.* 2012). Nonetheless, the contribution to water flow regulation by peatlands at a larger catchment scale is small (Western *et al.* 2009), and the importance of healthy alpine peatlands may be seen more in their ability to remove sulphates and nitrates from stream water (Silvester 2007), export dissolved organic carbon, and provide pH buffering for downstream biogeochemical processes (Silvester 2009).

Impacts on fauna

Fauna are also affected by damage to peatlands and streams. Sediment disturbance from cattle leads to an increase in-stream sedimentation (Simpson 2002) which can smother and asphyxiate the demersal eggs and young larvae of *Galaxias* species, as well as smothering and reducing their in-stream food supply (T. Raadik, pers. comm.). Sediment also infills important interstitial spaces in the stream substrate which are used as drought refugia, which the fish need when stream flow becomes very low (and surface flow may cease). In streams, threatened Alpine Spiny Cray (*Euastacus crassus*) may be similarly impacted.

Small, ground-dwelling animals such as skinks, frogs and mammals that are reliant on complex vegetation structure for shelter, thermoregulation and foraging can also be impacted through structural damage to habitat by cattle grazing (N. Clemann, pers. comm.). Trampling damages and destroys aquatic breeding habitat (including margins of streams and pools), collapses underground warren systems, increases siltation and destroys oviposition sites (N. Clemann, pers. comm.).

Cattle may introduce or spread the Amphibian Chytrid Fungus, which causes chytridiomycosis, the disease that is the proximate cause for the global loss and decline of many frogs (Stuart *et al.* 2004, Skerratt *et al.* 2007). The fungus comes in different strains that vary in virulence (Berger *et al.* 2005), so introduction of new strains by cattle into already infected areas is a serious risk. Damaged habitat can attract and favour other frog species such as the Common Froglet (*Crinia signifera*) which is a reservoir host for the fungus (Clemann *et al.* 2009); therefore such damage can exacerbate the risk of disease. Populations persisting with the fungus are in a very precarious state and further damage to habitat may be enough to cause loss of populations (e.g. Scheele *et al.* (2015).

Wider conservation issues, including social and economic impacts

There is overwhelming evidence that alpine grazing has negligible, if any, environmental benefit and research suggests it has had little impact on the likelihood or severity of fire. After the 2003 alpine fires, research on the Bogong High Plains showed that fire risk and intensity were related to the abundance of shrubs, not the presence of grazing (Williams *et al.* 2006). In forested areas, analysis of remotely-sensed data showed that the probability of high-severity fire in 2003 was slightly greater in grazed areas than in ungrazed areas (Williamson *et al.* 2014). Thus, any reduction in fuel by cattle appears to be more than cancelled out by other grazing related factors.

The Alpine Grazing Taskforce conducted a major investigation of all aspects of alpine grazing, and made several pertinent conclusions that are well supported by scientific research (DSE 2005):

- "*The Taskforce finds significant damaging impacts and no overall benefits for the environment from cattle grazing in the Alpine National Park*"
- "*The taskforce concludes that cattle grazing does not make an effective contribution to fuel reduction and wildfire behaviour in the Alpine National Park*"

In addition, the Taskforce found that, while cattle grazing in alpine areas has provided economic benefits to local communities and individual farmers, this was not significant at the regional or state level. Further, the Taskforce found there was an implicit subsidy by the State due to the cost of administering licences, supervising and monitoring grazing and its impacts, and repairing damage caused by cattle (DSE 2005).

There are also cultural aspects to grazing history, with High Country grazing being a long tradition, viewed by some as an important and active part of Victoria's living cultural heritage. Others desiring a natural environment or a wilderness experience see grazing in certain areas as detracting from the natural experience (DSE 2005). The Alpine Grazing Taskforce suggested that the economic value to the tourism industry derived from historical grazing was greater than from its ongoing practice, and concluded that "..*the cultural heritage related to the grazing of livestock in the high country does not depend on ongoing grazing in the park*" (DSE 2005).

<u>Water quality</u>

The alpine region is vital for the provision of high quality water for domestic use, hydro-electricity,

recreation, agriculture and environmental stream flows, and in Victoria many alpine areas are designated as Special Areas under the *Catchment and Land Protection Act 1994*. Cattle harbour pathogens that impact on human health, such as *Campylobacter* (a leading bacterial causative agent of acute diarrhoea in humans), *Escherichia coli* and *Cryptosporidium* (Eamens *et al.* 2003, Olson *et al.* 2004, Barlow and Mellor 2010). The Department of Health found that the risks to public health due to pathogens shed by stock accessing waterways upstream of drinking water off-takes would be several orders of magnitude in excess of tolerable levels without adequate downstream water treatment being in place (Billington *et al.* 2011).

In 2005, consultants Sinclair Knight Merz (SKM) calculated that the estimated 3,980 billion litres of water generated by the Alpine National Park catchment each year was worth over $4 billion (PV 2010). Catchment condition is critical for high quality water yield, yet 60% of the sub-catchments in the Australian alps are in a poor or moderate state because of soil erosion, weed invasion, increased fire and the historic and current presence of introduced ungulates, including cattle (Worboys and Good 2011). Soil erosion in the catchments increases the amount of silt in streams, shortens the life of water impoundments and hydroelectric turbines, and increases the costs of water treatment for downstream users (Worboys and Good 2011).

Climate change impacts

The alpine region represents one of the Australian ecosystems most vulnerable to 'tipping points' from the effects of climate change (Laurence *et al.* 2011), which are already being seen in increased temperatures and reduced snowfall. Flora and fauna taxa that are restricted to the alpine zone are particularly likely to be impacted (Bennett *et al.* 1991, Brereton *et al.* 1995, Whetton 1998, Green and Pickering 2002, Hennessy *et al.* 2003, Hughes 2003). With no true nival (permanent snow) zone in Australia, flora and fauna species have no alternative sites to colonise as the snowline and temperatures ascend the altitudinal gradient. Peatlands are likely to shrink because of a reduction in their climate envelope, with increased temperatures, reduced precipitation, shorter duration of snow cover and increased decomposition of organic peat (Whinam *et al.* 2003b, Jones *et al.* 2006, Whinam and Copson 2006). Control of threatening processes such as cattle grazing is therefore critical to ensure that alpine ecosystems are buffered as much as possible against these climate-induced changes, and that avoidable and manageable threats to endemic species are mitigated as much as possible to give these species the greatest chance of adapting to a changing climate.

