Chapter 10

fauna values (with reference to introduced vertebrates)

Ian Mansergh, Alan Newsome
and David Shorthouse

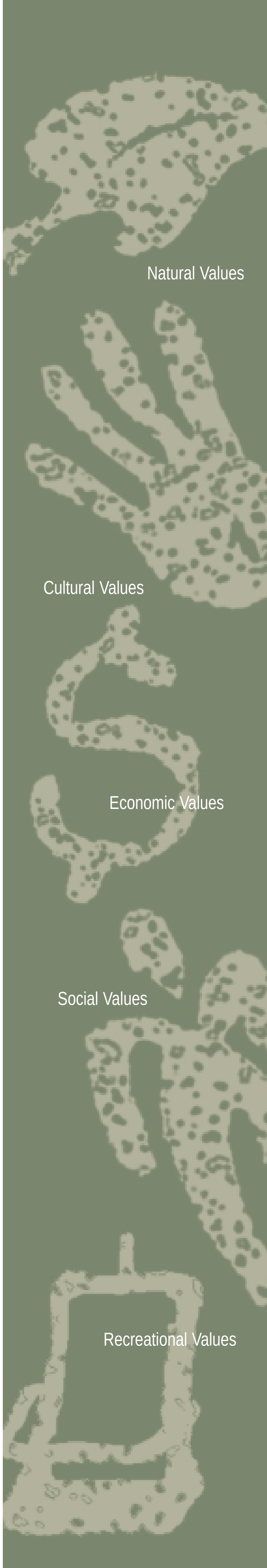
"The park's diverse habitats support populations of about 300 native terrestrial (non-aquatic) vertebrate species — mostly Australian endemics — and an unknown number of invertebrate species."

Summary

This report was commissioned by New South Wales (NSW) National Parks and Wildlife Service (NPWS) as part of the brief to the Independent Scientific Committee (ISC) to examine the scientific significance and condition of attributes of the Kosciuszko National Park. The park's diverse habitats support populations of about 300 native terrestrial (non-aquatic) vertebrate species — mostly Australian endemics — and an unknown number of invertebrate species. The Kosciuszko faunal assemblage is of national significance, and it makes a major contribution to an internationally significant environmental region that includes the adjacent Alpine National Park in Victoria and Namadgi National Park in the Australian Capital Territory (ACT).

Contribution to international significance

- The total vertebrate biodiversity of Kosciuszko National Park compares very well with other (large) temperate montane/alpine national parks in North and South America, and is significant for the presence of representatives of all subclasses and infraclasses of mammals (Monotremata, Marsupialia and Eutheria). The high diversity of reptile species, especially above the snowline, is also notable.



- Thirteen vertebrate taxa with populations in the park are listed as threatened or near threatened by the World Conservation Union (IUCN).

- The international significance of the mountain pygmy-possum and a variety of other features lends strength to the acceptance of the area under World Heritage criterion (i). If invertebrates — poorly known at present — are considered, criterion (iii), perhaps criterion (i), and the biodiversity representation aspects of (iv) would be met or exceeded.

- Some long-term studies in the park are internationally important in helping to resolve global scientific-conservation questions, and the park is well placed to assist the international investigations into greenhouse climate change and its effects on biodiversity.

Contribution to national and state significance

- Terrestrial habitats of the alpine and subalpine zone (15% of the park area) support populations of 100 native species, including endemic or alpine specialists — one mammal, four frogs, four reptiles and a range of invertebrates (eg 10 species of Orthoptera and 10 species of megascolecid earthworms).

- The unique features of the Australian Alps bioregion and the high percentage of its area that is managed for biodiversity conservation indicate that its actual and potential value in a continental context will increase in the future.

- The size and land management status (national park) and altitudinal gradients of the forest and woodland habitats surrounding the alpine environment enable a wide range of taxa to be supported. Habitats in these areas support numerous populations of threatened species and provide critical elements of habitat that have been depleted elsewhere (eg mature seral stages). From an ecological viewpoint, the fauna contributes to the health of the vegetation and the provision of ecosystem services.

- Predications of the effects of enhanced greenhouse climate change suggest that the alpine environments and their dependent biota are amongst the most vulnerable environments in Australia, and their protection and that of the adjacent eucalypt montane forests and woodlands are vital for biodiversity conservation at the national scale.

Condition

General assessments of condition and trends are difficult to make. An important element that is yet to be undertaken is a systematic evaluation of the condition of vegetation and habitats in Kosciuszko National Park, based on a scientifically valid methodology.

- Although most of the land area is managed positively or benignly for biodiversity conservation, populations of some species (and the taxa themselves) are declining or remain highly threatened — most notably, amphibians and some mammals in the alpine area and drier forests.

- The extent of mature seral vegetation types and the consequent critical resources (eg tree hollows) affects the distribution and abundance of many threatened species, and needs to be maximised in management. Fire regimes are a critical process in this regard, and in the distribution and abundance of other functional elements (eg nutrient- cycling fungi).

- About 20 exotic vertebrate species have established feral populations in Kosciuszko National Park and each adversely effects the native fauna, and/or its habitat and trophic level function, in various ways. These pest animals include grazing ungulates (feral horse *Equus caballus*, sambar deer *Cervus unicolor*), rabbits *Orytolagus cuniculus*, mammalian predators (red fox *Vulpes vulpes*, feral cat *Felis catus*) and a variety of birds. The natural pre-European grazing regime is under pressure.

- The natural pre-European predator hierarchy (dingo *Canis familiaris dingo* and two quoll species) is highly disrupted and being replaced by a dingo/dog–fox–cat regime. Restoration of the prior regime should be a major priority of management. This will make a major contribution to the conservation of many threatened species. The disruption of the predator regime is likely to have a 'trophic cascade' effect on other trophic levels.

- The large number of exotic herbivores in the park collectively is a major threat to Kosciuszko National Park.

Introduction

This report was commissioned by NSW NPWS as part of the brief given to the ISC to examine the scientific significance, condition and trends of attributes of the Kosciuszko National Park. This is being done in the context of the review of the Kosciuszko National Park Plan of Management (NSW NPWS 1992) which, although revised in 1992, essentially dates from over two decades ago. Since the publication of the management plan in 1982 (NSW NPWS 1992 rev.), there have been scientific advances in our understanding of the biology, ecology and conservation of the vertebrate fauna. A major reason for these advances has been the threatened status of several species, and taxonomic work has further clarified the status of several species.

This report examines the terrestrial fauna, with particular emphasis on native vertebrates. The basic structure (eg basis for management, examination by broad habitat types), themes (eg ecological function) and time frame were provided to the NPWS as part of the broader work of the ISC. The condition and trends of the biodiversity assets is a difficult and complex issue, data sources are few and, where they exist, what is the baseline? Here we endeavour to present and synthesise some available knowledge, discuss relevant issues and, hopefully provide some perspectives and insights that may inform both the community and future management of Kosciuszko National Park.

Basis for management

The fauna of the park is protected under legislation that is specific to the park as well as under other NSW and Commonwealth legislation. Thus, the *National Parks and Wildlife Act 1974* (NSW) provides for a plan of management for the park, and requires that consideration be given to a range of objectives. In addition to conservation of wildlife, the plan of management includes other objectives relating to fauna conservation, such as maintaining the natural environmental processes as far as possible, and encouraging scientific and educational inquiry into environmental features and processes.

In addition to the *National Parks and Wildlife Act 1974*, the *Threatened Species Conservation Act 1995* (NSW) provides for the protection of threatened animals and plants native to NSW (with the exception of fish and marine plants) and requires the integration of threatened species into the planning process for a national park. The Act also provides for the conservation and recovery of threatened species and makes provision for the management of threats to species.

The *Threatened Species Conservation Act 1995* lists species that have been classified as threatened. Threatened species are listed under two categories: schedule 1 (endangered species) and Schedule 2 (vulnerable species). Schedule 1 (endangered species) includes endangered species, endangered populations, endangered ecological communities and species presumed extinct.

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) requires any proposal that may have an impact on a matter of 'national environmental significance' to be referred to Environment Australia for assessment and approval. This Act also lists nationally threatened species and communities. Matters of national significance include species that are listed as vulnerable or endangered species under the EPBC Act (see Attachment 10A).

The Japan–Australia Migratory Bird Agreement (JAMBA) and the China–Australia Migratory Bird Agreement (CAMBA) provide legal protection for all international migratory bird species between the respective countries. Latham's Snipe (*Gallinago hardwickii*) is listed under JAMBA and CAMBA, and is the most frequent visitor to the park of all the listed migratory species.

Some faunal species found in the park are also recognised in the IUCN list of threatened species. A list of all threatened fauna recorded from the Australian Alpine National Parks, and their conservation status from various jurisdictions and the IUCN, is provided in Attachment 10A.

The 1992 Rio Earth Summit produced the *Convention on the Conservation of Biological Diversity*, which provides the international framework for biodiversity conservation. Australia signed the Convention and as a result the Commonwealth produced the *National Strategy for the Conservation of Australia's Biological Diversity* in 1996. The *NSW Biodiversity Strategy* was published in 1999. All these strategies emphasise the need for conservation at the ecosystem, species and genetic level, and reserved areas, particularly large national parks, are recognised as having a key role at all scales, from regional to global. A review of the national strategy was undertaken by the Australian and New Zealand Environment and Conservation Council, which indicated that results varied widely from achieved to not achieved (ANZECC 2001).

International, national and bioregional context and significance

Introduction: observations on significance

Significance is a somewhat anthropocentric and relativist term. For species of fauna, some 'significance' classification systems exist (eg IUCN — threatened species), some of which may have legal meaning (*Threatened Species Conservation Act 1995*). Broad diversity (species counts) may assist in comparisons and it is possible to weight the 'uniqueness' of a faunal complement. We analysed the significance of the fauna under the following headings, although it is recognised that these overlap:

- international comparison;
- degree of uniqueness, comparative extent of biological diversity;
- unusual ecological functioning (eg trophic layers);
- national (continental) – state – bioregional context;
- degree of uniqueness on (continental) Australia and significance to adjacent environments;
- individual species and communities
  - endemism
  - rarity and conservation status (this may have legal significance; see Attachment 10A for listings)

- cultural importance, icon species, Aboriginal use (eg bogong moths)
- scientific studies and long-term monitoring studies providing insight to conservation science questions, some of which may be of international significance;

- Contribution to ecological services and the functioning of ecosystems; including externalities such as catchment protection. The Australian Alps are significant for being 'soil mountains' (Costin 1989) and thus it is argued that the fauna that played a major role *in their formation and their continued health* (eg 10 species of megascolecid earthworms) are of immense importance. Kirkpatrick (1994) recognised the eucalypt forest from 'alps to sea' as part of the international significance of the area. In these forests, as elsewhere, the role of fauna in pollination, nutrient cycling and other ecological functions is widely recognised as an integral part of all functioning ecosystems.

Also related to significance for elements that can degrade (eg biota) is capacity or the 'potential' condition. In NSW, legal land use and responsibility for biodiversity conservation and potential habitat manipulations (eg use of fire) is the highest in national parks and conservation reserves. In the present report, the Kosciuszko National Park has very high significance because of its status under the *National Parks and Wildlife Act 1974* (NSW).

What is culturally significant may change over time. Most of the vertebrate species in the park are Australian endemics and the ecosystems 'Australian.' These are part of our collective 'sense of place' — our culture. Australia has the worst record of mammal extinctions of any country in the last 200 years, and this is also part of our history and culture. Our perceptions of our native fauna appear to be changing toward a more conservation ethic, and places such as Kosciuszko National Park have an important role in this change.

International context and significance

As most of the fauna is endemic to Australia it has a uniqueness and consequent significance. Good (1992) observed a significance for Kosciuszko in 'its parallel evolutionary radiation in isolation from other alpine regions'. Other comparative factors include: the extent of biologically diversity (numbers of species); the ecological differences (eg the role of fauna in maintenance of the distinctive 'soil' mountains); and the differing dominance of classes of fauna in the ecological functioning of the Australian Alps.

A comparison of the faunal complements of three temperate (latitudinally) montane national parks on three different continents (Table 10.1) indicates that, despite its much smaller size and narrower altitudinal range, Kosciuszko National Park supports a similar number of species. What is distinctive is the relatively high number of reptiles in Kosciuszko National Park. The Australian Alps and the park are also significant for the number of reptile species that occur above the snowline (Green and Osborne 1994; Green, K, pers comm, September 2002). The Kosciuszko mammalian fauna is also distinctive for its lack of native ungulates (hoofed grazers) and diversity of marsupials. The park (and the Australia Alps in general) has representatives of all subclasses and infra-classes of mammals (Monotremata, Marsupialia and Eutheria), which is unique compared with the temperate regions of other continents.

In examining the mainland alps as a whole for international significance, Kirkpatrick (1994) summarised the work of Good (1992) and Busby (1990). He concluded that the international significance of the mountain pygmy-possum and a variety of other features 'lends strength' to the acceptance of the area under World Heritage criterion (i). When considering the invertebrates (poorly known at present), Kirkpatrick (1994) thought it is likely that criteria (iii), perhaps (i), and the biodiversity representation aspects of (iv) will be met or exceeded. Since that publication our knowledge has advanced, notably: the formal bioregionalisation of Australia; long-term assessment of amphibian populations; advances in taxonomy and genetics; the importance of the alpine–montane areas in the context of greenhouse and long-term refugia; and advances in our ecological understanding of the ecology of some environments.

Thirteen taxa with populations in the park are listed as threatened (endangered and vulnerable) or near threatened by the IUCN (Attachment 10A). They include the endangered mountain pygmy-possum.

Several faunal studies that have been or might be conducted in the park are of international scientific importance. They include studies on: alpine species such as the mountain pygmy-possum; global declines in amphibians, particularly high altitude; restoration of the predator hierarchy in large conservation reserves; and monitoring the effects and adaptive strategies for climate change.

Table 10.1 Number of indigenous vertebrate species recorded in three alpine montane national parks on three continents: Kosciuszko (Australia), Yellowstone (North America), Patagonia (South America)

Vertebrate group	Kosciuszko latitude 33–35°S area 6800km^2 altitude 800–2200m	Yellowstone[1] latitude 43–46°N area 40,800km^2 altitude 1372–4177m	Patagonia[1] latitude 39–42°S area 40,800km^2 altitude 200–3554m
Frogs	15	9	19
Reptiles	41	9	20
Birds	196	203	152
Mammals	41	83	48
Total	293	304	239

[1] From Barnosky et al (2000)

National and bioregional context and significance

The alpine area of mainland Australia is the highest and coldest area of the Bassian zoo-climatic region. It encompasses the Australian Alpine bioregion, which straddles NSW, ACT and Victoria (Figure 10.1). The Australian Alpine bioregion has many unique intrinsic biological features, noted for Kosciuszko by Good (1992). Of the bioregions in southeastern Australia, the Australian Alpine bioregion has the largest proportion set aside in a reserve system (Williams et al 2002). The Kosciuszko National Park forms the central segment of the Australian bioregion (Figure 10.1), which supports *all* the alpine endemic fauna species found on the Australia mainland. The Kosciuszko National Park forms about 50% of the area of the Australian Alpine National Parks system (with Victoria and ACT) and is less fragmented than the alpine regions of Victoria, which are separated by dissected landforms (Figure 10.1, Williams et al 2002).

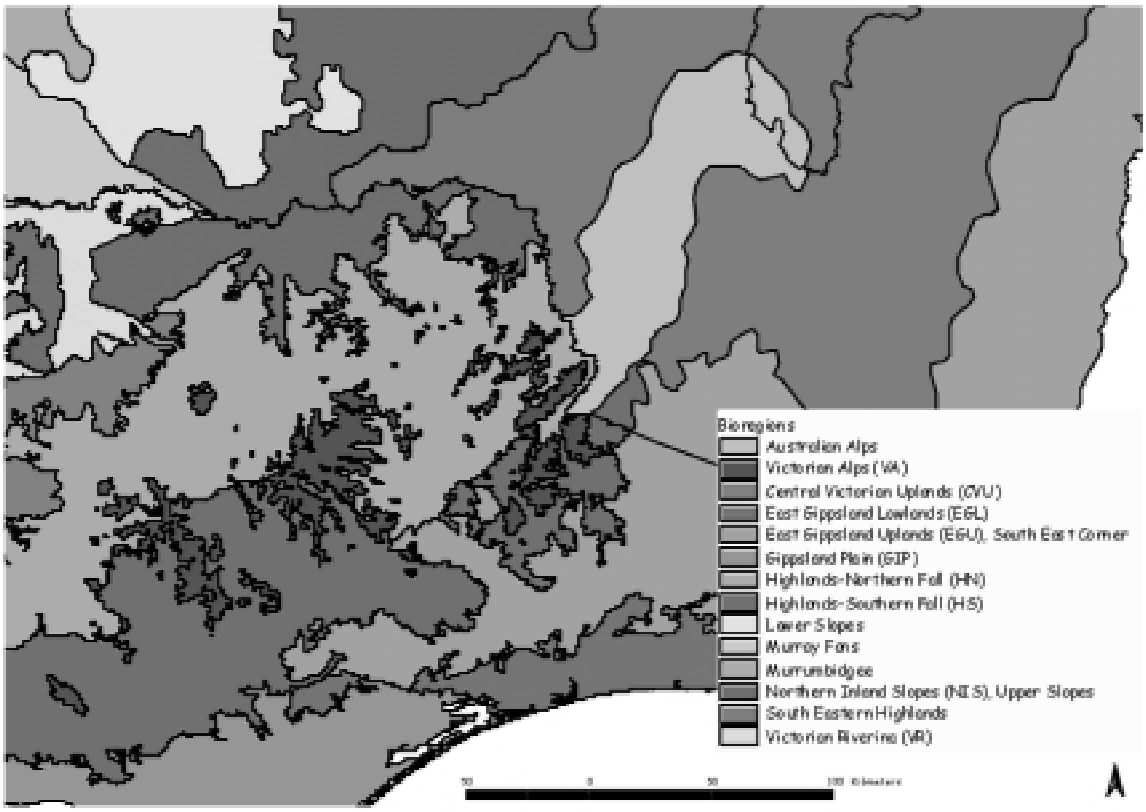
The attributes and importance of the alpine region and its biota have been discussed by various observers (eg Good 1992), and most recently by Williams et al (2002). The alpine–subalpine area of the park (above 1500 m), which supports populations of some of the most significant specialised cold-climate fauna species, covers about 15% of the park. These higher altitudes are surrounded by a range of predominantly latitudinally and topographically influenced forests, woodlands and shrublands (Figures 10.2 and 10.3, Table 10.3). Many of the latter vegetation types, and the vertebrates populations that they support, are more extensive outside the park (eg private property, forestry areas), where biodiversity conservation might not be a major management priority.

The park supports populations of about 300 native terrestrial vertebrates and an unknown number (thousands) of invertebrate species (Table 10.3). Over 20 introduced vertebrates have been recorded, and many of these pose significant and ongoing threats to the native species and their habitats. The diversity and distribution of the native species reflects the range of habitats available in the park: the vegetation and its condition; the geology and geomorphology; and, wetland associated habitats.

Coyne (2000) compiled a complete list of the threatened terrestrial and freshwater fauna that occur in the Australian National Park system (Attachment 10A). Although some of these species (eg regent honeyeater *Xanthomyza phrygia*, trout cod *Maccullochella macquariensis*) are marginal to the alpine park environments, the list records 17 mammals, 15 birds, 9 reptiles, 9 frogs and 11 fish. In addition, 30 invertebrates are regarded as significant. A suite of significant invertebrates is restricted to the karst cave complex (Table 10A.7 in Attachment 10A; Thurgate et al 2001a,b; also see Chapter 7).

The fauna of the alpine environment (and the alpine environment itself) is generally acknowledged as among the most vulnerable in Australia to future climate change caused by the enhanced greenhouse effect (Brereton et al 1995). Most literature supports the proposition that montane areas will become critical refugia for fauna under enhanced greenhouse scenarios (eg Bennett et al 1992). The altitudinal range and the diversity of habitats is therefore an important feature of the park at the continental scale.

Figure 10.1 The Australian Alps Bioregion



Generalised habitats of Kosciuszko National Park

The fauna of Kosciuszko National Park depends on the availability of habitats that support it and in which it performs its ecological function (consumer, decomposer, pollinator, predator, etc). Fauna play a critical role in the health, and in some cases, the microdistribution of these habitats. The broad vegetation types and their extent are shown in Figure 10.2 and Table 10.2. (Note that Figure 10.2 does not show wetlands, streams, and other specialised habitats such as caves). For the purposes of this discussion, the terrestrial environments are categorised as alpine–subalpine, tall wetter forests, drier woodlands, wetlands and bogs, and 'specialised' habitats (eg caves and rocky outcrops). More specific descriptions of the habitats of the park have been made by Good (1992) and Green and Osborne (1994).

Costin (1989) provides an idealised cross-section of part of Kosciuszko National Park (Figure 10.3) which, in conjunction with Figures 10.1 and 10.2, indicates the 'island' nature of the alpine habitats — an important feature of the evolution and conservation of alpine fauna. The subalpine and alpine environments are those broadly above 500 m altitude. In Kosciuszko National Park the treeline lies between 1800 and 1900 m, above which lies the alpine zone and below which (down to the winter snowline) lies subalpine woodland dominated by Snow Gums *Eucalyptus pauciflora* (Figures 10.2 and 10.3, Table 10.2). Above the treeline is a mosaic of vegetated, geomorphological and wetland habitats (Costin et al 2000). This paper emphasises the alpine and subalpine environments because of their uniqueness in Kosciuszko National Park in the context of NSW.

More than 85% of the non-alpine area consists of a variety of eucalypt forests and woodlands, with about 16% subalpine woodland (Table 10.2). The different distribution of the taller forests and drier woodlands reflects rainfall, topography and soil types. The number of species varies in each broad habitat. For example, the diversity of the avifauna varies between treed environments — subalpine woodland supports only half the number of species as woodland at lower altitudes — and the number of species declines with altitude (Table 10.3).

Critical habitat components, such as tree hollows, for a wide range of vertebrate species occur in all treed environments. The density of hollows increases with the maturity (seral stage) of the vegetation and hollows may take more than a century to develop in eucalypts. Management of and to maturity must be a critical element of management. It is noteworthy that *all but three* threatened bird species in Kosciuszko National Park (pink robin *Petroica rodinogaster*, olive whistler *Pachycephala olivacea* and Latham's snipe) are hollow-dependent species (eg owls, cockatoos and parrots) (Table 10A.2 in Attachment 10A).

The treed environments also link to habitats outside the Kosciuszko National Park. Because some of the larger species that rely on the treed environments have relatively large home ranges (eg powerful owl *Ninox strenua*, > 500 ha; spotted-tailed quoll *Dasyurus maculatus*, many square kilometres), the available habitat in the park may support only part of a metapopulation. Indeed, the Kosciuszko National Park population(s) may not be large enough for long-term conservation. However, populations of such species in Kosciuszko National Park emphasise the role of the park as a refugium. Kosciuszko National Park may well be, or become, a source for population recruitment to other areas. This is particularly evident for forest and woodland dependent species. Management of such populations should be coordinated with habitat management by adjacent land managers.

Table 10.2 Areas of vegetation types in Kosciuszko National Park*

Vegetation type	Area (ha)	Percent of KNP (%)
Montane Moist Forests	214,582	31%
Montane & Tableland Snow Gum Woodlands	130,393	19%
Subalpine Woodlands	107,153	16%
Alpine Herbfields / Grasslands & Bogs	80,415	12%
Lower Snowy Shrubby Woodlands	76,655	11%
Tablelands Dry Forests	52,757	8%
Eastern Tablelands Grasslands Woodland Mosaic	8,912	1.29%
Dry Shrubby Woodlands	4,093	0.59%
Eastern Tablelands Wet Forests	4,022	0.58%
Rain Shadow Woodland	345	0.05%
Montane Health	298	0.04%
Cool Temperate Forest	106	0.02%
Tablelands & Slopes Box-Gum Woodlands	3.63	<0.01%
Tablelands Grasslands	2.63	<0.01%
Inholdings, disturbed areas, etc	10,687.74	1.55%
Total	**690,425**	**100%**

***(after: Thomas, V. et al (2002) Forest Ecosystem Classification and Mapping for the Southern CRA Region, A report undertaken for the NSW CRA/RFA Steering Committee)**

Table 10.3 Diversity of birds in relation to altitude in Kosciuszko National Park (after Good 1992)

Zone	Montane			Subalpine		Alpine	
Vegetation	Mixed woodland	Wet sclerophyll forest		Subalpine woodland		Alpine herbfields	
Altitude	1070–1225m	1225–1370m	1370–1530m	1530–1680m	1680–1840m	1840–1990m	1990–2140m
No. species	106	87	67	44	27	4	4

Figure 10.2 Vegetation classes of Kosciuszko National Park

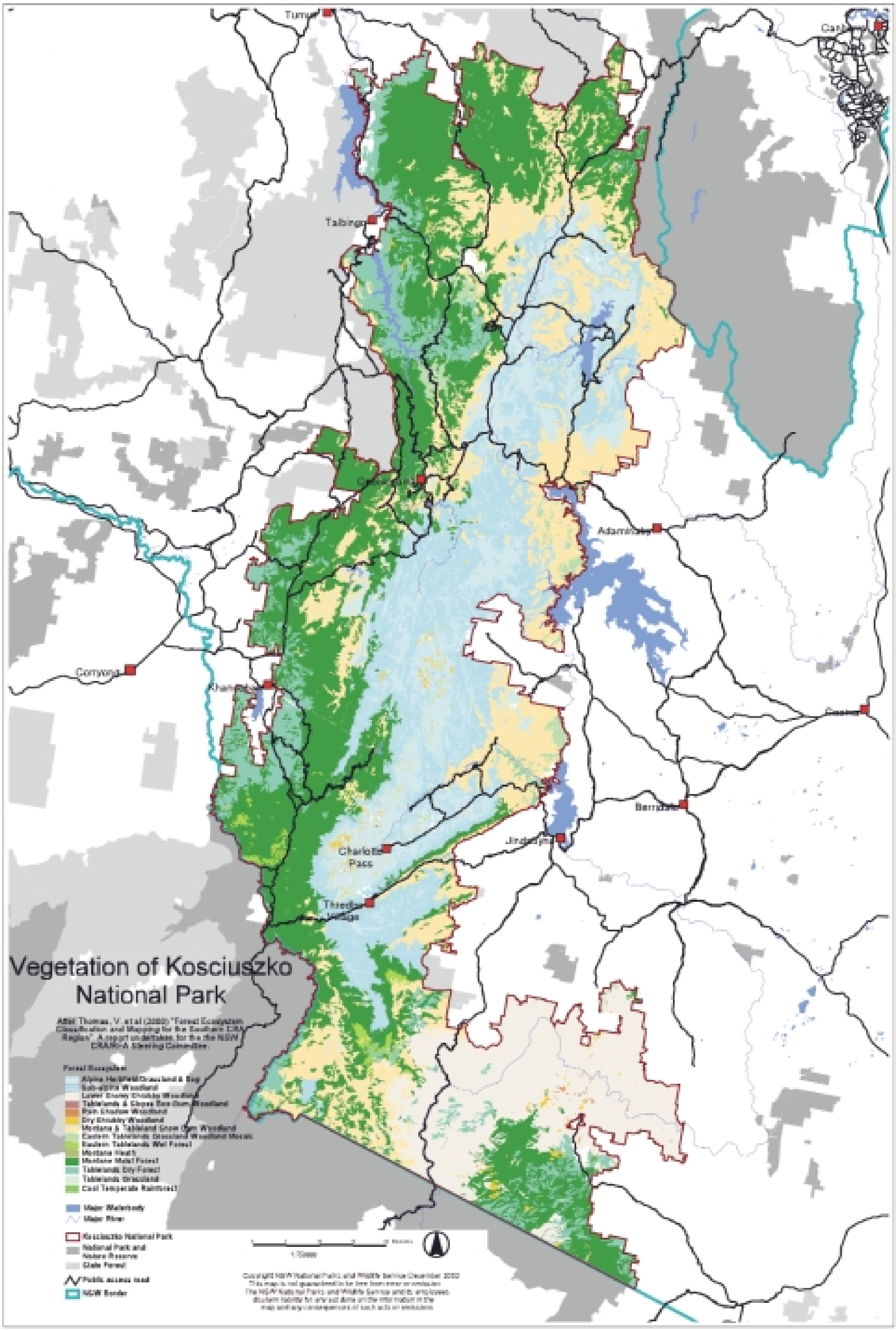
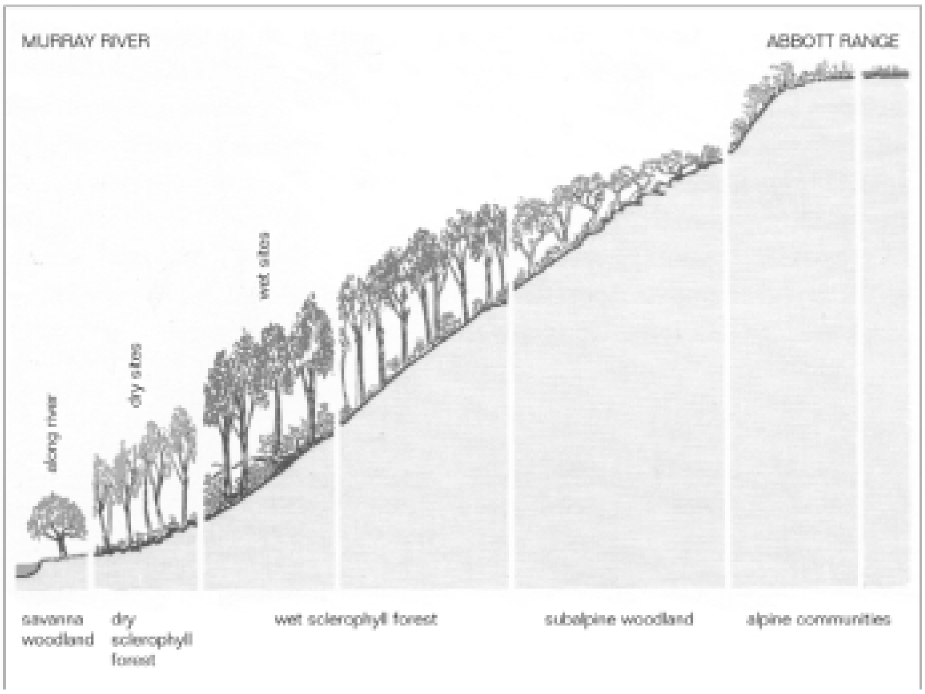


Figure 10.3 Idealised cross-section of vegetation ascending the Main Range of Kosciusko National Park from the west (from Good 1992 after Costin 1979)



Conservation status of fauna in Kosciuszko National Park

Compared to the fauna of both NSW and Victoria, the park contains a substantial number of species: about one-third of the terrestrial mammals, one-fifth of the amphibians and reptiles, and two-fifths of the bird species found in NSW (Table 10.4). If the marine and coastal avifauna were excluded, the birds would represent an even higher proportion. Of note is the relatively high percentage of threatened frogs compared to the total for NSW, and also the percentage of threatened mammals. The conservation status of the fauna of the Australian Alpine National Parks is summarised in tables in Attachment 10A. Coyne (2000) compiled detailed notes on each of the significant and threatened species.

In terms of condition, a threatened status at the national or state level suggests that there is evidence of the species' decline (as opposed to being naturally rare), and thus an adverse change in condition. Depending on the clarity of definition and extent of the threatening processes, populations of threatened species in the park may or may not be declining. For example, the large owls may be threatened across their broad range (by logging and land clearing), but populations in the park may not have (yet) changed in condition. For many threatened species the 'condition' of the park population remains, unfortunately, unknown.

About 75% of the vertebrate fauna of Kosciuszko National Park is regarded as common to uncommon. These species comprise the vast majority of the faunal biomass and would do most of the ecological 'work' of the fauna across the landscapes. The magnitude of the 'work' by the abundant and more common species in providing ecosystem services and keeping the overall ecosystems healthy cannot be over emphasised. Although this report highlights threatened vertebrate species, the common species are of critical importance to the health and resilience of the natural environment.