Climate change is also likely to increase fire frequency and severity, with increased temperatures and reduced rainfall leading to a higher number of days of very high or extreme fire danger (Hennessy *et al.* 2005, Hennessy 2007). Post-fire recovery of alpine vegetation communities, especially wetlands and heathlands, is hampered by grazing (McDougall 1989, Wahren *et al.* 2001b), and a combination of increased fire with grazing would likely to lead to abrupt, long-term contraction of key vegetation types.

Conservation status

National conservation status

The five parks that comprise Victoria's contribution to the Australian Alps National Parks are included on the National Heritage List (Commonwealth of Australia Gazette No. S237, 7 November 2008). Seven fauna species, eleven flora species and one floristic community listed as threatened under the EPBC Act that are probably affected by cattle grazing (see *Taxa and/or communities of flora and fauna affected*) are within National Heritage areas and are considered 'matters of national environmental significance'.

Victorian conservation status

'Soil erosion and vegetation damage and disturbance in the alpine regions of Victoria caused by cattle grazing' is listed as a potentially threatening process under the FFG Act (Government Gazette G26, p. 1517, 29 June 2000). The Final Recommendation on a Nomination for Listing was satisfied that "The potentially threatening process, in the absence of appropriate management, poses or has the potential to pose a significant threat to the survival of a range of flora or fauna" (SAC 1992).

Cattle grazing also poses a risk to a number of flora, fauna and floristic communities listed as threatened under the FFG Act or on Victorian threatened species advisory lists (*see Tables 1, 2 & 3* (DEPI 2014),(DSE 2013).

Two threats similar to that posed by cattle are also listed under the FFG Act: 'Degradation and loss of habitats caused by feral horses (*Equus caballus*)', and 'Reduction in biodiversity of native vegetation by Sambar (*Cervus unicolor*)'. These heavy ungulates can cause similar damage to cattle, and many of the management actions that would be required to mitigate damage from these taxa would also apply to cattle. 'Degradation of native riparian vegetation along Victorian rivers and streams' is also an FFG-

listed potentially threatening process, with cattle grazing being a major contributor to that process (DSE 2003).

Management issues

The major management issues are the maintenance of natural processes such that natural biodiversity is maintained, and the maintenance of adequate plant cover for soil, water and fauna conservation. Management of the alpine regions within Victoria should be based on firm ecological principles and the evidence of impacts of livestock which have been elucidated over more than 70 years of research.

Past management actions

In 1946, the government departments and graziers acted together to modify land management practices. Grazing by sheep, horses and unauthorised burning-off by grazing licence-holders were banned; the length of the grazing season was limited; and cattle numbers were held at then current levels. Over the following decades, cattle were excluded incrementally from various areas, including Mounts Bogong, Feathertop, Loch and Hotham in the 1950s (DSE 2005), Mount Buffalo in 1958, Mount Baw Baw in 1962 and Lake Mountain in 1978 (Stephenson 1980). Summer grazing at Mt Buller was phased out in the 1970s while additional areas, including the northern Bogong High Plains, Howitt Plains and Wonnangatta Valley, were withdrawn from grazing in 1989 and 1991 (DSE 2005). Most of the remaining national park grazing licences were withdrawn in 2005, with the final four withdrawn in 2006. This grazing had generally been restricted to the summer and autumn months, although it continued year-round in some lower-elevation areas (C. Pascoe, pers. comm.).

Numerous other management actions have been undertaken over the years of cattle grazing in the alpine regions of Victoria:

- Regulation of grazing and administration of grazing licences. This included inspections of licence areas, seasonal forecasts and determination of stocking rates, enforcement of licence conditions and monitoring of impacts
- Working and consulting with researchers, traditional owners, licensees and other stakeholders with respect to grazing issues
- Limited fencing of a small amount of grazing-sensitive or grazing-damaged vegetation
- Vegetation monitoring, and limited fencing and protection of vegetation communities, especially peatlands, following fires in 1998 and 2003
- Rehabilitation of grazed and burnt peatlands on the Wellington Plain and Bogong High Plains following fires in 1998 and 2003 respectively
- Protection of a small number of peatlands from horses and cattle on the Nunniong Plateau
- Removal of ‘wild’ cattle from areas of the Alpine and Snowy River National Parks
- Management of illegal grazing and ‘escapes’ into park or resort areas, including impoundment of stock
- Limited weed control in some grazed areas, mostly by Parks Victoria and to a lesser degree by some licensees. Includes peatland weed control.
- Monitoring of stock access routes (including historic) for weeds and physical impacts
- On-going, long-term condition assessments of peatlands in the Alpine National Park (Wild 2011)
- On-going weed management and rehabilitation of threatened plant species and communities by alpine resorts
- On-going commitment to actions for alpine areas and fens in regional catchment strategies and regional waterway management strategies (e.g. WGCMA 2012, WGCMA 2014)

Past research

The Australian alps caught the attention of both biological and physical scientists over a century ago, and the alps are now one of the most researched environments in Australia. Scientific endeavour commenced with the early explorations of Dr John Lhotsky, Baron Dr Ferdinand von Mueller, Paul Edmund de Strzelecki and includes the later research of the meteorologist Clement Wragge and geologists Reverend W B Clark and Alfred Howitt (DEWHA 2008). In the post-war period, pioneering work by Mrs Maisie Carr (nee Fawcett) and Prof. J. S. Turner on the Bogong High Plains, and Dr Alec Costin and Dane Wimbush in the Kosciuszko region of NSW, examined the intrinsic biological processes operating in the alps, addressing the issue of land degradation in a scientific manner.

Over seven decades of research in the Australian alps, both on the mainland and in Tasmania, has elucidated the natural patterns and processes of plant community distribution and regeneration, and the impacts that livestock have on native vegetation. The research has covered all the major vegetation types - woodland, heathland, grassland, herbfield and peatland (bog) (Costin 1954, 1957b, Carr and Turner 1959a, b, Costin *et al.* 1959, Costin *et al.*

1960, Wimbush 1970, Wimbush and Costin 1979a, b, c, 1983, Leigh *et al.* 1987, Williams and Ashton 1987b, a, Wimbush and Forrester 1988, Leigh *et al.* 1991, Wahren *et al.* 1994, Kirkpatrick and Bridle 1998, 2013). These ecological studies have generally examined responses after the removal of livestock, rather than after the introduction of stock, as all alpine areas were long-grazed when research began in earnest (McDougall *et al.* 2012).