Table 10.4 **Number of species of vertebrate fauna in NSW, Kosciusko National Park and Victoria at the time of European settlement (Sett.), and percentage (of original total) of extinct (Ext.) and threatened (Thr.) species (includes extinct)**

	New South Wales [1]			Kosciusko National Park [2]				Victoria [3]		
	Sett.	Ext. (%)	Thr. (%)	% of NSW total	Sett.	Ext.[4] (%)	Thr. (%)	Sett.	Ext. (%)	Thr. (%)
Frogs	70	0	12.9%	21.4%	15	0	33.3%	33	0	30.3%
Reptiles	209	0.04%	12.4%	19.6%	41	0	7.3%	133	0.8%	21.1%
Birds	474	3.2%	20.7%	41.4%	196	0	4.1%	450	0.2%	16.7%
Mammals (terrestrial)	139	20.7%	38.5%	29.5%	41	4.8%	29.3%	110	18.2%	39.1%

[1] NSW EPA website, September 2002; data is from mid-1990s

[2] Green (1998)

[3] DNRE website, September 2002; data is for 2000

[4] Spotted tree frog, not included because of Upper Murray population

Table 10.5 **Numbers and conservation status of native vertebrate species in Kosciusko National Park. Numbers from the alpine–subalpine region (above 1500 m) are shown in square brackets (data derived from Green 1998)**

Group	Common		Uncommon		Rare		Threatened Vulnerable		Endangered		Extinct		Total
Frogs	10	[2]			–		1	[1]	4	[2]	–		15 [5]
Reptiles[a]	35	[12]	3	–	–	–	2	[2]	1	[1]	–		41 [15]
Birds[b]	99	[53]	38	[4]	37	[2]	8	[4]	–		–		197 [61]
Mammals	25	[16]	3	[1]	2+	[–]	7	[3]	2	[1]	3	[–]	42 [21]
Total	169	[83]	44	[5]	39	[2]	18	[8+]	7	[4]	3	[–]	295 [102]

a Includes undescribed *Egernia* species

b Includes 15 bird species recorded in the park that are vagrants or live in suitable habitat close to the park

Species of significance in the subalpine and alpine environments

Introduction

The faunal attributes of this environment have been well described by Green and Osborne (1994). About 100 terrestrial native vertebrate species in Kosciuszko National Park occur in the subalpine and alpine environments as do all the cold-climate specialists. As the global climate has warmed, populations of low mobility alpine specialists (some invertebrates, small terrestrial mammals, reptiles and frogs) have 'retreated' up the mountain. Over time they have became genetically isolated at higher altitudes (see Figures 10.1, 10.2 and 10.3) and may now persist as a series of island (isolated) populations or, in some cases, as endemics to a particular area.

Of particular importance are the endemic vertebrates such as the southern corroboree frog *Pseudophryne corroboree* and the cold-climate specialists that are dependent on the park and adjacent alpine and subalpine environments (eg the alpine tree frog *Litoria verreauxii alpina*). Recent taxonomic advances have resulted in the identification of 'new' alpine species such as the alpine she-oak skink *Cyclodomorphus praealtus*, and the clarification of the genetic differences within others (eg mountain pygmy-possum).

The alpine zone is notable because in each broad environment there is at least one alpine–subalpine cold-climate vertebrate specialist that is threatened. Boulderfields and related heathlands (mountain pygmy-possum), grasslands and low heath (alpine she-oak skink), grasslands and sedgelands (broad-toothed rat *Mastacomys fuscus*); wetlands (alpine water skink *Eulamprus koscuiskoi*, southern corroboree frog, alpine tree frog), wet sedgeland (broad-toothed rat). There are no endemic birds in these environment and their diversity is low (Table 3), with few overwintering (Green and Osborne 1994).

Significant species and communities and some of their ecological functions

The southern corroboree frog and mountain pygmy-possum are arguably the iconic fauna of the Australian Alps and the park; both are endangered and their populations are far from secure. Although the alpine–subalpine environments support populations of about 30% of the faunal complement of the park, a disproportionate number of species — about 55% — are threatened (Table 10.5).

Although the invertebrate fauna of the Australian Alps is not well understood, the park appears to fit the 'usual alpine model' of a low number of species but a high number of individuals, with the Orthoptera (grasshoppers) and Hymenoptera (ants, wasps and bees) being ecologically more important here than overseas (Green and Osborne 1994). Recent research in Kosciuszko National Park (Stock and Pickering 2002) has found higher abundance and diversity of these groups in alpine areas than montane, where they play a crucial role in pollination of alpine plants.

Significant and threatened species are listed in Tables A5 and A6 of Attachment 10A. The alpine thermocolour grasshopper *Kosciuscola tristis* is one of the few insects known to change colour in response to temperature change, and the genus is largely restricted to the snow country (Key and Day 1954). The case moth *Plutorectis caespitose* may be a periodically important grazer of alpine herbfields and could play a role in vegetation succession (Carr and Turner 1959). Victorian studies on the invertebrates (eg stoneflies, flatworms (St Clare et al 1999) suggest high levels of speciation. More work on the invertebrates, particularly given their functional importance, is required.

The seasonal occurrence of bogong moths in the alpine region represents the spring–summer climax of an insect migration that is one of the longest in the world (Common 1954). The congregations of these aestivating moths in rock crevices provided an important food source for Aboriginal peoples (Flood 1980), and are the major food source of the mountain pygmy-possum. This rich food source is exploited by a range of birds and mammals and provides a major energy input into the alpine environment. This moth species and its ecology is of particular scientific, cultural and conservation significance.

In the subalpine and alpine zone, the variety of wetlands and streams are vitally important for all amphibians, freshwater invertebrates and fish. There has been worldwide concern about the conservation plight of amphibians, and this concern has been voiced in Australia (Gillespie et al 1995). Of the five frogs known from the alpine–subalpine zone, four are threatened. The southern corroboree frog (endemic to the park) inhabits wet heathland, grassland and sphagnum bogs, and is disappearing from lower altitude sites (Osborne et al 2001). The alpine tree frog, a once-widespread alpine endemic, has suffered recent large-scale population declines and range contractions. The cause(s) of the declines of these species remains unclear (Osborne et al 2000).

These populations and long-term studies are important in resolving global conservation questions concerning amphibians. The alpine water skink is also restricted to alpine wetlands, and wetlands are the favoured habitats for the majority of migratory birds that are regular or occasional visitors to the park, such as Latham's snipe.

Somewhat counter-intuitively, recorded densities of some populations of reptiles in the Australian Alps are among the highest recorded anywhere in the world. All are heliotherms (requiring sunlight for warmth), but above 2000 m only one species, the mountain log skink *Pseudemoia entrecasteauxii,* persists (Green and Osborne 1994). The high species diversity of the reptiles is a distinctive feature of Kosciuszko National Park (Table 10.1). The reptilian diversity is dominated by skinks (10 species, three of which are threatened; see Table 10.5), with only two elapid snakes and a dragon. The Australian (Kosciuszko National Park) area is notable internationally for the large number of reptiles that occur above the snowline — 15 as against very few in other parts of the world examined to date (K Green, pers comm, September 2002). Recent taxonomic work has erected several new species (eg alpine she-oak skink, snowy mountains rock skink, tan-backed rock skink), and there is regional endemism in the group. Three skink species (alpine she-oak skink, *Egernia guthega* and *E. montanum*) are all restricted to the alpine zone and the former two are threatened.

The most significant, internationally recognised feature of the mammalian fauna is the mountain pygmy-possum. It is the only marsupial alpine specialist and the longest lived small terrestrial mammal, with a life span of over 12 years. The species is a relict from a genus that was once widespread across Australia. Since its discovery as an extant species in 1966 it has been the subject of intensive study. Populations have been monitored continually since 1979 in Victoria (Mansergh et al 1989) and since 1986 in Kosciuszko National Park (Broome 2001(b), which makes them zoologically significant in an Australian, and perhaps a world, context. There have been numerous papers published on this species (see references); the most pertinent to this discussion are:

- Heinze et al (in prep) — a review of ecological studies;
- Broome (1992, 1996, 2001(a), (b), in prep), Broome and Mansergh 1989, Smith and Broome (1992) — results of recent ecological work in Kosciuszko NP;
- Mansergh and Broome (1994) a monograph on the species;
- Osborne et al (1999, 2000) – genetics; and
- Broome and Geiser 1995, Geiser and Broome 1991, 1993, Geiser et al 1990, Körtner and Geiser 1996, Walter 1996, Walter and Broome 1998 – hibernation.

These studies, their longevity, and the inherent biological and zoological insights this species may provide (eg management and genetics of metapopulations) make the species of significant scientific interest.

The favoured habitat of the mountain pygmy-possum is alpine periglacial boulderfields frequently overlain by closed heathland of mountain plum-pine, which is limited and disjunct both in a bioregional sense and within the park. Bogong moths are a favoured food source. The species exhibits varying degrees of segregation between the sexes, depending on habitat availability quality and population density. The species is endangered, with at least three, possibly five, genetically recognisable populations (Osborne et al 1999, Heinze et al in prep). The population in the park is currently being reassessed (Broome et al in prep), with a best estimate of 250 breeding females (about 15% of the world population), spread across numerous small colonies (> 40) up to 3 km apart. Populations in resort areas are vital to the survival of the species in the park (Broome 2001a) and elsewhere (Mansergh and Scotts 1989).

The occurrence of the several vertebrate species are significant at the state level. The vulnerable broad-toothed rat, is an 'old endemic' cold-climate rodent with a vegetarian diet. Although it reaches the coast in southern Victoria, it is restricted to montane sites in NSW, where it inhabits dense wet grassland and sedgelands. There have been extensive studies of this species in the park by Happold and Bubela (Bubela and Happold 1993, Bubela et al 1991, Carron et al 1990, Happold 1978, 1989).

The alpine–subalpine zone would be part of the annual foraging range of the vulnerable eastern false pipistrelle *Falsistrellus tasmaniensis* and migratory common bent-wing bat *Miniopterus schreibersii*. Cave and communal breeding sites would be important for the latter, and tree hollows for the former. It is likely that these species form part of a large bat complement that exploits the abundance of summer insects, including bogong moths.

As noted above there are no endemic or alpine specialist bird species, although over 60 species exploit the resources over summer either as international or altitude migrants. The only threatened bird species of the zone, the olive whistler, inhabits the denser scrub and woodlands, particularly at higher altitudes. The populations in the park are viewed as in stable and good condition (K Green, pers comm, September 2002) Habitats and populations outside the park may be vulnerable to forestry activities. The spotted-tailed quoll is an occasional visitor to alpine environments, favouring treed areas at lower altitudes (see below).

Ecological function

Although our knowledge remains imperfect, each species of the fauna has a separate role in ecosystem function, for example, through predation, nutrient recycling and capture, pollination, soil disturbance and aeration, seed dispersal and grazing. These happen at all scales of the landscape, both above and below ground, both vertebrate and invertebrate. Three examples indicate the 'scale' of some of this work. Ten species of megascolecid earthworms play a major role in the formation and continuing health of the humus soils of Kosciuszko National Park (Costin 1989). In essence they helped create and maintain the unique high altitude 'soil mountans' of the Australia Alps upon which much of the vascular plant communities depend. Tall alpine herbfield is largely absent from the Tasmania alpine zone and Bridle and Kirkpatrick (1998) attribute this absence to the lack of grazing pressure of marsupials. The extended periods of snowlie in Kosciuszko National Park prohibit macropods (Green and Osborne 1994) and tall herbfields can flourish in the absence of this grazing pressure. Over time, predation, by a variety of birds and mammals, of the bogong moths when they arrive in their millions, provides nutrient transfer from the plains environment to the alpine environment, which increases soil fertility (Mansergh 1989). This represents a major energy input to the alpine environment.

The bird species that migrate to the park to exploit the seasonally available food resources also recycle nutrients to the system – the predation of insects by birds may prove to be of major importance in nutrient recycling, given the absence of large herbivores typical of other alpine and grassland systems. Fungi are increasingly seen as having an important role in nutrient recycling in southeastern Australia (Claridge 1997), and the ubiquitous bush rat *Rattus fuscipes* may play a role in spore dispersal in the alpine environment (Carron et al 1990, Mansergh et al 1990).

Macropods are poorly adapted to movement in deep snow (Green and Osborne 1994), and the common wombat *Vombatus ursinus* may struggle to survive through heavy snow seasons. Thus, in contrast to alpine areas in the northern hemisphere, the Australia Alps are distinctive for evolving without major large herbivores and, perhaps consequently, without large carnivores (the dingo was a late arrival to the continent). The terrestrial mammalian fauna is relatively depauperate and the strong altitudinal species zonation exhibited elsewhere is absent (Happold 1989). Indeed, the bush rat and the dusky antechinus *Antechinus swainsonii* occur from high altitudes to the coast.

The ecological functionality of some groups of fauna may be more important in Australia than elsewhere: for example, case moths, seral stages of some vegetation, and the high diversity and density of skinks. At higher altitudes the major mammalian grazer is the broad-toothed rat, compared with deer and other ungulates on other continents. These differences, and the relatively small size and area-to-perimeter ratio of the park, make it vulnerable to introduced species of grazers (European hares *Lepus capensis*, deer) and predators (foxes and cats) that can constantly reinvade from lower altitudes, if they are not already resident. These species adversely effect the functioning of the natural system.

The flora and fauna also play a critical role in maintaining the natural water quality, both in the local environment and that which flows down the catchment. We have mentioned earlier that several of the threatened species that occur in the park are wetland-dependent.

Condition of populations

'Condition' encompasses at least two concepts: how much has been destroyed (extent/depletion), and the state (compared with the natural state) of the remainder. In the alpine–subalpine zone, areas of some habitats have been destroyed by resort development and related infrastructure, so their extent has declined. The direct European impact across the park is not insubstantial (2.5% by area: see Table 10.2), and is concentrated higher in the alpine–subalpine zone because of the resorts and consequent infrastructure.

There is no standard measure of condition for vegetation and/or habitats. Such a measure is required, and must be put into an ecological defensible policy framework, such as net gain in extent and condition. The broad condition is affected by the scale and effect of the threatening processes. Condition assessments are confounded because baseline data is generally not collected prior to the threatening processes operating. Further, Costin et al (2000) have also shown how much time alpine vegetation communities need to recover (eg bogs from grazing) which is measured in decades. The alpine area was heavily grazed by sheep then cattle up to the 1960s.

The indirect effects of introduced species are most insidious and relentless on the terrestrial habitats: weed invasion, predation by foxes and cats, and trampling by ungulates (horses, potentially deer). Green (2002) has shown that the red fox selectively preys upon the broad-toothed rat in the subalpine environment, and fox predation is implicated in the species decline across its range. In fact, the prey of the red fox includes *all* threatened mammal species of this environment (Mansergh and Broom 1994, Green 2002). To the extent that this is a new (rather than replaced) predation pressure, the condition of the populations would have declined. Feral cats *Felix catus*, being more selective predators, have the potential to be much more destructive although definite empirical data are few in the alpine area. At present the distribution of cats appears to be most predominant around resorts.

Entomologists in the 1920s and 1930s, including Waterhouse, recorded far greater populations of butterflies of several species than are presently observed in the alps (Good 1992). Good suggested that this 'gross' change may be cause for concern, but the reason remains unknown. Is this observed change due to changed grazing regimes? If so, this decline in abundance and diversity may be a result of improved management, but this remains unknown.

In the subalpine and alpine environments few species have been monitored, but for those that have the results are disturbing. Osborne et al (2001) reported on the long-term monitoring of the alpine tree frog and the southern corroboree frog. Both species (and the other high-altitude species examined, eg the Victorian corroboree frog) and have undergone dramatic range and population declines over the last decade. Importantly, the authors provide evidence that these are not natural fluctuations. The causes remain obscure; they do not appear to be related to direct on-ground management, but may reflect global change, eg UV increase or changing climate. If trends continue, extinction of these species in the foreseeable future is possible (Osborne et al 2001).

Broome 2001(a), (b) recently published the results of an 11-year study on the mountain pygmy-possum, concluding that 'there was no evidence that the ski resort at Mount Blue Cow had any significant impacts above the natural yearly variation in demographics.' Importantly, the development was influenced by knowledge of the species requirements and the capability to restore habitat (Mansergh and Scotts 1989). Previous habitat destruction and fragmentation have reduced the available habitat and its continuity. The population is far from secure, with a total estimate of 250 breeding females (previous estimates have been around a 1000) and the highest quality habitats (population size and stability) within resort concessions. A total population of 250 breeding females is in the danger zone by any criteria. Further, the movement and survival of the species between small areas of habitat, which is absolutely critical to long-term viability, is affected by predation by foxes and cats. The conclusions of Broome 2001(b) regarding management of this species as a metapopulation have wider applicability for all the alpine specialist species and consequently for land management. Habitat enhancement and creation should be a goal of management.

Recently, it has been discovered that Bogong Moths transport arsenic to the alpine regions, presumably from their 3–4 years as larvae in the self-mulching soils of western NSW (Green et al 2001). The effect of this on the condition of the moth population and the effects up the food chain has yet to be determined, but is possibly significant.