In the Victorian alps, experimental and monitoring work commenced in the mid-1940s (McDougall *et al.* 2012) when several long-term, permanent research plots were established on the Bogong High Plains by Mrs Maisie Carr, including the Pretty Valley grassland and Rocky Valley heathland plots. Since then studies have included vegetation mapping (McDougall 1982, Walsh *et al.* 1984), investigating plant-environment relationships (Costin 1955, Williams 1987, Williams and Ashton 1987a, b, 1988, Williams 1990a, Wahren *et al.* 2001c, Kirkpatrick *et al.* 2014), monitoring of long term trends in vegetation and soil condition in grazing-exclusion plots (Carr and Turner 1959b, Wahren *et al.* 1994, McDougall 2007), simulating disturbances associated with grazing (Williams and Ashton 1987b), assessment of the modes of growth and regeneration of major species (Williams 1990b, a, 1992), the behaviour and diet of cattle (van Rees 1984), the effects of grazing on fire severity or recovery (Wahren *et al.* 2001b, Williams *et al.* 2006, Williamson *et al.* 2014) and the ecology of small invertebrate and vertebrate animals, especially the Mountain Pygmy-possum (e.g. Mansergh and Scotts 1986).

A wide range of other specialised research has been undertaken in recent years, most of which included historic or on-going grazing as an explanatory variable, including studies of climate change (Jarrad *et al.* 2008, Hoffmann *et al.* 2010, Wahren *et al.* 2013), plant functional traits (Venn *et al.* 2011), peatland soils and processes (Grover 2006, Shannon 2011), peatland ionic regulation (Silvester 2009), ecophysiology (Tolsma 2002) and the interactions between grazing and bushfire extent and severity (Williams *et al.* 2006, Williamson *et al.* 2014). As a result of this intense scientific investigation, the ecology of alpine ecosystems and many individual species and plant communities, and in particular their response to grazing, is well-understood.

Three years of data from the Bushfire CRC related to the effects of planned burning and cattle grazing on fuel loads (BFCRC 2009) did not produce conclusive results, with researchers stating that "*the combined effects of fire and grazing may take decades to be fully apparent*" (BFCRC 2014).

University research in progress is examining climate change (ITEX / OzTEX), snowpatch vegetation dynamics, invertebrate trends, wetland trends and plant phenology (H. Wahren, La Trobe University, pers. comm.) and responses being detected in current data are still partially attributable to the long history of alpine grazing. The persistent effects of grazing are also being captured in on-going assessments of peatland vegetation condition across the Victorian alps (Wild 2011)(and subsequent reports) and in on-going monitoring of established plots as part of the Long Term Ecological Research Network (LTERN) (Williams *et al.* 2014).

Conservation objectives

Long term objective

Minimise the impact of cattle on the soils and vegetation of all alpine and sub-alpine ecosystems, such that they can recover from past disturbances and are protected from further degradation.

Objectives of this action statement

The primary objectives are to:

- Improve the knowledge of post-grazing vegetation dynamics and rehabilitation techniques
- Undertake remedial action in areas damaged by cattle grazing to accelerate recovery of alpine ecosystems from past disturbance
- Increase community awareness and support

Intended management actions

The actions in this action statement have been developed taking into consideration relevant social and economic matters, as required under the FFG Act.

The actions in this action statement should have no impact on greenhouse gas emissions above that already occurring in the course of general State Government administration in Victoria (e.g. through use of offices, workforce travel, purchase of goods etc.). Any impact on emissions will be offset by Victorian Government actions to mitigate climate change (see www.climatechange.vic.gov.au for more information).

The intended management actions listed below are further elaborated in DELWP's Actions for Biodiversity Conservation (ABC) system. Detailed information about the actions and locations, including priorities, is held in this system and will be updated annually for land managers and other authorities.

Objective	Objective explanation
To improve the knowledge of post-grazing vegetation dynamics and rehabilitation techniques	Over seven decades of grazing research has been undertaken in the Victorian alps, including some of the longest-running ecological research programs in the world. Long-term data have been critical in allowing us to understand the responses of alpine ecosystems and many individual species and plant communities to grazing. New research into the impacts of grazing is considered redundant because cattle are no longer permitted in most alpine areas, and the re-introduction of cattle to undertake such research would further damage sensitive alpine ecosystems. This action statement will therefore focus on continued monitoring in established research plots, and additional research with a view to improving our understanding of ecosystem processes or remedial actions in key vegetation types. Monitoring of impacts and actions may also be relevant to two other FFG-listed threats: feral horses and Sambar.

Action	Details	Responsible agents
Maintain and support existing monitoring sites to allow long-term comparisons of previously-grazed and long-ungrazed areas in alpine regions	Research questions should include: • How do long periods (over 70 years) of grazing exclusion impact on plant composition and richness? • How long do seeds of alpine plant species remain in the soil seedbank? • How long do seeds of weed species remain in the soil seedbank? • Is there a point at which some sort of disturbance is necessary to ensure all species remain *in-situ*? • How do the direction and rate of contemporaneous changes in recently-grazed plots compare to those measured after grazing was removed in the 1940s? • What changes in long-ungrazed plots might be due to climate change? • To what extent can research from existing alpine research plots be transferred to other alpine areas? Can key plant traits or processes be identified that assist with this transfer?	DELWP

Action	Details	Responsible agents
Determine if alpine vegetation, especially snowpatch herbfield and peatland, is able to recover adequately from grazing impacts without management intervention	Research questions should include: • Has previous management intervention accelerated improvements in vegetation composition or structure? • Has previous management intervention adversely affected peatland structure or vegetation? • Is management intervention needed to repair stream bank damage? • Are cattle-damaged peatlands more susceptible to fire? • Which weed taxa, particularly those associated with past grazing practices (e.g. *Cytisus scoparius* and *Juncus effusus*), require ongoing active management? • Is long-term protection on its own sufficient for eventual displacement of many weeds by native plant species?	DELWP
Develop detailed population monitoring protocols	Establish protocols for assessing alpine vegetation condition, including erosion, bare ground and concentration of weeds	DELWP
Instigate an alps-wide condition assessment of grazing-damaged areas with a view to establishing baseline data and key areas for monitoring and intervention	Priorities include: • Complete the mapping of alpine treeless vegetation types • Map baseline alpine vegetation condition and determine areas of high vulnerability for triage with a view to management intervention • Monitor alps-wide condition and report results spatially on a 5-yearly basis to coincide with state of the parks reporting • Identify key areas requiring additional targeted monitoring, particularly related to management intervention outcomes	DELWP
Identify weed management priorities and develop detailed plan	Investigate cost-effective methods for reducing weed infestations Particular consideration of pasture species, in long-grazed areas	DELWP, Parks Victoria
Monitoring of peatlands	Continue on-going condition monitoring of alpine peatlands. Monitoring of threatened fauna in sensitive ecosystems such as peatlands as those systems recover.	DELWP