There are critical ecological elements and processes that will affect the condition of the fauna populations in these environments (see also the section on threats below). These include:

- habitat protection (enhancement and continuity) — all development must be in context of net gain of habitat and inappropriate development should be avoided;
- management of populations as metapopulations;
- control of introduced predators and preferable restoration of natural predator regime;
- protection of wetlands and hydrology;
- increased research into invertebrates and their role in ecosystem function.

Species of significance in the tall and wet forest habitats

Introduction

Tall and wet forests comprise about 100,000 ha (Table 10.1) and generally occupy the altitudinal band below the subalpine woodland (*E. pauciflora*). These forests also spread down the valleys, where they may be limited to the riparian zone and surrounds. Tall and wet forests are broader on the western slopes (Figures 10.2 and 10.3). No species in these habitats is endemic to the park, but several species are significant. The invertebrate fauna remains little known. Attributes of maturity in all forest types (eg tree hollows that develop in mature trees older than 120 years of age) are critical for a wide range of threatened and more 'common' species, such as possums, gliders, cockatoos and parrots. Providing mature seral stages is a critical component of management for the park's biodiversity. This is also related to fire management. Many general aspects of this environment are shared with other treed environments.

Significant species and communities and some of their ecological functions

The alpine ash (*E. delegatensis*) forests generally consist of pure stands, while the other forests are generally of mixed eucalypt species. In comparison to other forests, Alpine ash forests tend to have a low vertebrate species diversity (Norris et al 1983), perhaps because if their propensity to grow as a monoculture following fire or logging. Fauna species mentioned below, particularly those with large home ranges, may also occur in alpine ash forests, but this is not the 'favoured habitat' of any of these species. Mature stands of alpine ash (and all tall wet forests), or those managed for maturity, are of significance given that these types are favoured for logging.

The mixed species tall open forests provide more diverse habitats than the alpine ash forests. Here, tree hollows and fallen logs provide breeding sites for a range of dependent species, many of which are threatened and/or depleted across their range; for example, the yellow-bellied glider *Petaurus australis*, powerful owl and spotted-tailed quoll. The latter two species and others require relatively large home ranges (eg 8–10 km^2 for the powerful owl) to support their prey base (eg gliders), which may also be dependent on hollows. Populations of such species in the park are vital to their long-term survival, and they must be managed in the park as part of a metapopulation that includes areas of habitat outside the park. The functionality of these medium-sized predators in the forest environment is important for ecosystem health.

The wetter, denser gullies are inhabited by the threatened pink robin, which has been recently recorded breeding in the park. A few montane streams were inhabited by the spotted tree frog *Litoria spenceri*, which is critically endangered nationally, but the most numerous population known in the park crashed in about 1997 and only a single male was found, which has now been taken from the wild for captive breeding. The reasons for the sudden decline to extinction remain unclear, but possibly relate to disease in the population (M Scroggie, pers comm, September 2002). Introduced trout, which eat tadpoles but not adults, are not believed to be the proximate cause for the extinction of this population, although they are implicated in the endangerment of populations elsewhere (Gillespie 2001). The spotted tree frog might persist in the upper reaches of the Murray River in Kosciuszko National Park (M Scroggie, pers comm, September 2002).

Some montane species (eg the spotted tree frog) require specific management of their habitats and catchments, and these areas can be progressively identified and managed accordingly. As a generality, it appears more prudent and practical to manage the broad habitats of the park at a landscape level (eg use of fire). However, it must be noted that some of the resident fauna and many of the threatened fauna (eg those that are reliant on mature seral stages, tree hollow dependent, or very large home ranges) rely for their long-term conservation on areas outside Kosciuszko National Park as well. It is a challenge for the future as to how much bias is given to the requirements of these species in the management of habitat. Although we would argue that a benchmark for vegetation condition is a imperative for the park (eg at European settlement) it is also important to ask whether it is prudent to bias the age structure of the park vegetation communities to allow for the proliferation of younger seral stages elsewhere. The management of Kosciuszko National Park must be cognisant of adjacent public land (Victorian National Parks and forestry).

Ecological function

Over 240 vertebrate species have been recorded from the forested habitats of the park, and all would play a role in the health of the forests as pollinators, seed dispersers, predators or nutrient recyclers. The invertebrates remain little known although Recher and Majer (1996, quoted in Williams 2002) estimated that around 250 000 species of just one group of terrestrial invertebrates would be found in association with the *Eucalyptus* genus (700 species). Further, May and Simpson (1997) estimated that eucalypts are likely to have 7000 species of associated fungi. All the species and communities which they form, both the generalists and the specialists, do the ecological work to keep the forests healthy and provide its resilience to disturbance.

Recent research into hypogeal mycorrhizal fungi has indicated that they may prove to be a critical element in the nutrient recycling and nitrogen availability in the ‘nutrient-deficient’ soils of Australia and its forests. An overseas study in Oregon–Douglas Fir forest (Amaranthus et al 1990) suggests that the biological productivity of sites that are cold and susceptible to drought or hot fires may decline because of the decrease in beneficial microorganisms. All of these factors operate in the park. These relationships may prove to be critical for fauna and forest health (Claridge and Lindenmayer 1998; Claridge et al 2001). The importance of fungus species as food has been studied for some mammals, such as the long-footed potoroo *Potorous longipes*, swamp wallaby *Wallabia bicolor* and mountain brushtail *Trichosurus caninus*, but the role of mammals in dispersing the spores of these species may be equally as important (May et al 1999). Fungi also forms part of the diet of the bush rat (Mansergh et al 1990). Grazing and dispersal of spores may play a critical role in keeping the forest healthy. At a national level, many fungivore specialists are threatened or have declined in distribution underlining the importance of management of the system (Claridge 1997).

High-order predators perform a major function in all forests types and it is of some concern that this level appears to be disrupted and vulnerable; all large owls are threatened, and medium-sized predators (quolls) are either extinct or threatened. NSW NPWS has monitored the numbers and breeding success of the peregrine falcon *Falco peregrinus* (T Stubbs, pers comm,September 2002). The dingo is ‘controlled’ and red foxes and feral cats are common. Predation by foxes and cats is a major problem in these environments and threatens several species. Their presence and replacement of natural predators would affect the abundance and distribution of prey, and cause consequent changes down the food chain. This is discussed further below. Similarly, the proliferation of ungulates (horses, deer, feral goats *Capra hirsus*) and other grazers is also a major threatening process in these environments (see below).

The lower levels of predation in the food chain are critical for the ecological health of the forests; for example, for controlling certain insect populations. A sugar glider *Petaurus brevipes* will consume up to 200 kg of insects each year (Suckling 1984), and a bat can eat more than its weight in nocturnal invertebrates during each night of activity.

Condition of populations

In these environments there have been some positive discoveries (eg pink robin), although whether these represent changes or are artefacts of collection remains unclear. Some adverse changes (eg the spotted tree frog) have been recorded, but the condition of the vast majority of populations of species in these environments is not extensively monitored. The degree of threat to the species as reflected in ‘listing’ under legislation generally relates to their plight outside the park. In some instances it may be related in part to management (eg predator control, fire management). The condition of the populations in the park may also be related to land use elsewhere.

There are critical ecological elements and processes that will affect the condition of the fauna populations (see also threats discussed below). These include:

- the extent and condition of mature seral vegetation stages;
- the availability of the natural range of size and type of hollows;
- the maintenance or restoration of natural predator–prey relationships; and
- fire regimes.

Species of significance in the drier more open forests and woodlands

Introduction

Drier forests and woodlands comprise over half the area of Kosciuszko National Park (Figure 10.2). They support a fauna that is generally more widely distributed, although the elements of woodland bird and reptile fauna may be threatened as a group at the national scale (eg Robinson and Traill 1996, Brown 2002). Within this generalisation there are several populations of threatened species of vertebrates that are threatened. Some occupy specific habitats, such as the rocky outcrops of the brush-tailed rock-wallaby *Petrogale pencillata*, or were once widespread, for example, brush-tailed phascogale (*Phascogale tapoatafa*. Historically, it is in these environments of the park where most of the known past extinctions (all mammals) have occurred: the koala *Phascolarctos cinereus* (in 1960), eastern quoll *Dasyurus viverrinus* and brush-tailed rock-wallaby. The precise causes (eg disease, persecution, predation by foxes) of the declines across such large ranges remain imperfectly understood, but are at the subcontinental scale, and do not appear to be a result of Park management regimes.

Significant species and communities and some of their ecological functions

These environments have the largest diversity of birds (Table 10.3) and mammals. Species perform ecological functions across a range of trophic levels and interact with other species (predator–prey) and the vegetation as grazers, pollinators, seed dispersers and decomposers (see above). As for the wet forests, several of these threatened species are hollow dependent; such as brush-tailed phascogale and glossy black-cockatoo *Calyptorhynchus lathami,* Barking Owl *Ninox connivens* and several bat species. The extent of these environments, (over 3000 km^2) and their juxtaposition to adjacent protected areas of similar habitats makes them highly significant for long-term biodiversity conservation.

In Victoria, the koala has recovered from the population crash of early in the 20th century, and it is not inconceivable that the park may be recolonised from the south. Conversely, the brush-tailed phascogale is presumed extinct in adjacent Gippsland (Norris et al 1983) and populations in the park are significant as a potential natural source. Recent research indicates that the brush-tailed phascogale, an insectivore, also plays an important role as a pollinator (Goldingay 2000), as does the eastern pygmy-possum. The decline or demise of such species may thus affect vegetation in the long term.

One threatened species, the smoky mouse *Pseudomys fumeus* is a seasonal seed and truffle (hypogeal fungi) eater, and is dependent upon appropriate fire regimes for the maintenance of appropriate understorey and fungi within its habitat. Current records for the park suggest this species occurs in the karst areas, but it may be more widespread. The species' range is primarily in Victoria, but extends to Kosciuszko National Park and the ACT. Most populations are in the reserve system (ie habitat that was not suitable for alienation and agriculture), but require active habitat management (fire and foxes). This species is of state significance, as are populations of the square-tailed kite *Lophoictinia isura*, predominantly a low altitude species.

The red fox has been implicated in the demise of the brush-tailed rock-wallaby and the eastern quoll. If foxes and cats are controlled and the food sources and other habitat parameters remain present, these species may be able to be reintroduced which should be a long-term aim of the management of the park in these environments.

The endangered spotted-tailed quoll is the largest surviving marsupial carnivore on the mainland, and is of conservation concern. It is a close relative the eastern quoll, which once occurred in the park but is now presumed extinct throughout the mainland. A population of spotted-tailed quoll has recently been discovered in the Byadbo

Wilderness Area of the park at very high densities (22 animals in a 50 km^2 area), providing unprecedented home range information for a single population (Claridge, NSW NPWS, pers comm, September 2002). This population is higher than any yet recorded in Victoria and possibly southeastern Australia, and is of high scientific significance and conservation interest. Predator management (eg fox control) needs to be very carefully considered in these areas (see discussion below of meso-predator release).

Condition of populations

Historically, drier open forest and woodland environments in the park have suffered the most extinctions of vertebrate species. Mostly, declines of these species have been at a continental scale. A suite of woodland bird species are regarded as being threatened at the continental scale (Robinson and Traill 1996), as a result of changes in land use change, clearing, etc. Similar patterns may also be affecting reptiles (Brown 2002). Although the drier woodlands and forests of the park have received less attention biologically, they should not be neglected, because large segments of the fauna of these environments are threatened in southeastern Australia. In a scenario of continuing threats outside the reserve system, areas that are protected and appropriately managed in parks and reserves will become of increasing scientific and conservation importance. They should be managed as a national asset, in conjunction with similar areas outside the park.

The dramatic depletion of fallen wood debris (estimated to be now 16% of the pre-European amount) has recently been quantified for woodlands elsewhere, such as river red gum floodplains (MacNally et al 2002). This depletes a wide range of habitats for fauna and changes the functional condition. Such data is disturbing, but emphasises the need for areas in conservation parks and reserves to be managed to achieve a closer surrogate of the pre-European habitats. Since other threatening processes (logging, fire wood collection) may be controlled, fire management is critical.

The decline or extinction of native medium-sized predators is significant in these environments, as is the replacement by feral predators (dogs and foxes). There is a long-term opportunity for restoration of the predator hierarchy, which would restore the balance in the condition. This would involve the restoration of dingoes and quolls (presuming long-term reestablishment of the eastern quoll) and elimination of feral dogs, foxes and cats (see below). With the presence of foxes in Tasmania, re-establishment of a viable eastern quoll population on the mainland will become imperative. Kosciuszko National Park would be a highly appropriate site.

There are critical ecological elements and processes that will effect the condition of the fauna populations (see also the section on threats below). These include:

- the maintenance or restoration of natural predator–prey relationships
- the extent and condition of mature seral vegetation stages and tree hollows
- fire regimes for dependent fauna (eg smoky mouse) and habitat restoration.

Species of significance in wetlands, bogs, streams and specialised habitats

Introduction

The wetlands of Kosciuszko National Park have not been systematically mapped, and are therefore not shown in Figure 10.2. The alpine, subalpine and montane bogs and wetlands are a very significant conservation feature of the environment, not least because their hydrology may have direct effects lower down the catchments. The area of the wetlands has shrunk, and many bogs are degraded. These environments are still in a recovery phase following the removal of grazing several decades ago. Recovery in the condition of some bogs have been recorded

(Costin et al 2000), but there remains great scope for improvement. Unfortunately this far-sighted land management decision has not been replicated in Victoria, where substantial areas of bogs and wetlands are still open to cattle grazed under government licence, with deleterious effects (Williams et al 2002). The situation in Victoria enhances the conservation and scientific significance of these habitats in Kosciuszko National Park.

Significant species and communities, some of their ecological functions and condition[1]

Several alpine–subalpine endemic species that depend on the wetland and bogs (eg the alpine water skink, alpine tree frog, southern corroboree frog) have been discussed earlier. Under the JAMBA and CAMBA agreements, Australia is obligated to protect listed international migratory bird species and their habitat. The park's wetlands are used by some listed international migratory wetland species, such as Latham's Snipe. The park does not support large populations of these species, and the importance of its wetlands to the various species, either as a stopover or as a destination, is unknown.

The threatened northern corroboree frog *Pseudophryne pengilleyi*, formerly considered a northern form of *P. corroboree*, is found in the wetlands of the north of the park and in the Brindabellas. Osborne et al (2001) has recorded a recent decline of this species in both abundance and range since 1989 in parts of its range, and the causes of this decline remain uncertain. The threatened booroolong frog *Litoria booroolongensis* also exists in the northern part of the park, but no monitoring has been done on the populations. The function of tadpoles (grazers/prey) and frogs (as smaller predators) in Kosciuszko National Park is not well understood.

Threats to these environments include changes in water quality and quantity and general degradation. Trampling by horses, deer, pigs and humans. At least two ungulate species appear to be expanding their ranges and abundance into the alpine–subalpine environment. If this expansion remains unchecked, the ecological and catchment improvements resulting from the removal of cattle in the 1950s and 1960s may be jeopardised.

Many areas of wetland and stream remain trout-free, primarily because of the 80kilometres of aqueduct constructed by the Snowy Mountains Authority. Indeed, the most abundant spotted tree frog population was able to persist in a trout-free stream protected by an aqueduct and waterfall (K Green, pers comm, Septebmer 2002). Trout are a known predator of spotted tree frog tadpoles (Gillespie 2001).

Other specialised habitats include caves, cliffs, and sites of communal roosting and breeding. The cave fauna is of particular interest, being largely confined to one or a few caves because movement in the open is difficult or impossible (Coyne 2000). Many troglobites (species which can live only in caves) are relicts of some antiquity and only distantly related to surface forms. They may be phylogenetic relicts, with no close living relatives, or they are distributional relicts, having survived in a geographic region in subterranean refugia. They provide valuable insights into the zoogeographic and evolutionary history of our faunas (eg Thurgate et al 2001, also see Chapter 7).

Cliff and rock faces are important nesting sites for the peregrine falcon, a cosmopolitan species that has experienced historical declines across large parts of its range. Monitoring in the park suggests the population of about 30 pairs appears to be stable (K Green,pers comm, September 2002). Conversely, brush-tailed rock-wallabies appear to be extinct in the park and have also become extinct in other areas. Fire appears to be the proximate cause in the park but the last colony to disappear was in a remote area apparently not subject to obvious threats (K Green, pers comm, September 2002). Once the full gamut of threatening processes have been understood and ameliorated in the park (foxes, goats, rabbits, food availability), this species should be a candidate for reintroduction to its habitat at rocky outcrops, ravines and caves.