Objective	Objective explanation
Undertake remedial action in areas damaged by cattle grazing to accelerate recovery of alpine ecosystems from past disturbance	On-going threats to biodiversity values will be addressed by integrated, cross region management actions by a range of agencies, including catchment management authorities. Actions may include the removal of cattle from key state forest areas, the prevention of cattle access to sensitive areas or the rehabilitation of damaged vegetation types. Management actions will be applied to achieve biodiversity objectives at a range of scales and will be monitored and evaluated.

Action	Details	Responsible agents
Conduct surveillance and information gathering for compliance investigation	Increase compliance activities regarding the protection of *Sphagnum* and associated ecological communities consistent with any existing Forest Management Plans, *National Parks Act*, FFG Act, EPBC Act and *Planning and Environment Act*. Undertake surveillance as part of compliance activities in areas where there are reports of wild or deliberately/illegally introduced cattle.	DELWP
Identify alpine vegetation types in State Forests and conservation reserves in which livestock grazing is currently permitted and examine options for protecting them from livestock	Consider options for removing cattle from all State Forest areas with sub-alpine vegetation or EPBC-listed bogs (peatlands) mapped in Departmental databases (areas generally above 1000 m elevation) Fence off sensitive alpine vegetation such as peatlands to prevent cattle access Provide water points independent of the vegetation community, such as spring-fed troughs	DELWP
Prevent access of cattle to sensitive areas	Consider options for removing cattle grazing above 1000 m where grazing impacts on the values of areas designated as Special Protection Zones (for flora protection purposes) under the Comprehensive Adequate & Representative (CAR) Reserve System (e.g. protection of old growth or protection of EVC). Consider options for removing cattle grazing above 1000 m in areas designated as Special Areas under the *Catchment and Land Protection Act 1994*. Implement removal programs for new or current small populations of wandering or wild cattle. Ensure protocols are in place to prevent stock wandering away from licensed grazing areas, or allow rapid detection and remediation of such wandering. Investigate reference areas to identify potential impacts of cattle grazing	DELWP

Action	Details	Responsible agents
Manage environmental weeds	Minimise the impacts of weeds in currently or previously grazed alpine areas, by: • Identifying and mapping areas with severe weed infestations • Determining priority areas for management action • Undertaking surveillance of weeds, including new outbreaks • Eradicating, containing or controlling existing or new weeds	DELWP
Manage erosion	Minimise non-natural soil erosion in the alps catchments, by: • Identifying areas with grazing-induced soil erosion and evaluate potential for remedial action • Undertaking remedial action if practicable. This may include controlling feral horses and deer that might be interfering with remedial action.	DELWP
Rehabilitation of damaged peatlands	Identify areas where artificial drains associated with historic grazing activities are impacting on alpine peatlands, and examine feasibility of removing or rehabilitating them. Identify areas where grazing-induced drainage lines are impacting on the water-holding capacity of bogs, and undertake remedial action if practical.	DELWP

Objective	Objective explanation
Increase community awareness and support	Meeting the conservation objectives of this action statement requires strategic management of the grazing threat across various land tenures. This needs cooperation between all stakeholders, including government agencies, landholders and the broader community. Improving community awareness of the effects of cattle grazing, including impacts on biodiversity, threats to riparian vegetation, impacts on water supply and quality, and its ineffectiveness as a fire management tool, will assist in meeting the conservation objective.

Action	Details	Responsible agents
Liaise with private landowners	Encourage landowners to minimise the impact of cattle on sensitive vegetation on freehold land, especially alpine peatlands. Encourage landowners to provide water points that are independent of sensitive vegetation.	DELWP

Action	Details	Responsible agents
Promote community involvement programs	Involve stakeholder groups and volunteers in remediation programs, such as weed control and riparian revegetation. Encourage the community to report sightings of wandering or wild cattle, or signs such as cowpats, pugging or salt licks, to their local DELWP or Parks Victoria office.	DELWP
Engage licensees	Ensure current state forest licensees are aware of the implications of stock wandering from their grazing licence areas, and that they take adequate steps to prevent this.	DELWP

Personal Communications

Charlie Pascoe, District Program Manager, Parks Victoria

David Burton, Ranger in Charge, Parks Victoria

Felicity Brooke, Natural Resource Manager, Parks Victoria

Dr Henrik Wahren, Department of Agricultural Sciences, La Trobe University

Nick Clemann, Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning

Dr Tarmo Raadik, Arthur Rylah Institute, Department of Environment, Land, Water and Planning

References

Ashton, D.H., and Williams, R.J. 1989. Dynamics of the sub-alpine vegetation in the Victorian region. Pages 143-168 *In* Good, R. (eds) The Scientific Significance of the Australian Alps: *The Proceedings of the First Fenner Conference on the Environment. Australian Alps National Parks* Liaison Committee.

Barlow, R.S., and Mellor, G.E. 2010. Prevalence of enterohemorrhagic Escherichia coli serotypes in Australian beef cattle. *Foodborne Pathogens and Disease* **7**: 1239-1245.

Bennett, S.B., Mansergh, I., Berwick, S., Sandiford, K., and Wellington, C. 1991. *The Potential Effect of the Enhanced Greenhouse Climate Change on Selected Victorian Fauna*. Technical Report Series No. 123, Arthur Rylah Institute, Heidelberg.

Berger, L., Marantelli, G., Skerratt, L.F., and Speare, R. 2005. Virulence of the amphibian chytrid fungus Batrachochytrium dendrobatidis varies with the strain. *Diseases of Aquatic Organisms* **68**: 47-50.

BFCRC 2009. Fire and cattle: impacts on high country. Fire Note 28, Bushfire CRC

BFCRC. 2014. The highfire project. <http://www.bushfirecrc.com/projects/b6/highfire-project> Bushfire CRC.