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[1] The wetland habitats and their invertebrate and fish fauna are discussed more fully in Chapter 8.

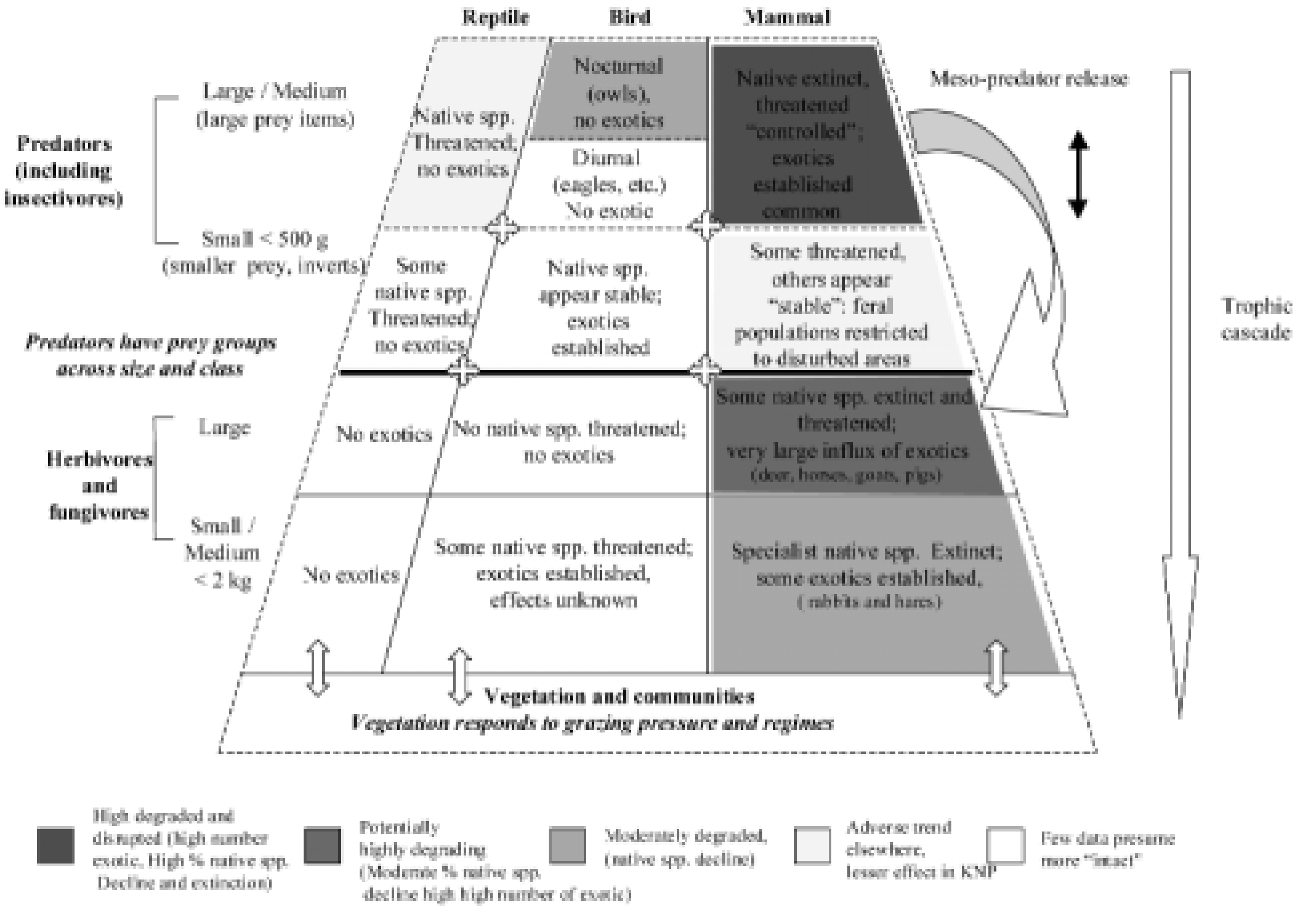
There are critical ecological elements and processes that will effect the condition of the fauna populations (see also threats below). These include:

- maintaining or restoring the hydrological cycle and the health of wetlands;
- protecting and actively monitoring specialised habitats: caves, roosting and maternity sites for communally breeding species; and
- keeping existing trout-free areas free of trout, and expanding trout-free areas if practicable (see Chapter 8).

Condition of vertebrate fauna by trophic level

In order to get an overview of the condition of ecological functions that vertebrates perform, we can examine the fauna by trophic levels — predator and herbivore. Each faunal group is examined by the number (and percentage) of extinctions or declines and the number and abundance of invasive exotic species. This provides an approximate index of variation from the natural pre-European condition (Figure 10.4), although it should be remembered that all of these groups interact (eg Table 10.6). This allows us to conceptualise the 'balance' in the park and, importantly, what elements may drive undesirable change.

Figure 4. Gross simplified estimates of condition of trophic levels of vertebrate fauna in Kosciuszko National Park, by class.
(Predation occurs across class, different species exert different prey and grazing pressure
- status reflects estimate of variance from pre-european situation, see text, amphibians not included).



Gross or even subtle changes at one level may affect a 'trophic cascade' of changes. A study in Yellowstone National Park in the United States found that wolf reintroduction has affected the behaviour of their prey (elks), which consequently modified aspen regrowth and distribution (Ripple et al 2001). In Kosciuszko National Park the pre-European medium-sized predators are extinct (eastern quoll and dingo) or threatened, with a decline in abundance and distribution (spotted-tailed quoll). The introduced red fox is now common and is implicated in the decline (to extinction in some cases) of quolls, potoroos, bettongs and many small mammals of the forests and woodlands. The latter grazing species spread the spores of hypogeal fungi, which provide nutrient cycling in the phosphorus- and nitrogen-poor Australian soils (Claridge 2001). Thus, the effect of the red fox is spread across its trophic level and down through its prey levels, some of which it has apparently eliminated, to the producer level (vegetation).

Our empirical and theoretical understanding of these concepts continues to evolve (eg Este 2001). However, even a simple view of the park from this perspective (Figure 10.4) is sobering. Many nocturnal predators (eg large owls and bats) are threatened, and declines in their abundance would effect the abundance of insects either directly or indirectly through abundance of prey. The park has a suite of introduced large herbivores (horses, goats, deer, pigs), populations of which are well established and are capable or likely of expansion. Sustained grazing by introduced herbivores (or changed distribution of native herbivores) will initiate vegetation change (eg Bridle and Kirkpatrick 1998, Williams et al in prep), and there is a huge potential for adversely effecting vegetation. Most of the medium–large native species still appear common (wombats, kangaroos and wallabies), the declines being predominantly in habitat specialists such as rock-wallabies. The effect of rabbits on native vegetation, and in some cases soil stability, in the Australian landscape is well documented.

Figure 10.4 suggests that priority areas should be managed in priority order: first the exotic mammalian predators, then the exotic grazing regimes and large owl/bat predator roles. The latter may prove to be more intact in the park than in adjacent forests, although there is little data. The ecological changes initiated by the introduced grazers remain unknown and are probably underestimated (eg Pulsford 1991). To date there has been insufficient research in this broad area for the park. Other land managers should also be involved (eg forestry managers in the case of forest species), and the park should form strategic alliances with other partners, such as forestry, Department of Natural Resources and Environment (DNRE) and Cooperative Research Centres (CRCs), since the alpine–subalpine region of the park has a particular, indeed unique responsibility, in the context of NSW.

Management and research should be focused on areas where adverse changes to the natural ecology have the capacity to be most profound. In the longer term, changes that affect a 'trophic cascade' may fundamentally change the vegetation and habitat available within the park. From this perspective we now examine the concept of meso-predator release within the most disrupted trophic level: the medium–large predators.

Table 10.6 Prey identified in scat collections from Brindabella and northern Kosciuszko National Parks (Triggs and Story 1998–2001), Tinderry Nature Reserve (Triggs and Story 1997–2001) and Tin Mines (Newsome et al 1983)

	Brindabella and northern Kosciuszko		Tinderry Nature Reserve		Tin Mines
Prey	**Feral dog**	**Red fox**	**Feral dog**	**Red fox**	**Dingo**
Swamp wallaby	29%	18%	28%	15%	5.7%
Eastern grey kangaroo			6%	3%	2.9%
Red-necked wallaby			0.6%		1.9%
Brushtail possum	8%	14%	6%	12%	2.9%
Ringtail possum		7%	5%	9%	9.2%
Eastern pygmy-possum				0.4%	
Yellow-bellied Glider[a]	1%				
Greater glider	1%	3.5%			
Sugar glider	1%		2%	3%	
Dusky antechinus	2%	7%	1%	4%	2.2%
Bush rat	2%	3.5%	0.6%	3%	2.5%
Broad-toothed rat[a]		3.5%			0.2%
Short-beaked echidna	29%		10%	1%	
Insects	2%		3%	7%	
Vegetation	6%	3.5%	3%	2%	
Common wombat			2%	6%	51.3%
Reptiles	2%	3.5%	1%	1.5%	
Birds	5%	18%	6%	5%	
Fish	1%				
European rabbit[b]	5%	11%	3%	14%	17.8%
Brown hare[b]			2%	1%	
Cat[b]	1%	7%		0.8%	
Black rat[b]	1%				
Sheep[b]	3%		3%	4%	
Cattle[b]	1%		3%	1%	
Pig[b]	1%		10%	5%	
Goat[b]			3%		
Red fox[b]			0.6%		
Horse[b]					1.3%
Total sample size	**111**	**28**	**173**	**252**	**314**

Note: Multiple species may be identified within a single scat

[a] Threatened species

[b] Introduced species

Ecological processes: meso-predator release

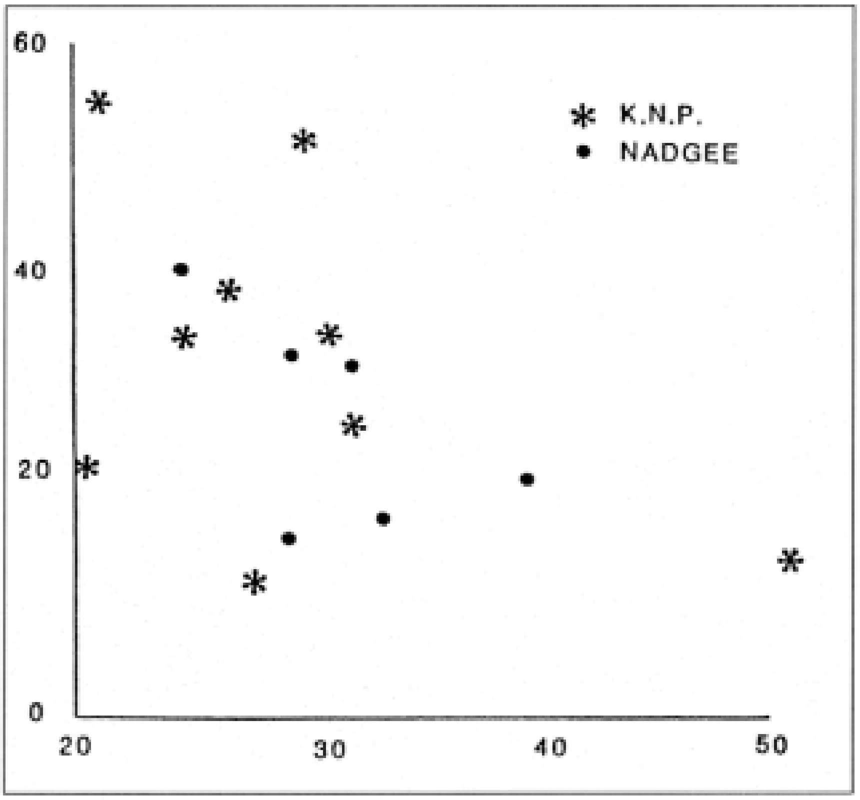
Introduction

Predators can exist in a hierarchy where the dominant predator influences (suppresses) the abundance of subdominants. Removal of a higher predator releases the subdominant to become dominant. This is termed meso-predator release (Crooks and Soule 1999, Estes 1996, Soule et al 1988). The control of dingoes/wild dogs is one of the most contentious Kosciuszko National Park management issues with adjacent landholders and is currently given first priority by NPWS in pest management. This section endeavours to explain the value of encouraging restoration of a natural predator hierarchy that, if achieved, could assist land managers and landowners alike. It would also assist a suite of threatened species in the park, by removing the pressure of fox predation, at least at altitudes below the subalpine.

There has been a major change in the high order predator–prey relationship since European settlement. The dingo/dog–fox–cat dynamic, has replaced the dingo–eastern quoll–spotted-tailed quoll hierarchy (Figure 10.4). Elimination of the dingo in other areas has led to the increase in foxes and increase in abundance of dingo prey (emu *Dromaius novaehollandiae*, kangaroos) (Newsome et al 1998). The larger species (dingo) can naturally suppress numbers of the smaller introduced predator species in a hierarchy of dingo–dog–fox–cat. Results (Figure 10.5) from research in Kosciuszko National Park where red fox and dingo population competition was studied demonstrate this meso-predator release (Newsome et al 1983). Parallels have been demonstrated in the United States with the coyote–fox–skunk–cat relationships and in several environments (chaparral, grasslands) (Estes 1996). The change in the abundance and type of predators produces a different predation regime and abundance of prey and, consequently, differing grazing regimes in a trophic cascade (Ripple et al 2001, Estes 1996).

Figure 10.5 **Two examples of meso-predator release between dingoes and red foxes, from the Tin Mine Region in Kosciuszko National Park down to the coast at Nadgee Nature Reserve (Newsome et al 1983)**

Number of fox tracks



Number of dog tracks

Basis for management

Under the *National Parks and Wildlife Act 1974*, NPWS has a legislative duty to protect native species and control feral animals. Control and management of introduced animals is primarily governed by the provisions of this Act and the *Rural Lands Protection Act* 1998. Control programs within the park need to be consistent with NPWS's statewide field management policies and the provisions of the current management plan for the park. Currently, priorities and approaches for introduced animal control in the park are contained within pest management strategies for the two NPWS regions covering the park.

Significance and condition

The natural large and meso-predator regime in Kosciuszko National Park is highly significant and potentially more so. Kosciuszko National Park contains one of the few remaining dingo populations in southeast Australia, which plays a key role within the meso-predator relationship (Newsome 1988). There are large pressures and effects outside the park from dogs and foxes, and impacts on the relative abundance of native fauna populations, which are also highly significant (Newsome et al 1983). Predation by the red fox is a nationally listed threatening process under the EPBC Act and listed as a threatening process in the park under the *Threatened Species Conservation Act 1995* — a process exacerbated by meso-predator release. The park also has one of the largest known spotted-tailed quoll populations in southeastern Australia (NPWS 2002). Over the last two decades there have been major efforts in Europe and North America to restore large predators (eg bears and wolves) to the landscape (a costly and controversial exercise) [2]. It is suggested that efforts by Kosciuszko National Park to restore the natural predator regime would achieve international recognition.

The condition of the large predator hierarchy in Kosciuszko National Park is very poor and highly degraded, and one species in the hierarchy, the eastern quoll, is already extinct in the park. There also needs to be active management of the spotted-tailed quoll population in order that it can be restored to numbers where its ecological function and its place in the predator hierarchy can be expressed at the landscape level. Currently, dingoes are removed from the park and, perhaps, even more significantly, this species is subject to a genetic dilution from introduced dogs. This trend of genetic dilution is magnified by the comparative disparity in breeding cycles; dogs breed twice a year, while dingoes breed once a year (Catling et al 1992). This trend is expected to continue if the dingo is actively pursued as a pest. The nexus of the problem is it that is very difficult to scientifically distinguish in the field between a dingo and a wild dog that looks like a dingo. Positively, there have been recordings of the spotted-tailed quoll where a change in baiting practices from aerial to ground has occurred.

The pressures on restoration of a balanced predator relationship are: management practices that do not specifically target dogs and foxes, and disadvantage the dingo; increased opportunities for foxes and cats over winter because of the presence of ski resorts and other developments; a lack of research and funding; and the increase in domestic dog incursions (eg by pig dogs; Green,K, pers comm, September 2002) in the park. Even with restoration of the pre-European predator relationship there will remain a problem above the snowline and around resorts where cats and foxes are the major predators. For the cat, it is likely that a cat-specific toxin will be available for field use in the foreseeable future (Marks,C, DNRE, pers comm, September 2002), and fox-baiting techniques will probably improve.

In this context it is highly probable that efforts to control the dingo/dog in the park exacerbate the fox and cat problems, and may be counter-productive to improved ecological outcomes. An alternative is to restore a stable dingo population, which would control the populations of the smaller fox and probably cat. This might also provide

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[2] A bibliography on this issue can be viewed at www-lib.uwyo.edu/LibSci/wolf.

some 'natural' predation pressure to overcome problems with feral horses and deer. Such a strategy would have to be implemented in concert with the restoration of the spotted-tailed quoll population and in the context of adaptive experimental management.

Opportunities

There is an obvious opportunity for research and funding to increase the knowledge of the dynamics of this relationship, so that the meso-predator process can be manipulated to benefit both graziers and conservationists. In the long term the reestablishment of the eastern quoll would be an opportunity for the alps and also a safeguard against its potential demise in Tasmania where the fox has been recent introduction. At present there is an opportunity to restore the place of the dingo and the natural meso-predators in the natural system of the park. Todd (2002) describes a method and an example for building community consensus on a similar issue in Alaska, which may be a useful guide for Australian policy makers.

Indicators and monitoring

The most obvious indicators to monitor this meso-predator relationship are dingo and spotted-tailed quoll numbers. It would be necessary to have an index of the numbers of all predators in the park, and thus form a picture of the relative structure of the predator community. Monitoring of sheep kills could also be considered in conjunction with the Rural Lands Protection Board (RLPB). The latter data should be linked to the positive identity of the predator dog–dingo hybrid. Pest management programs should be cognisant of the predator hierarchy dynamic and land tenure, preferably tenure blind. Such a program may have multiple target species both for control and enhancement. The current Cooperative Wild Dog/Fox Control Plan for the Brindabella and Wee Jasper Valleys provides a current example (Hunt et al 2002).

A major policy objective must be to restore the natural (pre-European) meso-predator regime in the park, in order to reduce fox and dog populations. This will decrease the exotic predator pressure on native species in the park, hopefully to a point where they do not play a major role in meso-predator relationship. This would also have associated positive effects on fauna populations, including the maintenance of a stable dingo population and increasing quoll populations.

Ecological processes: grazing herbivores

We noted earlier that, in Tasmania, grazing by marsupials influences the distribution and abundance of tall herbfields (Bridle and Kirkpatrick 1998), and the major grazers in the alpine area of Kosciuszko National Park are insects. There are, however, a large number of introduced vertebrate herbivores in Kosciuszko National Park, some having a major effect, others localised or at present seen as having low impact (hares, deer). The licensed grazing of cattle ceased many years ago (although there remain three 'stock routes'), but the individual and combined grazing pressure of introduced species (rabbits, hares, horses, pigs, deer) is substantial. Populations of these herbivores are affecting vegetation and sensitive areas like bogs. The populations of some, such as horses, are increasing; some, such as pigs, may increase in the future; and others are still expanding their range (for example, sambar deer are now commonly recorded above 1600 m in Victoria). The altitude at which habitat becomes marginal for rabbit populations appears to be substantially higher at present than several decades ago. Species, such as horses, that can persist at higher elevations (Green and Osborne 1994) are of particular concern.

At present, the alpine area may well be protected by the seasonal snow cover and is not presently overly effected, except in the case of bogs. However, it is highly vulnerable, particularly under changing population sizes and climate change. Unchecked invasion by some of these herbivores is likely to change the structure of the alpine vegetation and move it away from the present insect-dominated system. In the absence of natural enemies (predators, parasites) or control, these species represent a major threat to the natural integrity of the park. Reestablishment of the pre-European predator system should be incorporated into control measures.

According to the ecological concept of 'trophic cascades,' the suite of exotic herbivores current present in the park may represent a major problem that is not perceived at present. Control of introduced herbivores within an adaptive experimental management framework should be a major management program of the park.

Ecological processes: fire

NSW NPWS and Kosciuszko National Park management have obligations to protect assets from the impacts of wildfires, as well as use fire in ecological management. Fire in Kosciuszko National Park and its implications for management (eg risk) are discussed elsewhere (Chapter 12), however, fire is such an important determinant of habitat that it requires some discussion in relation to fauna. Apart from the alpine area, where wildfire is a very rare 'catastrophic' event, most environments within the park have evolved under a regime of relatively frequent fire. Kosciuszko National Park has been subject of several major and extensive bushfires (eg 1939) and Banks (1989) records 18 fires in the Brindabella Range between 1820 and 1973.

Fire (or lack of it) is a major determinant of vegetation and its seral stages across the Australian landscapes – this affects the spatial and temporal availability of habitat for fauna. Present vegetation distribution is an expression of past fire regimes. Nevertheless, pre-European (Aboriginal) fire regimes are imperfectly understood. Banks, (1989), through dendrochronology (tree ring dating, fire scars) and historical records, found that fires in Kosciuszko National Park were more frequent following settlement and less frequent from the 1960s. He qualified this generalisation, observing that the magnitude of this increase was site dependent, and that fires were probably patchy in the intensity of their effect. Certainly, fire regimes have changed and may have affected faunal distributions.

Management using fire (both naturally and purposely ignited) is important for habitat manipulation and vegetation condition and fires may contribute to tree hollow production. Some species are reliant on specific fire regimes for maintaining attributes of habitat (eg Smoky Mouse, seed plants and fungi) whilst others may be more tolerant of broader fire regimes. Species requirements, particularly threatened species, need to be incorporated into the management of the fire regime in Kosciuszko National Park.

Recently, fire management for ecological purposes has developed the concept of using the life history characteristics (vital attributes) of constituent flora and fauna and ecologically tolerable intervals to determine appropriate fire regimes (Fire Ecology Working Group 2002). Fire history (controlled burns and wildfires) is mapped to vegetation class and compared to an 'idealised' age class distribution – thus active management can be targeted (exclusion and controlled burning). To be operational, this process requires a GIS system that incorporates layers of vegetation condition (see below). Within this framework management decisions regarding any bias for maturity, catchment and wildlife protection, etc, can be transparently embedded.

In order to improve management of fauna and its habitat, while recognising the need to protect property outside the park, fire management should be driven by ecologically-based fire regimes using life history characteristics, and spatially address needs of fire dependent threatened species, and vegetation age class and maturity.

Overall condition and trend in condition: interpretation

The condition of the fauna in the park is difficult to assess. The condition of some populations and trophic levels has been discussed earlier. For the vast majority of species no routine monitoring is undertaken to determine trends. Indeed, there is no long-term contextual framework within which such studies can be conducted. Peregrine falcon breeding success is monitored annually and, as part of monitoring for global warming, bird migrations are monitored weekly in relation to snow depth and cover, emergent vegetation and flowering (Green,K, pers comm, September 2002). For some groups, such as birds, there is a system of informal 'surveillance' monitoring (by birdwatchers and others).

For other faunal groups, most notably frogs (eg Osborne et al 2000) and mammals (Broome 2001a,b), more detailed species accounts are available from the park and elsewhere. The broad-toothed rat has the longest monitoring history in the park — since 1978 at Smiggins Holes (Green,K, pers comm, September 2002). Relevant studies of species and communities outside the park can help to guide management. Even some of these must be seen in the context of long-term cyclical change (eg El Niño droughts) and the recovery of habitats from major disturbances (grazing, bushfires, etc), the effects of which are not fully understood but have a recovery period measured in decades.

Newsome and Catling (1979) proposed a simple measure of habitat complexity for small mammals, however, there is also no general measure of condition of the vegetation which could assist assessment and long-term monitoring (DNRE 2002). Indeed, a measure such as habitat hectare (Parkes et al in press) is vital for the ongoing measurement of condition. In order to accomplish this, some point in time (a benchmark date) against which to measure changes needs to be established. The arrival of Europeans would appear to be the most appropriate, even though absolute knowledge of the condition then is impossible and must be intelligently surmised. All benchmarks have disadvantages, but this point would also recognise the Aboriginal knowledge embedded in their land management, and encourage investigations of this knowledge.

Notwithstanding their limitations, general observations gleaned from the literature about the condition of specific species, habitats and communities, the ecosystem services that are provided by the fauna, and the condition of their habitats, have been discussed above. Figure 10.4 indicates that faunal assemblages of some of the trophic levels of the park are in a disrupted and poor condition. The natural predator–prey balance has been markedly disturbed: all large owls are threatened (declined across their range); large and medium-sized mammalian predators are either extinct (eastern quoll), have declined in abundance (spotted-tailed quoll) or have been 'controlled' (dingo). Populations of foxes and cat are prevalent, frequently around important biological areas (eg mountain pygmy-possum habitat) and have introduced selective predation pressures (eg on the broad-toothed rat, Green 2002). Changes in predation (increase or decrease) will cause consequent changes in prey species and the extent of their ecological function.

Grazing and trampling pressures are evident from a suite of introduced species, including rabbits, horses, deer and pigs. These populations cause a general decline in habitats (at variance from the 'natural' condition) and may destroy some components, such as bogs, if left unchecked. Other elements adversely affecting the condition are discussed below.

There are critical elements that will improve our understanding of condition. These include:

- The establishment and implementation of systematic framework for monitoring vegetation condition;
  This should be part of a statewide or perhaps national framework, and should evolve to encompass habitat condition (eg wetlands) (see Parkes et al in press);

- Current monitoring of some key and focal species and communities is relatively good for the alpine–subalpine areas and should continue. It is relatively poor for the forests, particularly the drier woodlands;
- The effect of introduced species on basic ecological functions, roles and processes should be used to prioritise management, eg predator–prey relationships, grazing. Restoration of natural systems should be the goal.

The assets — taxonomic advances

Since the original Plan of Management for Kosciusko National Park (1982) there have been many advances in taxonomy and the scientific tools derived from the study of genetics. Genetics offers a most valuable new tool for park management and should be incorporated into future research plans. New taxa (species and subspecies) have been erected, several of which are alpine endemics (eg alpine she-oak skink and alpine tree frog). In Victoria, a field investigation of an alpine flatworm *Spatula tyrssa* found several new species that are endemic to various mountain areas (St Clair et al 1999), and these findings could well be 'typical' of the alpine environment. In the case of the mountain pygmy-possum, arguably the most studied species of fauna in the park, it has only been found recently that the small population (250) consists of two genetically identifiable halotypes (Osborne et al 1999). Further, the global population (only 2000 adults) consists of three or four genetically distinct subpopulations (Osborne et al 2000). Observations such as these should have profound effect on fauna population management into the future.

These examples highlight our imperfect of knowledge of the fauna (particularly invertebrates), and suggests the prudent use of the precautionary principle in park management activities. We do not know the extent and diversity of many our assets. Genetic studies are being undertaken for the spotted tree frog, northern corroboree frog, mountain pygmy-possum, spotted-tailed quoll, broad-toothed rat, brush-tailed rock-wallaby and smoky mouse (NSW NPWS 2000). Such studies of the fauna of the park are to be encouraged for the inevitable insights that they will provide.

These advances at the species and subspecies level should be complemented by studies that provide insights into how the ecosystem works.

Some additional threatening processes

Some of the key threatening processes have been discussed earlier, or elsewhere by the ISC (eg weeds), and are not discussed below. Although the causes of the threatening processes discussed here are beyond local park management, an adaptive management response is required.

Climate change

The potential consequences of the enhanced greenhouse effect for the global climate (ie global warming) and for the climate of southeastern Australia are profound. Bennett et al (1992) and Brereton et al (1995) provided future scenarios for selected fauna of southeast Australia. Green and Pickering (2002) examined the reduction of the area of snowlie for mammals and birds in the Snowy Mountains. Distributions will change drastically, and alpine species appear to be among the most vulnerable, with many 'climatic envelopes' likely to be extinguished. However, for some other species, the mountains, which provide altitudinal gradients, will become increasingly important as refugia.

The snowline is predicted to rise, causing a dramatically reduced snow season, possibly as early as 2030 (Whetton et al 1996). If the period and extent of snowlie declines then this will cease to be a limiting factor in the distribution of some species. Green and Pickering (2002) suggest that altitudinal increases in distribution are already observable at Kosciuszko National Park (eg swamp wallaby). Other fauna (eg macropods) may exploit the expanded snow free area and thus induce novel grazing pressures that may initiate vegetation change (Bridle and Kirkpatrick 1998). A further implication is the loss of competitive advantage for species that have behavioural or physiological adaptations for the present alpine climate (eg hibernation), and they may be exposed to increased competition from species presently confined to lower altitudes. Over a long period, the vegetation communities (habitats) shown in Figure 10.3 would shift in their altitudinal extent, and the treeline would move upward as conditions for the germination and persistence of Snow Gums became available. Fauna are predicted to follow these trends, and more mobile generalist species may be able to persist in the larger snow-free areas.

It is likely that invertebrates will initially be the most sensitive to climate change. This has potentially profound effects on the alpine vegetation, where insects are major native grazers and influence the seral succession of some vegetation types. A major research proposal — part of an international system, ITEX — is in train and the park has an important role. This research should illuminate the 'robustness' of the alpine and montane vegetation to climate change.

Some broad implications for faunal conservation and 'greenhouse-proofing' in the park are:

- Alpine environments are a key area for research and monitoring;
- A better understanding of the ecological functions at the systems level is needed;
- The present habitats must be as robust and healthy as possible (Bennett et al 1992) in order to maximise resilience. This includes the control of introduced predators;
- Registration of the importance of the park as a refugium and the integration of adjacent land uses to maximise biodiversity conservation. This suggests, for example, the need for planning of regional-scale corridors across landscapes outside the park.

Increased UV-B radiation

There has been much scientific debate concerning the biological effects of elevated solar UV-B radiation, particularly at higher latitudes and altitudes, because of ozone depletion. Alpine amphibians (frogs and tadpoles) are seen as particularly vulnerable because this radiation can penetrate several metres into water (Blaustein et al 1994). Current research suggests that a declining species (the alpine tree frog) is significantly more sensitive to ambient UV-B than a non-declining species (*Crinia signifera*) (Broomhall, quoted in Osborne et al 2001). The global problem of ozone depletion has been addressed through the Montreal Protocol (for the control of CFCs), and recent reports suggest that ozone levels may be stabilising, and could return to normal levels by 2050 (Macey 2002). However, this may be too late for some species if increased UV-B radiation is indeed the primary cause of decline.

Exotic diseases and pathogens

The wildlife populations of the park may be vulnerable to exotic diseases and pathogens. Disease (eg toxoplasmosis) has been suggested as a cause of the rapid declines of marsupials early in the 20th century (quolls, koala). Diseases such as canid mange in wombats and chytridiomycosis in frogs have been recorded in the park. The latter disease, caused by a fungus-like organism, has been recorded in both wild and captive spotted tree frogs, and many other species (M Scroggie, pers comm,), although there is still debate as to whether it constitutes a primary cause of observed population declines (see Alford and Richards 1997, Berger et al 1998, Bosch et al 2001).

Exotic diseases have the potential to have long-term detriment to the parks fauna. It is a difficult problem to counter act. In the national sense, the Australian Quarantine Inspection Serviced is the first line of defence, and park managers have powers to stop deliberate release. However, parks staff must remain vigilant in their surveillance and reporting of unusual events, and at least several staff should be keeping abreast of the literature.

Gaps in the knowledge required for management

Some of the gaps in our understanding have been discussed above. In this section we discuss some of the generic gaps and the specific studies required. There is a need to establish an overall framework for strategic research. Incorporating many of the research projects into a program of adaptive experimental management is arguably the most rewarding. In the recent past, threatened species have attracted a substantial research effort. This has been worthwhile, but a more holistic landscape approach may prove more productive. The research within Kosciuszko National Park should be linked to other areas, and for some topics (eg large owls, predation, health of system, subterranean biodiversity, and nutrient cycling) the major drivers could well be outside the park system.