Billington, K., Deere, D., Ryan, U., Stevens, D., and Davison, A. 2011. Public Health Issues Associated With Stock Accessing Waterways Upstream of Drinking Water Off-Takes. Report to Department of Health Victoria, Water Futures Pty Ltd, Killara.

Brereton, R., Bennett, S., and Mansergh, I. 1995. Enhanced greenhouse climate change and its potential effect on selected fauna of SE Australia: a trend analysis. *Biological Conservation* **72**: 339-354.

Cabena, P.B. 1980. Grazing the High Country: an Historical and Political Geography of High Country Grazing in Victoria, 1835-1935. MA Thesis, The University of Melbourne.

Carr, S.G.M., and Turner, J.S. 1959a. The ecology of the Bogong High Plains I. The environmental factors and the grassland communities. *Australian Journal of Botany* **7**: 12-33.

Carr, S.G.M., and Turner, J.S. 1959b. The ecology of the Bogong High Plains II. Fencing experiments in grassland C. Australian *Journal of Botany* **7**: 34-63.

Castelle, A.J., Johnson, A.W., and Conolly, C. 1994. Wetland and stream buffer size requirements - A review. *Journal of Environmental Quality* **23**: 878-882.

Clemann, N., Hunter, D., Scroggie, M., Pietsch, R., and Hollis, G. 2009. Vanishing frogs: prevalence of the Amphibian Chytrid Fungus (Batrachochytrium dendrobatidis) in populations of key species from the Australian Alps. Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Heidelberg.

Costin, A.B. 1954. A Study of the Ecosystems of the Monaro Region of New South Wales. Soil Conservation Service, NSW, Sydney.

Costin, A.B. 1955. Alpine soils in Australia with reference to conditions in Europe and New Zealand. *Journal of Soil Science* **6**: 35-50.

Costin, A.B. 1957a. High Mountain Catchments in Victoria in Relation to Land Use. Soil Conservation Authority of Victoria.

Costin, A.B. 1957b. The high mountain vegetation of Australia. *Aust. J. Bot*. **5**: 173-189.

Costin, A.B. (1983). Mountain lands in the Australasian region. Proceedings of the Ecological Society of Australia 12: 1-13.

Costin, A.B., Wimbush, D.J., and Kerr, D. 1960. Studies in catchment hydrology in the Australian alps. II. Surface run-off and soil loss. Technical paper Technical Paper No. 14, CSIRO Division of Plant Industry, Melbourne.

Costin, A.B., Wimbush, D.J., Kerr, D., and Gay, L.W. 1959. Studies in catchment hydrology in the Australian alps. I. Trends in soils and vegetation. Technical paper Technical Paper No. 13, CSIRO Division of Plant Industry, Melbourne.

Davies, P.E., and Nelson, M. 1994. Relationships between riparian buffer strip widths and the effects of logging on stream habitat, invertebrate community composition and fish abundance. *Australian Journal of Marine and Freshwater Research* **45**: 1298-1305.

Department of the Environment (DE) 2014. Draft Alpine Sphagnum Bogs and Associated Fens Recovery Plan. Department of the Environment, Canberra.

DE. 2015a. EPBC Act List of Threatened Fauna. Retrieved March 2015: <http://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=fauna.

DE. 2015b. EPBC Act List of Threatened Flora. Retrieved March 2015: http://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=flora.

Department of Environment and Primary Industries (DEPI) 2014. Advisory List of Rare or Threatened Plants in Victoria - 2014. Retrieved March 2015: http://www.depi.vic.gov.au/environment-and-wildlife/threatened-species-and-communities/threatened-species-advisory-lists.

Department of the Environment, Water, Heritage and the Arts (DEWHA). 2008. AHC final assessment report: Australian Alps. Retrieved March 2015: http://www.google.com.au/url?url=http://www.environment.gov.au/system/files/pages/c513f592-8647-4651-b772-480635213c34/files/australian-alps.rtf&rct=j&frm=1&q=&esrc=s&sa=U&ei=dwUBVYXeJdS68gX6noAw&ved=0CBQQFjAA&usg=AFQjCNFDC1Cjo1ocJ9wqLUTZjwx2Dqw-oQ.

Downes, R.G. 1962. The Victorian high plains - the environment and its use. *Proc. R. Soc. Vic*. **75**: 339-347.

Department of Sustainability and Environment (DSE) 2003. FFG Action Statement No. 183. Degradation of native riparian vegetation along Victorian rivers and streams.

DSE. 2005. Report of the Investigation Into the Future of Cattle Grazing in the Alpine National Park. Department of Sustainability and Environment, for the Alpine Grazing Taskforce, East Melbourne.

DSE 2009. Advisory List of Threatened Invertebrate Fauna in Victoria - 2009. Retrieved March 2015: http://www.depi.vic.gov.au/environment-and-wildlife/threatened-species-and-communities/threatened-species-advisory-lists..

DSE 2013. Advisory List of Threatened Vertebrate Fauna in Victoria - 2013. Retrieved March 2015: http://www.depi.vic.gov.au/environment-and-wildlife/threatened-species-and-communities/threatened-species-advisory-lists..

Eamens, G.J., Hornitzky, M.A., Walker, K.H., Hum, S.I., Vanselow, B.A., Bailey, G.D., Cronin, J.P., and Gill, P.A. 2003. A study of the foodborne pathogens: Campylobacter, Listeria and Yersinia in faeces from slaughter-age cattle and sheep in Australia (online). *Communicable Diseases Intelligence Quarterly Report* **27**: 249-257.

Gibson, N., and Kirkpatrick, J.B. 1989. Effects of the cessation of grazing on the grasslands and grassy woodlands of the Central Plateau, Tasmania. Aust. *J. Bot.* **37**: 55-63.

Green, K., and Pickering, C.M. 2002. A scenario for mammal and bird diversity in the Snowy Mountains of Australia in relation to climate change. In Korner, C. and Spehn, E.M. (eds) Mountain Biodiversity: A Global Assessment. Parthenon, London.

Greenwood, K.L., and McKenzie, B.M. 2001. Grazing effects on soil physical properties and the consequences for pastures: a review. Australian *Journal of Experimental Agriculture* **41**: 1231-1250.

Grover, S.P.P. 2006. Carbon and Water Dynamics of Peat Soils in the Australian Alps. PhD thesis, La Trobe University.

Grover, S.P.P., McKenzie, B.M., Baldock, J.A., and Papst, W.A. 2005. Chemical characterisation of bog peat and dried peat of the Australian Alps. *Australian Journal of Soil Research* **43**: 963-971.

Hennessy, K., Lucas, C., Nicholls, N., Bathols, J., Suppiah, R., and Ricketts, J. 2005. Climate Change Impacts on Fire-Weather in South-East Australia. CSIRO Marine and Atmospheric Research, Bushfire CRC and Australian Bureau of Meteorology.

Hennessy, K., Whetton, P., Smith, I., Bathols, J., Hutchinson, M., and Sharples, J. 2003. The Impact of Climate Change on Snow Conditions in Mainland Australia. CSIRO Atmospheric Research, Aspendale.

Hennessy, K.J. 2007. Fire weather. In Pearce, K.B., Holper, P.N., Hopkins, M., Bouma, W.J., Whetton, P.H., Hennessy, K.J., and Power, S.B. (eds) Climate Change in Australia: Technical Report 2007. CSIRO Marine and Atmospheric Research, Aspendale.

Hoffmann, A.A., Camac, J.S., Williams, R.J., Papst, W., Jarrad, F.C., and Wahren, C.-H. 2010. Phenological changes in six Australian subalpine plants in response to experimental warming and year-to-year variation. *Journal of Ecology* **98**: 927-937.

Hope, G., Nanson, R., and Jones, P. 2012. Peat-Forming Bogs and Fens of the Snowy Mountains of NSW. Technical Report. Office of Environment and Heritage, Sydney South.

Hosking, J.R., Smith, J.M.B., and Sheppard, A.W. 1998. Pages 77-88 *In* Panetta, F.D., Groves, R.H., and Shepherd, R.H.C. (eds) The Biology of Australian Weeds, Vol. 2: Cytisus scoparius L., Scotch Broom. R.G. and F.J. Richardson, Melbourne.

Hughes, L. 2003. Climate change and Australia: trends, projections and impacts. *Austral Ecology* **28**: 423-443.

Jarrad, F.C., Wahren, C.-H., Williams, R.J., and Burgman, M.A. 2008. Impacts of experimental warming and fire on phenology of sub-alpine open-heath species. *Australian Journal of Botany* **56**: 617-629.

Jones, M.B., Donnelly, A., and Albanito, F. 2006. Responses of Irish vegetation to future climate change. Biology and Environment: Proceedings of the Royal Irish Academy 106B: 323-334.

Kirkpatrick, J.B., and Bridle, K.L. (1998). Environmental relationships of floristic variation in the alpine vegetation of southeast Australia. *Journal of Vegetation Science* **9**: 251-260.

Kirkpatrick, J.B., and Bridle, K.L. 2013. Natural and cultural histories of fire differ between Tasmanian and mainland Australian alpine vegetation. *Australian Journal of Botany* **61**: 465-474.

Kirkpatrick, J.B., Green, K., Bridle, K.L., and Venn, S.E. 2014. Patterns of variation in Australian alpine soils and their relationships to parent material, vegetation formation, climate and topography. *Catena* **121**: 186-194.

Laurence, W.F., Dell, B., Turton, S.M., Lawes, M.J., Hutley, L.B., McCallum, H., Dale, P., Bird, M., Hardy, G., Prideaux, G., Gawne, B., McMahon, C.R., Yu, R., Hero, J.-M., Schwarzkopf, L., Krockenberger, A., Douglas, M., Silvester, E., Mahony, M., Vella, K., Saikia, U., Wahren, C.-H., Xu, Z., Smith, B., and Cocklin, C. 2011. The 10 Australian ecosystems most vulnerable to tipping points. *Biological Conservation* **144**: 1472-1480.

Lawrence, R.E. 1995. The effects of grazing activity on the hydrology of the Bogong High Plains, Australia. *Rangeland Journal* **17**: 138-153.

Lawrence, R.E. 1999. Vegetation changes on the Bogong High Plains from the 1850s to 1950s. Proceedings of the Royal Society of Victoria 111: xxix-lii.

Leigh, J.H., Wimbush, D.J., Wood, D.H., Holgate, M.D., Slee, A.V., Stanger, M.G., and Forrester, R.I. 1987. Effects of rabbit grazing and fire on a subalpine environment. I. Herbaceous and shrubby vegetation. *Aust. J. Bot*. **35**: 433-464.

Leigh, J.H., Wood, D.H., Slee, A.V., and Holgate, M. 1991. The effects of burning and simulated grazing on productivity, forage quality, mortality and flowering of eight subalpine herbs in Kosciusko National Park. *Aust. J. Bot*. **39**: 97-118.

Mansergh, I.M., and Scotts, D.J. 1986. Winter occurrence of the Mountain Pygmy-possum Burramys parvus (Broom) (Marsupialia: Burramidae) on Mt Higginbotham, Victoria. *Australian Mammalogy* **9**: 35-42.

McDonald, L.G., and Stretton, L.E.B. 1946. Victoria. Report of the Royal Commission to Inquire Into Forest Grazing: Together With Minutes of Evidence. J. J. Gourley, Government Printer, Melbourne.

McDougall, K. 1982. The Alpine Vegetation of the Bogong High Plains. Environmental Studies Series No. 357, Soil Conservation Authority, Victoria.

McDougall, K.L. 1989. The effect of excluding cattle from a mossbed on the Bogong High Plains, Victoria. Department of Conservation, Forests and Lands, East Melbourne.

McDougall, K.L. 2007. Grazing and fire in two subalpine peatlands. *Australian Journal of Botany* **55**: 42-47.

McDougall, K.L., Morgan, J.W., Walsh, N.G., and Williams, R.J. 2005. Plant invasions in treeless vegetation of the Australian Alps. Perspectives in Plant Ecology, *Evolution and Systematics* **7**: 159-171.

McDougall, K.L., and Walsh, N.G. 2007. Treeless vegetation of the Australian Alps. *Cunninghamia* **10**: 1-57.

McDougall, K.L., Williams, R.J., and Wahren, C.-H. 2012. The ecology of domestic grazing in the Australian Alps. Pages 27-40 In Arevalo, H.R. (eds) Grazing Ecology: Vegetation and Soil Impact. Nova Science Publishers Inc., New York.

McMahon, A., Carr, G., and Sutton, F. 2009. Fainter Ridge Willow Infestation. Report to Parks Victoria, Ecology Australia.