Recommended studies include the following:

- Systematically evaluate the condition of the vegetation (and progressively habitat) of the park (linked to surrounds). This should be GIS-based and would assist in the resolution of questions concerning seral stages and area of mature vegetation. It is also linked to fire regimes;
- Examine the meso-predator system in the park, with the aim of restoring the dingo–quoll predator system. In the foreseeable future, when techniques are available, landscape control of both foxes and cats should be possible;
- Within the above framework, knowledge is required on the processes of the system. This is particularly important regarding the role of insects and invertebrates as major grazers, in the alpine area in particular and should include subterranean biodiversity and nutrient availability;
- Increase knowledge of several key species/groups to assist in their management:
  - spotted-tailed quolls and meso-predators,
  - Smoky Mouse: role of fire and fungi,
  - a suite of alpine species, eg alpine tree frog, three 'new' reptiles: some of these will prove suitable for long-term monitoring and indicators of health (eg mountain pygmy-possum),
  - Bogong Moths, which provide a major energy input to the alpine environment: the recent discovery of arsenic should be investigated, as should the breeding grounds response to greenhouse warming; and
  - other species, eg brush-tailed rock-wallaby, that have legal requirements for recovery;
- Grazing animals. The suite of feral grazers (eg horse, deer, pig and rabbit) in the park are altering the natural ecological grazing regime. The extent of the grazing pressure may also be related to predator management. The effect of this on the natural capital of the park is more than likely profound. Research to thwart the expansion of the range of these animals into the alpine areas should be initiated, with efficient and effective control or elimination being the aim; and
- Enhanced greenhouse climate change. As biodiversity assets are among the most vulnerable, and alpine environments the most vulnerable of these, we need to understand the specific changes in the context of global changes. This understanding must be related to feasible management options for the park. 'Robustness' or ecological health are important attributes in the alpine environments. Within this framework, the role of the park as a refugia for species outside the park must be included.

Indicators

The NSW NPWS indicated that a series of indicators for the condition of fauna in Kosciuszko National Park were required for management. A preliminary contribution is illustrated Table 10.7. The range of these indicators includes some focal species (several of which are icon species), keystone species indicative of the condition of a process (predator hierarchy), and surrogates for the condition of habitat (vegetation condition). As noted elsewhere, these indicators and the research and monitoring they imply should all be done within an adaptive management framework, and thus remain capable of refinement over time.

Much of the trend to use indicators derives from the need to measure progress and many derive from the condition–pressure–response model made popular by the OECD and used in state of the environment reporting. The indicators below are put forward as suggestions for the long-term, perhaps reporting on every 5 years with frameworks and intellectual infrastructure in place as early as possible. Others used indicators for a multitude of purposes. The indicators below are not necessarily amenable to 'annual targets' or other such more immediate management requirements.

Table 10.7 Preliminary set of indicators for assessing the faunal values in Kosciuszko National Park

Value	Indicator	Notes	Priority
12.1 Alpine and subalpine fauna	Condition of populations of selected threatened or significant species/communities	Mountain pygmy-possum, southern corroboree frog, alpine tree frog, bogong moth (incl. arsenic). Invertebrate grazing community in alpine grassland.	High
		Species sensitive to (or indicative of) climate change. These may include altitudinal migrants.	
12.2 Forests and woodlands	Condition of populations of selected threatened	Hollow-dependent birds and mammals.	High
	or significant species/communities	Woodland/ dry forest bird communities (surveillance/baseline) – link to broader studies.	Medium
		Specialists – smoky mouse, spotted tree frog, brush-tailed rock wallaby, cave communal breeders (bats).	Strategic
		Species sensitive to (or indicative of) climate change. These may include altitudinal migrants.	High
12.3 General terrestrial habitat	Condition of vegetation type (habitat hectare value) and % mature seral stage	Need to establish measure of vegetation condition, bench mark at pre-European and correlate faunal communities. This measure would need to incorporate fire histories.	Medium - Long term
12.4 Restoration of pre-European meso-predator system	a. Density (condition) of dingo and fox populations b. Density and extent of quoll population c. (Above snowline) – fox and cat density	Integrate control into an AEM framework. Need to establish integrity of dingo population. Need landholder liaison. Mastacomys populations may be a good response indicator for fox above the snowline.	High - long term
12.5 Integrity of natural grazing regime	a. Extent and density of introduced grazers b. Change in distribution of native grazers	Grazers include pigs, deer, brumbies, rabbits and hares. The objective is to have decrease in current extent and density. The distribution of native grazers/browsers may change in response to climate change. Medium	Medium

Some results of faunal management — 'Vision for 2020'

In the year 2020, Kosciuszko National Park is viewed as a national asset for biodiversity conservation. In conjunction with alpine parks in Victoria and ACT, it has achieved World Heritage Area status, in recognition of the parks' outstanding and increasingly important biodiversity assets. The park makes a highly significant contribution to the economy, as its faunal values are most valued by visitors and contribute to the attractiveness of the park.

The condition of all the vegetation and habitats is demonstrably improving relative to the benchmarks of pre-European settlement. Having adopted the goal of net gain in condition and extent of native habitats, governments and the community have adequately funded management to achieve these tangible goals. As a consequence, viable representative populations of all fauna species in the park are conserved and are able to perform their ecological function.

Several species have recovered sufficiently to be removed from the threatened species list, although the alpine endemics remain threatened because of the restricted nature of the habitats. The condition of several of these populations has, however, improved due to habitat enhancements and a decrease in predation pressure from introduced carnivores. It is acknowledged that species that are threatened in NSW and occur in the park, have their most secure populations in the park. Populations in the park provide an invaluable biodiversity reservoir and refugium. Brush-tailed rock-wallabies have been reintroduced into the park, while Koalas reestablished without assistance.

The pre-European meso-predator hierarchy is in the final stages of restoration, with healthy dingo and spotted-tailed quoll populations. The eastern quoll has been successfully reintroduced, and in the drier habitats is once again taking up its place in the ecology. These species are common enough to be an obvious feature of the park and can be readily seen by many visitors. Importantly, this has also allowed some natural control of the indigenous grazers such as kangaroos. Fox and cat populations have drastically declined in the park, and in adjacent areas.

The emphasis on protecting mature vegetation has enabled many fauna species to persist in the park and, importantly, the increasing availability of tree hollows has seen a gradual restoration of populations of hollow-dependent species.

By 2020, the effects of enhanced greenhouse climate change are occurring, and subtle yet sure changes in the distribution of some species of fauna are evident at the continental scale. The park has become one of the central pillars in 'greenhouse-proofing' the natural landscapes of southeast Australia. The alpine and subalpine environments have been progressively made more healthy and robust, and are now more resilient to changes that are wrought by disturbance, such as invasion by weeds.

Acknowledgements

Michael Scroggie and Greg Hollis (DNRE) provided information on frogs, and Clive Marks and Gordon Friend (DNRE) commented on aspects of predation and fire. Ken Green and Mark Adams (NSW NPWS) provided valuable guidance on structure and content, while Andy Spate provided advice on an early draft. Thanks to Heather Anderson for assistance with the graphics and David Meagher who provided editorial support.

References

Alford RA and Richards SJ (1997). Lack of evidence for epidemic disease as an agent in the catastrophic decline of Australian rain forest frog. *Conservation Biology* 11:1026–1029.

Amaranthus MP, Trappe JM and Molina RJ (1990). Long-term forest productivity and the living soil. *Forest Research Laboratory, Oregon State University, Oregon Paper* 2265.

ANZECC (2001). Review of the National Strategy for the conservation of Australia's biological diversity. Australian and New Zealand Environment and Conservation Council, Canberra.

Banks JC (1989). A history of fire in the Australian Alps. In: Good R (ed), *The Scientific Significance of the Australian Alps*. Australian Academy of Science, Canberra, 265–280.

Barnosky A, Hadly E, Mauer H and Christie M (2000). Temperate terrestrial vertebrate faunas in North and South America: interplay of ecology, evolution and geography with biodiversity. *Conservation Biology* 15:658–674

Bennett S, Brereton R, and Mansergh I (1992). *Enhanced Greenhouse and the Wildlife of South Eastern Australia*. Department of Conservation and Environment, Melbourne.

Berger L, Spear R and Hyatt AD (1999). Chytid fungi and amphibian declies: an overview, implications and future directions. In: Campbell A (ed), *Declines and disappearances of Australian frogs*. Environment Australia, Canberra.

Blaustein AR, Wake D, Hokit D, Kiesecker J, Walls S and Hays J (1994). UV repair and resistance to solar UV-B in amphibian eggs: a link to population declines? *Proceedings of the National Academy of Sciences USA* 91:1791–1795.

Bosch J, Martinez-Solano I and Garcia-Paris M (2001). Evidence of a chytrid fungus infection involved in the decline of the common midwife toad (*Alytes obstetricans*) in protected areas of central Spain. *Biological Conservation* 97:331–337.

Brereton R, Bennett S and Mansergh I (1995). Enhanced greenhouse climate change and its potential effect on selected fauna of southeast Australia. *Biological Conservation* 72:339–354.

Bridle KL and Kirkpatrick JB (1998). Why do tall herbs rarely dominate Tasmanian alpine vegetation? Evidence from islands in the Ouse River system. *Papers and Proceedings of the Royal Society of Tasmania.* 132:9-14.

Broom R (1985). On a new fossil mammal allied to *Hypsiprymnus* but resembling in some points the Plagiaulacidae. *Abstracts of the Proceedings of the Linnaean Society of NSW* 26:11.

Broome LS (1992). Ecology and management of the mountain pygmy-possum, *Burramys parvus* Broom, in Kosciusko National Park. Report to the NSW National Parks and Wildlife Service, Sydney, NSW.

Broome LS (1996). Draft Recovery Plan for the mountain pygmy-possum (*Burramys parvus*) in New South Wales. NSW National Parks and Wildlife Service, Southern Zone.

Broome LS (2001a). Intersite differences in population demography of mountain pygmy-possum *Burramys parvus* (Broom) (1987–97): implications for a metapopulation in Kosciusko National Park, Australia. *Biological Conservation* 102:309–323.

Broome LS (2001b). Density, home range, seasonal movements and habitat use of the mountain pygmy-possum *Burramys parvus* (Marsupialia:Burramyidae) at Blue Cow, Kosciusko National Park. *Austral Biology* 26:275–292.

Broome LS (in prep). Survival and recruitment of the mountain pygmy-possum in relation to snow cover in the Snowy Mountains, Australia.

Broome LS and Geiser F (1995). Hibernation in free-living mountain pygmy-possums, *Burramys parvus* (Marsupialia: Burramyidae). *Australian Journal of Zoology* 43:373–379.

Broome LS, Green K and Walter MA (in prep). Re-assessment of *Burramys parvus* population size and distribution of habitat in Kosciuszko National Park.

Broome L and Mansergh I (1989). The mountain pygmy-possum (*Burramys parvus*) Broom: an alpine endemic. In: Good R (ed), *The Scientific Significance of the Australian Alps*. Australian Academy of Science, Canberra, 241–265.

Brown G (2002). The distribution and conservation status of the reptile fauna of the Murray River region in Victoria. *Victorian Naturalist.* 119(4):133–143.

Bubela TM, Dickman CR and Newsome AE (1998). Diet and winter foraging behaviour of the Red Fox (*Vulpes vulpes*) in alpine and subalpine New South Wales. *Australian Mammalogy* 20:321–30.

Bubela TM and Happold DCD (1993). The social organisation and mating system of an Australian subalpine rodent, the broad-toothed rat, *Mastacomys fuscus* Thomas. *Wildlife Research* 20:405–15.

Bubela TM, Happold DCD and Broome LS (1991). Home range and activity of the broad-toothed rat, *Mastacomys fuscus* in subalpine heathland. *Wildlife Research* 18:39–48.

Busby, JR (1990). The National and International Significance of the National Parks of Eastern Victoria. Department of Conservation and Environment, Melbourne.

Carr SGM and Turner JS (1959). The ecology of the Bogong High Plains. Parts I & II. *Australian Journal of Botany* 7:12–63.

Carron PL, Happold, DCD and Bubela TM (1990). Diet of two sympatric Australian subalpine rodents *Mastacomys fuscus* and *Rattus fuscipes*. *Australian Wildlife Research* 17:479–489.

Catling PC, Corbett LK and Newsome AE (1992). Reproduction in captive and wild Dingoes (*Canis familiaris dingo*) in temperate and arid environments of Australia. *Wildlife Research* 19:195–209.

Caughley J (1986). Distribution and abundance of the Mountain Pygmy-possum, *Burramys parvus* Broom, in Kosciusko National Park. *Australian Wildlife Reserach* 13:507–517.

Claridge A (1997). Truffle junkies. *Nature Australia*, Autumn:48–55.

Claridge A and Lindemayer D (1998). Consumption of hypogeous fungi by the mountain brushtail possum (*Trichosurus caninus*) in eastern Australia. *Mycology Research* 102 (3):269–272.

Claridge A, Trappe J and Claridge D (2001). Mycophagy by the swamp wallaby (*Wallabia bicolor*). *Wildlife Research* 28:643–45.

Common IFB (1954). A study of the ecology of the adult Bogong moth, *Agrotis infusa* (Boisd.) (Lepidoptera: Noctuidae), with special reference to its behaviour during migration and aestivation. *Australian Journal of Zoology* 2:223–63.

Corbett L (1995). *The Dog in Australia and Asia*. University of New South Wales Press Ltd, Sydney.

Costin AB (1989). The alps in a global perspective. In: Good R (ed), *The Scientific Significance of the Australian Alps: Proceedings of the First Fenner Conference*. Australia Alps National Parks Liaison Committee and Australian Academy of Science, Canberra, 7–19.

Costin AB, Gray M, Totterdell JC, Wimbush DJ (2000)*. Kosciuszko Alpine Flora.* Second edition, CSIRO, Collingwood.

Coyne P (2000). Protecting the Natural Treasures of the Australian Alps. Report to the Australian Alps Liaison Committee, Canberra.

Crooks K and Soule M (1999). Meso-predator release and avifaunal extinctions in a fragmented system. *Nature* 400:563–566.

Department of Natural Resources and Environment (2002). *Victoria's Native Vegetation Management: A Framework for Action.* Department of Natural Resources and Environment, Melbourne.

Dickman C, Green K, Carron P, Happold D and Osborne W (1983). Coexistence, convergence and competition among *Antechinus* (Marsupialia) in the Australian high country. *Poceedings of the Ecological Society of Australia* 12:79–99.

Estes JA (1996). Predators and Ecosystem Management. *Wildlife Society Bulletin* 24 (3):390–396.

Fire Ecology Working Group (2002). Analysis of disturbance by fire on public land in Victoria. Department of Natural Resources and Environment, Melbourne.

Fleming P, Corbett L, Harden R and Thompson P (2001). Managing the Impact of Dingoes and Other Wild Dogs. Bureau of Rural Sciences, Canberra.

Flood J (1980). *The Moth Hunters.* Australian Institute of Aboriginal Studies, Canberra.

Gall BC and Longmore NW (1978). Avifauna of the Thredbo Valley, Kosciusko National Park. *Emu* 78:189–196.

Geiser F and Broome L (1991). Hibernation in the mountain pygmy possum *Burramys parvus* (Marsupialia). *Journal of Zoology, London* 223:593–602.

Geiser F and Broome L (1993). The effect of temperature on the pattern of torpor in a marsupial hibernator. *Journal of Comparative Physiology* A 163:133–7.

Geiser F, Sink HS, Stahl B, Mansergh I and Broome LS (1990). Differences in the physiological response to cold in wild and laboratory-bred mountain pygmy possums, *Burramys parvus* (Marsupialia). *Australian Wildlife Research* 17:535–39.

Gillespie GR (2001). The role of the introduced trout in the decline of the spotted tree-frog (*Litoria spenceri*) in south-eastern Australia. *Biological Conservation* 100:187–198.

Gillespie GR, Osborne W and McElhinney N (1995). The conservation status of frogs in the Australian Alps: a review. Unpublished report to Australian Alps Liaison Committee, Canberra.

ldingay R (2000). Small dasyurid marsupials – are they effective polinators? *Australian Journal of Zoology* 48:597-606.

Good R (ed) (1989). *The Scientific Significance of the Australian Alps: Proceedings of the First Fenner Conference*. Australia Alps National Parks Liason Committee and Australian Academy of Science, Canberra.

Good R (1992). *Kosciuszko Heritage.* NSW NPWS, Sydney.

Green K (ed) 1998. *Snow: A Natural History; an Uncertain Future*. Australian Alps Liaison Committee, Canberra

Green K (2002). Selective predation on the broad-toothed rat *Mastacomys fuscus* (Rodentia: Muridae) by the introduced Red Fox *Vulpes vulpes* (Carnivora: Canidae) in the Snowy Mountains. *Austral Ecology* 27:353–359.

Green K (comp) (1998). *Native Wildlife of the Kosciuszko National Park: An Annotated List of the Native Vertebrate Fauna.* NSWNational Parks and Wildlife Service, Jindabyne.

Green KL, Broome L, Heinze D and Johnston S (2001). Long-distance transport of arsenic by migrating Bogong moths from agricultural lowlands mountain ecosystems. *Victorian Naturalist* 118:112–116.

Green K and Osborne W (1981). The diet of foxes (*Vulpes vulpes*) (L.) in relation to the abundance of prey above the winer snowline in New South Wales. *Australian Wildlife Research* 8:349–360.