Meagher, D. 2004. A count of cattle droppings in Pretty Valley, Bogong High Plains. Unpublished report to the Alpine Grazing Taskforce.

National Heritage Trust (NHT) 2003. Weeds of National Significance: Weed Management Guide, Willow - Salix spp., Department of the Environment and Heritage and the CRC for Australian Weed Management.

Olson, M.E., O'Handley, R.M., Ralston, B.J., McAllister, T.A., and Thompson, R.C.A. 2004. Update on Cryptosporidium and Giardia infections in cattle. *Trends in Parasitology* **20:** 185-191.

Parks Victoria (PV) 2010. Greater Alpine National Parks Management Plan - Water and Catchments Discussion Paper. Melbourne.

Scientific Advisory Committee (SAC) 1992. Final Recommendation on a Nomination for Listing: Soil erosion and vegetation damage and disturbance in the alpine regions of Victoria caused by cattle grazing (Potentially Threatening Process).

Scheele, B.C., Hunter, D.A., Skerratt, L.F., Brannelly, L.A., and Driscoll, D.A. 2015. Low impact of chytridiomycosis on frog recruitment enables persistence in refuges despite high adult mortality. *Biological Conservation* **182**: 36-43.

Shannon, J.M. 2011. Vegetation Patterns and Dynamics in the Highland Peatlands of Eastern Victoria, Australia. PhD Thesis. La Trobe University.

Sheppard, A.W., Hodge, P., and Paynter, Q. 2000. Factors affecting broom regeneration in Australia and their management implications. *Plant Protection Quarterly* **15**: 156-161.

Silvester, E. 2007. Diurnal Patterns in Stream Water Constituents as Indicators of Peatland Condition. Report to Parks Victoria. Research Centre for Applied Alpine Ecology, La Trobe University, Albury-Wodonga.

Silvester, E. 2009. Ionic regulation in an alpine peatland in the Bogong High Plains, Victoria, Australia. *Environmental Chemistry* **6**: 424-431.

Simpson, L.A. 2002. Assessment of the Effect of Cattle Exclusion on the Condition and Recovery of Subalpine Streams. Honours. University of Canberra.

Skerratt, L.F., Berger, L., Speare, R., Cashins, S., McDonald, K.R., Phillott, A.D., Hines, H.B., and Kenyon, N. 2007. Spread of chytridiomycosis has caused the rapid global decline and extinction of frogs. *EcoHealth* **4:** 125-134.

Stephenson, H. 1980. Cattlemen & Huts of the High Plains. Graphic Books, Armadale.

Stuart, S.N., Chanson, J.S., Cox, N.A., Young, B.E., Rodrigues, A.S.L., Fischman, D.L., and Waller, R.W. 2004. Status and trends of amphibian declines and extinctions worldwide. *Science* **306**: 1783-1786.

Tolsma, A., Shannon, J., Papst, W., Rowe, K., and Rosengren, N. 2005. An Assessment of the Condition of Mossbeds on the Bogong High Plains. Report to the Department of Sustainability and Environment. Arthur Rylah Institute for Environmental Research and Research Centre for Applied Alpine Ecology, La Trobe University.

Tolsma, A.D. 2002. The Effects of Fire and Grazing on the Energy Reserves of Resprouting Plants in Victoria's Alpine Grasslands. PhD Thesis, The University of Melbourne.

van Rees, H. 1984. Behaviour and Diet of Free-ranging Cattle on the Bogong High Plains Victoria. Environmental Studies Publication E.S.P. No. 409, Department of Conservation, Forests and Lands, Victoria.

Venn, S.E., Green, K., Pickering, C.M., and Morgan, J.W. 2011. Using plant functional traits to explain community composition across a strong environmental filter in Australian alpine snowpatches. *Plant Ecology* **212**: 1491-1499.

Wahren, C.-H., Camac, J.S., Jarrad, F.C., Williams, R.J., Papst, W.A., and Hoffmann, A.A. 2013. Experimental warming and long-term vegetation dynamics in an alpine heathland. Australian *Journal of Botany* **61**: 36-51.

Wahren, C.-H., Williams, R.J., and Papst, W.A. 1999a. Alpine and subalpine wetland vegetation on the Bogong High Plains, south-eastern Australia. *Australian Journal of Botany* **47**: 165-188.

Wahren, C.-H., Williams, R.J., and Papst, W.A. 2001a. Alpine and subalpine snow patch vegetation on the Bogong High Plains, SE Australia. *Journal of Vegetation Science* **12**: 779-790.

Wahren, C.-H.A., Papst, W.A., and Williams, R.J. 1994. Long-term vegetation change in relation to cattle grazing in subalpine grassland and heathland on the Bogong High Plains: An analysis of vegetation records from 1945 to 1994. *Australian Journal of Botany* **42**: 607-639.

Wahren, C.-H.A., Papst, W.A., and Williams, R.J. 1999b. Post-fire regeneration in Victorian alpine and sub-alpine vegetation. in Australian Bushfire Conference. School of Environmental & Information Sciences, Charles Sturt University, Albury.

Wahren, C.-H.A., Papst, W.A., and Williams, R.J. 2001b. Early post-fire regeneration in subalpine heathland and grassland in the Victorian Alpine National Park, south-eastern Australia. *Austral Ecology* **26**: 670-679.

Wahren, C.-H.A., Williams, R.J., and Papst, W.A. 2001c. Vegetation change and ecological processes in alpine and subalpine Sphagnum bogs of the Bogong High Plains, Victoria, Australia. Arctic, *Antarctic and Alpine Research* **33**: 357-368.

Walsh, N.G., Barley, R.H., and Gullan, P.K. 1984. The Alpine Vegetation of Victoria (excluding the Bogong High Plains Region). Environmental Studies Publication E.S.P. No. 376, Department of Conservation, Forests and Lands, Victoria.

Western, A., Rutherfurd, I., Sirawardena, L., Lawrence, R., Ghadirian, P., Coates, F., and White, M. 2009. The Geography and Hydrology of High Country Peatlands in Victoria. Part 2. The Influence of Peatlands on Catchment Hydrology. Arthur Rylah Institute for Environmental Research, Technical Report Series No. 174, Department of Sustainability and Environment, Heidelberg, Victoria.

West Gippsland Catchment Management Authority (WGCMA) 2012. West Gippsland Regional Catchment Strategy 2013-2019. Traralgon.

WGCMA. 2014. West Gippsland Waterway Strategy 2014-2022. Traralgon.

Whetton, P. 1998. Climate change impacts on the spatial extent of snow-cover in the Australian alps. *In* Green, K. (eds) Snow: A Natural History; An Uncertain Future. Surrey Beatty and Sons, Chipping North.

Whinam, J., Barmuta, L.A., and Chilcott, N. 2001. Floristic description and environmental relationships of Tasmanian Sphagnum communities and their conservation management. *Australian Journal of Botany* **49**: 673-685.

Whinam, J., and Chilcott, N. 2002. Floristic description and environmental relationships of Sphagnum communities in NSW and the ACT and their conservation management. *Cunninghamia* **7**: 463-500.

Whinam, J., Chilcott, N.M., and Morgan, J.W. 2003a. Floristic composition and environmental relationships of Sphagnum-dominated communities in Victoria. *Cunninghamia* **8**: 162-174.

Whinam, J., and Copson, G. 2006. Sphagnum moss: an indicator of climate change in the sub-Antarctic. *Polar Record* **42:** 43-49.

Whinam, J., Hope, G.S., Clarkson, B.R., Buxton, R.P., Alspach, P.A., and Adam, P. 2003b. Sphagnum in peatlands of Australasia: Their distribution, utilisation and management. *Wetlands Ecology and Management* **11**: 37-49.

Wild, A. 2011. Peatland Monitoring Protocol. Wild Ecology, Hobart.

Williams, R., Papst, W., McDougall, K., Mansergh, I., Heinze, D., Camac, J., Nash, M., Morgan, J., and Hoffmann, A. 2014. Alpine ecosystems. Pages 167-212 *In* Lindenmayer, D., Burns, E., Thurgate, N., and Lowe, A. (eds) Biodiversity and Environmental Change: Monitoring, Challenges and Direction. CSIRO Publishing, Collingwood.

Williams, R.J. 1987. Patterns of air temperature and accumulation of snow in subalpine heathlands and grasslands on the Bogong High Plains, Victoria. Aust. J. Ecol. 12: 153-163.Williams, R.J. (1990a). Cattle grazing within subalpine heathland and grassland communities on the Bogong High Plains: disturbance, regeneration and the shrub-grass balance. *Proc. Ecol. Soc. Aust*. **16**: 255-265.

Williams, R.J. 1990b. Growth of subalpine shrubs and snowgrass following a rare occurrence of frost and drought in southeastern Australia. *Arct. Alp. Res.* **22**: 412-422.

Williams, R.J. 1992. Gap dynamics in subalpine heathland and grassland vegetation in south-eastern Australia. *Journal of Ecology* **80**: 343-352.

Williams, R.J., and Ashton, D.H. 1987a. The composition, structure and distribution of heathland and grassland communities in the subalpine tract of the Bogong High Plains, Victoria. *Aust. J. Ecol.* **12**: 57-71.

Williams, R.J., and Ashton, D.H. 1987b. Effects of disturbance and grazing by cattle on the dynamics of heathland and grassland communities on the Bogong High Plains, Victoria. *Aust. J. Bot*. **35**: 413-431.

Williams, R.J., and Ashton, D.H. 1988. Cyclical patterns of regeneration in subalpine heathland communities on the Bogong High Plains, Victoria. *Australian Journal of Botany* **36:** 605-619.

Williams, R.J., and Costin, A.B. 1994. Alpine and subalpine vegetation. Pages 467-500 *In* Groves, R.H. (eds) Australian Vegetation. University Press, Cambridge.

Williams, R.J., Mansergh, I.M., Wahren, C.-H.A., Rosengren, N.J., and Papst, W.A. 2003. Alpine landscapes. *In* Attiwill, P.M. and Wilson, B. (eds) Ecology: An Australian Perspective. Oxford University Press, Oxford.

Williams, R.J., Wahren, C.-H., Bradstock, R.A., and Muller, W.J. 2006. Does alpine grazing reduce blazing? A landscape test of a widely-held hypothesis. *Austral Ecology* **31**: 925-936.

Williams, R.J., Wahren, C.-H., Stott, K.A.J., Camac, J.S., White, M., Burns, E., Harris, S., Nash, M., Morgan, J.W., Venn, S., Papst, W.A., and Hoffmann, A.A. in press. An IUCN Red List Ecosystems Risk Assessment for Alpine Snow Patch Herbfields, South-Eastern Australia. Austral Ecology.

Williams, R.J., Wahren, C.-H., Tolsma, A.D., Sanecki, G.M., Papst, W.A., Myers, B.A., McDougall, K.L., Heinze, D.A., and Green, K. 2008. Large fires in Australian alpine landscapes: their part in the historical fire regime and their impacts on alpine biodiversity. *International Journal of Wildland Fire* **17**: 793-808.

Williamson, G.J., Murphy, B.P., and Bowman, D.M.J.S. 2014. Cattle grazing does not reduce fire severity in eucalypt forests and woodlands of the Australian Alps. *Austral Ecology* **39**: 462-468.

Wimbush, D.J. 1970. Hydrological Studies on Sphagnum Bogs in the Snowy Mountains, New South Wales. Masters thesis, University ofSydney .

Wimbush, D.J., and Costin, A.B. 1979a. Trends in vegetation at Kosciusko. I. Grazing trials in the subalpine zone, 1957-1971. *Aust. J. Bot.* **27**: 741-787.

Wimbush, D.J., and Costin, A.B. 1979b. Trends in vegetation at Kosciusko. II Subalpine range transects, 1959-1978. *Aust. J. Bot.* **27**: 789-831.

Wimbush, D.J., and Costin, A.B. 1979c. Trends in vegetation at Kosciusko. III Alpine range transects, 1959-1978. *Aust. J. Bot.* **27:** 833-871.

Wimbush, D.J., and Costin, A.B. 1983. Trends in drainage characteristics in the subalpine zone at Kosciusko. *Proc. Ecol. Soc. Aust.* **12**: 143-154.

Wimbush, D.J., and Forrester, R.I. 1988. Effects of rabbit grazing and fire on a subalpine environment. II. Tree vegetation. *Aust. J. Bot.* **36**: 287-298.

Worboys, G.L., and Good, R.B. 2011. Caring For Our Australian Alps Catchments: Summary Report For Policy Makers. Department of Climate Change and Energy Efficiency, Canberra.

www.delwp.vic.gov.au