Green K and Osborne W (1994). *Wildlife of the Australian Snow-country.* Reed, Sydney.

Green K, Osborne W and Mansergh I (1992). La Faune des Alpes Australiennes: conservation et gestion. *Revue de Géographie Alpine v*, 2–3:381–408.

Green K and Pickering CM (2002). A scenario for mammal and bird diversity in the Snowy Mountains of Australia in relation to climate change. In: Koener Ch and Spehn EM (eds), *Mountain Biodiversity: A Global Assessment.* Parthenon, London, Chapter 19.

Green K, Tory M, Mitchell A and May T (1999). The diet of the Long-footed Potoroo (*Potorous longipes*). *Australian Journal of Ecology* 24:151–156.

Gullan P and Norris K (1984). The habitat of *Burramys parvus* (Broom) in Victoria. In: Smith A and Hume I (eds), *Possums and Gliders*, Surrey Beatty and Son, Chipping Norton, 417–421.

Happold DCD (1978). Studies on the ecology of small mammals in Kosciusko National Park. *Kosciusko Symposium, Occasional Paper No. 1.* NSW National Parks and Wildlife Service, Jindabyne.

Happold D (1989). Small mammals of the Australian Alps. In: Good R (ed), *The Scientific Significance of the Australian Alps: Proceedings of the First Fenner Conference, 221–239.*

Heinze DL, Broome LS and Mansergh I (in prep). An overview of the ecological studies on the mountain pygmy-possum *Burramys parvus* (Broom 1896). In: Smith A and Hume I (eds), *Possums and Gliders*. Surrey Beatty and Sons, Chipping Norton.

Howe RH and Davis GJ (1991). The demographic significance of ‘sink’ populations. *Biological Conservation* 57:239–255.

Hunt R and Brindabella and Wee Jasper Valley Wild Dog/Fox Working Group (2002). Brindabella and Wee Jasper Valleys Co-operative Wild Dog/Fox Control Plan. NSW Rural Lands Protection Board, NSW National Parks and Wildlife Service and NSW State Forests.

Key K and Day M (1954). A temperature controlled physiological colour response in the grasshopper *Kosciuscola tristis* Sjost (Orthoptera, Arcrididae). *Australian Journal of Zoology* 2:309–338.

Kirkpatrick J (1993). The interantional significance of the natural values of the Australian Alps. Report to the Australian Alps Liaison Committee, Canberra.

Körtner G and Geiser F (1998). Ecology of natural hibernation in the marsupial mountain pygmy-possums (*Burramys parvus*). *Oecologia* 113: 170–178.

Macey R (2002). Scientists hail ozone success. *The Age* 17 September 2002, p. 1.

MacNally R, Ballinger A and Horrocks G (2002). Habitat change in River Red Gum Floodplains: depletion of fallen timber and impacts on biodiversity. *Victorian Naturalist* 119 (4):107–113.

Mansergh I, Baxter B, Scotts D, Brady T and Jolley D (1990). Diet of *Burramys parvus* (Marsupialia: Burramyidae) and other small mammals in the alpine environment at Mt Higginbotham, Victoria. *Australian Mammalogy* 13:167–77.

Mansergh IM and Broome LS (1994). *The Mountain Pygmy-possum of the Australian Alps*. University of New South Wales Press, Sydney.

Mansergh IM, Kelly P and Scotts DJ (1989). Management strategy and guidelines for the conservation of the Mountain Pygmy-possum (*Burramys parvus*) in Victoria. *Arthur Rylah Institute Environmental Research Technical Report* 66.

Mansergh I and Scotts D (1989). Habitat continuity and social organization of the Mountain Pygmy-possum restored by tunnel. *Journal of Wildlife Management* 53:701-707.

Mansergh I and Scotts D (1990). Aspects of the life history and breeding biology of the Mountain Pygmy-possum (*Burramys parvus*) (Marsupialia: Burramyidae) in alpine Victoria. *Australian Mammalogy* 13:179–91.

Maxwell S, Burbidge A and Morris K (1996). *The 1996 Action Plan for Australian Marsupials and Monotremes*. Endangered Species Program, Wildlife Australia, Canberra.

May T and Simpson J (1997). Fungal diversity and ecology in eucalypt systems. In: Williams J and Woinarski J (eds), *Eucalypt ecology: individuals to ecosystems*, Cambridge University Press, Cambridge. 246–277.

Mosley G (1988). Australian Alps World Heritage nomination proposal. Victorian National Parks Association, Melbourne.

Murray A, Mifsud G, Claridge A, Dawson J and Poore R (2002). Spotted-tailed Quolls and the buried-baiting method: a case study in compatibility. Paper presented at the NSW Pest Animal Conference 2002, Dubbo, 15–18 October 2002.

NSW NPWS (New South Wales National Parks and Wildlife Service) (1992). *Kosciusko National Park: Plan of Management*. 2nd edn. NPWS, Sydney.

NSW NPWS (1999). *NSW Biodiversity Strategy*. NSW National Parks and Wildlife Service, Sydney.

NSW NPWS (2000). *Saving Our Threatened Species: Native Animals and Plants*. NPWS, Sydney.

Newsome A and Catling P (1979). Habitat preferences of mammals inhabiting heathlands of warm temperate coastal montane and alpine regions of south-eastern Australia. In: Specht RL (ed), *Heathlands and Related Shrublands of the World, Descriptive Studies.* Elsevier, Amsterdam, 301–316.

Newsome A, Catling P and Corbett L (1983). The feeding ecology of the Dingo II. Dietary and numerical relationships with fluctuating prey populations in south-eastern Australia. *Australian Journal of Ecology* 8:345–366.

Norris KC, Mansergh IM, Ahern LD, Belcher CB, Temby ID and Walsh NG (1983). Vertebrate fauna of the Gippsland Lakes Catchment. *Fisheries and Wildlife Victoria, Occasional Paper Series* 1.

Osborne MJ, Christidis L and Norman JA (1999). Population genetics of the Mountain Pygmy Possum *Burramys parvus* in the Kosciusko National Park. Unpublished report to the NSW NPWS, Southern Directorate.

Osborne WS and Green K (1992). Seasonal changes in composition, abundance and foraging behaviour of birds in the Snowy Mountains. *Emu* 92:93–105.

Osborne W, Hunter D and Hollis G (2001). Population declines and range contraction in Australian Alpine frogs. In: Campbell A (ed), *Declines and Disappearances of Australian Frogs.* Department of Environment and Heritage, Canberra.

Osborne MJ, Norman JA, Christidis L and Murray ND (2000). Genetic distinctiveness of isolated populations of an endangered marsupial, the mountain pygmy-possum, *Burramys parvus*. *Molecular Ecology* 9:609–613.

Parkes D, Newell G and Cheal D (in prep). Assessing the Quality of Native Vegetation — the habitat hectares approach. *Biological Conservation.*

Pulliam HR (1998). Sources, sinks and population regulation. *American Naturalist* 132:652–661.

Pulsford I (1991). History of disturbances in the white cypress pine (*Callitris glaucophylla*) forests in the lower Snowy River Valley, Kosciusko National Park. MSc thesis, Forestry Department, School of Resource and Environment Management, Australian National University.

Ripple W J, Larsen EJ, Renkin R and Smith DW (2001). Trophic cascades among wolves, elk and aspen on Yellowstone National Park's northern range. *Biological Conservation 10*2:227–234.

Robinson D and Traill B (1996). Conserving woodland birds in the sheep belts of southern Australia. *RAOU Conservation Statement No. 10.* Royal Australasian Ornithologists Union, Melbourne.

Rosengren NJ and Peterson JA (1989). Heritage values and the geological and geomorphological significance of the Australian alpine zone. In: Good R (ed), *The scientific significance of the Australian Alps*. Australian Academy of Science, 187–204.

Saunders G, Coman B, Kinnear J and Braysher M (1995). *Managing Vertebrate Pests: Foxes*. Australian Government Publishing Service, Canberra.

Smith A and Broome LS (1992). The effects of environment and sex on the diet of the Mountain Pygmy-possum and its implications for the species conservation and management in south-east Australia. *Australian Wildlife Research* 19:755–68.

Soule M, Bolger D, Alberts C, Wright J, Sorice M and Hui S (1988). Reconstructed dynamics of rapidly extinctions of chaparral requiring birds in urban habitat islands. *Conservation Biology* 2:75–92.

St Clair R, Doeg T and Winsor L (1999). A survey for *Spatula tryssa* and other freshwater flatworms in the Victorian Alps with an evaluation of conservation status. *Proceedings of the Royal Society of Victoria* 111(1):43–49.

Stock M and Pickering CM (2002). Seasonal and altitudinal differences in the abundance and species richness of some flying macroinvertebrates in Kosciusko National Park, Australia. *Victorian Naturalist* 119:216-221.

Suckling G (1984). Population of the Sugar Glider *Petaurus breviceps*, in a system of fragmented habitat. *Australian Wildlife Research* 10:249–258.

Thurgate ME, Gough JS, Clarke AK, Serov P and Spate A (2001a). Stygofauna diversity and distribution in eastern Australian cave and karst areas, subterranean biology in Australia 2000. *Records of the West Australian Museum. Supplement* 64:37–48.

Thurgate ME, Gough JS, Spate A and Eberhard SM (2001b). Subterranean biodiversity in NSW: from rags to riches. *Records of the West Australian Museum. Supplement* 64:49–62.

Todd S (2002). Building consensus on divisive issues: a case study of the Yukon wolf management team. *Environment Impact Assessment Review* 22:655–684.

Walter A-MJ (1996). The ecology of hibernating Mountain Pygmy-possum *Burramys parvus* in Kosciusko National Park. Honours thesis, University of Canberra.

Walter A-MJ and Broome LS (1998). *Snow as a factor in animal hibernation and dormancy*. In: *Snow a Natural History; An Uncertain Future*, Green k (ed), Australian Alps Liaison Committee, Canberra and Surrey Beatty, Chipping Norton, 165–191.|Whetton PH, Haylock MR and Galloway R (1996). Climate change and snow cover duration in the Australian Alps. *Climatic Change* 32:447–79.

Williams J, Read C, Norton T, Dovers S, Bergman M, Protor W and Anderson H (2002). *Biodiversity: Australia State of the Environment 2001*. CSIRO, Canberra.

Attachment 10A

Lists of threatened fauna taxa recorded from the Australian Alpine National Parks and their conservation status from various jurisdictions from Coyne 2000.

Table 10A.1 Mammal species of the Australian Alps national parks considered significant as rare, vulnerable or threatened.

Common name	Scientific name	IUCN	EPBC Act	ANZECC list	NSW TSC Act	Vic FFG Act	VROTS	ACT NC Act
Mountain pygmy-possum	*Burramys parvus*	E	EO	E	v	2A	v	
Leadbeater's Possum	*Gymnobelideus leadbeateri*	E	EP	E		2A	e	
Long-footed potoroo	*Potorous longipes*	E	E	E	eP	2A	e	
Smoky mouse	*Pseudomys fumeus*	V	EO	E	eP		r	eA
Spot-tailed quoll/Tiger quoll	*Dasyurus maculatus*	V	VO	V	v	2A	v	
Brush-tailed rock wallaby	*Petrogale penicillata*	V	VO	V	v	2A	e	eA
Yellow-bellied glider	*Petaurus australis*	L	S		v			
Squirrel glider	*Petaurus norfolcensis*	L	S		v			
Brush-tailed phascogale	*Phascogale tapoatafa*	L	S		vP	2A		
Koala	*Phascolarctos cinereus*	L	S		v			
Great Pipistrelle	*Falsistrellus tasmaniensis*				v			
Broad-toothed Rat	*Mastacomys fuscus*				v			
Common Bent-wing Bat	*Miniopterus schreibersii*	L			v	2	c	
Greater long-eared bat	*Nyctophilus timoriensis*	V			v			
Eastern horseshoe bat	*Rhinolophus megaphyllus*					2	c	
Dingo	*Canis familiaris dingo*						ins	
Eastern broad-nosed bat	*Scotorepens orion*							ins

IUCN = World Conservation Union	E = endangered; L = lower risk, near threatened; V = vulnerable
EBPC Act = *Commonwealth Environment Protection and Biodiversity Conservation Act*	E = endangered; O = recovery outline completed; P = recovery plan completed; S = taxon summary completed; V = vulnerable
ANZECC list = Australian and New Zealand Environment and Conservation Council	Cr = critically endangered; E = endangered; V = vunerable
NSW TSC = NSW Threatened Species Conservation Act	e = endangered; P = threatened species profile completed v = vulnerable;
Vic FFG Act = Victorian Flora and Fauna Guarantee Act	2 = listed on Schedule 2 as threatened; A = action statement completed
VROTS = Victorian Rare or Threatened Species list	c = restricted colonial breeding or roosting sites; e = endangered; ins = insufficiently known (suspected of being e, r or v); r = rare v = vulnerable
ACT NC Act = ACT Nature Conservation Act	A = action plan completed e = endangered; v = vulnerable

Table 10A.2 Bird species of the Australian Alps national parks considered significant as rare, vulnerable or threatened, or as migratory species:

Common name	Scientific name	IUCN	EPBC Act	ANZECC list	NSW TSC Act	Vic FFG Act	VROTS	ACT NC Act
Regent honeyeater	*Xanthomyza phrygia*	E	E	E	e	2A	e	eA
Swift parrot	*Lathamus discolor*	V	E	V	v	2	e	vA
Glossy black cockatoo	*Calyptorhynchus lathami*	V			v	2	v	
Grey falcon	*Falco hypoleucus*	V			v	2A		
Square-tailed kite	*Lophoictinia isura*	V			v		v	
Barking owl	*Ninox connivens*				v	2		
Powerful owl	*Ninox strenua*	V			v	2	r	
Olive whistler	*Pachycephala olivacea*				v			
Pink robin	*Petroica rodinogaster*				v			
Masked owl	*Tyto novaehollandiae*				v	2	r	
Sooty owl	*Tyto tenebricosa*				v	2	r	
White-bellied sea eagle	*Haliaeetus leucogaster*					2A	r	
Turquoise parrot	*Neophema pulchella*					2	r	
Peregrine falcon	*Falco peregrinus*							
Latham's snipe	*Gallinago hardwickii*							

IUCN = World Conservation Union	E = endangered; L = lower risk, near threatened; V = vulnerable
EBPC Act = *Commonwealth Environment Protection and Biodiversity Conservation Act*	E = endangered; O = recovery outline completed; P = recovery plan completed; S = taxon summary completed; V = vulnerable
ANZECC list = Australian and New Zealand Environment and Conservation Council	Cr = critically endangered; E = endangered; V = vulnerable
NSW TSC Act = NSW Threatened Species Conservation Act	e = endangered; P = threatened species profile completed v = vulnerable;
Vic FFG Act = Victorian Flora and Fauna Guarantee Act	2 = listed on Schedule 2 as threatened; A = action statement completed
VROTS = Victorian Rare or Threatened Species list	c = restricted colonial breeding or roosting sites; e = endangered; ins = insufficiently known (suspected of being e, r or v); r = rare v = vulnerable
ACT NC Act = ACT Nature Conservation Act	A = action plan completed e = endangered; v = vulnerable

Table 10A.3 Reptile species of the Australian Alps national parks considered significant as rare, vulnerable or threatened

Common name	Scientific name	EPBC Act	ANZECC list	NSW TSC Act	Vic FFG Act	VROTS	ACT NC Act
Alpine she-oak skink	*Cyclodomorphus praealtus/ Tiliqua casuarinae*				2	v	
Alpine water skink	*Eulamprus kosciuskoi/ Sphenomorphus kosciuskoi*				2	v	
High Plains/ alpine bog skink	*Pseudemoia cryodroma*				2		
Mountain dragon	*Amphibolurus diemensis/ Tympanocryptus diemensis*					ins	
Glossy grass skink	*Pseudemoia rawlinsoni*					ins	
Tree goanna	*Varanus varius*					ins	
Snowy Mountains skink	*Egernia sp*						
Skink	*Egernia sp. 1*						
Skink	*Egernia sp. 2*						

EBPC Act = *Commonwealth Environment Protection and Biodiversity Conservation Act*	E = endangered; O = recovery outline completed; P = recovery plan completed; S = taxon summary completed; V = vulnerable
ANZECC list = Australian and New Zealand Environment and Conservation Council	Cr = critically endangered; E = endangered; V = vulnerable
NSW TSC Act = NSW Threatened Species Conservation Act	e = endangered; v = vulnerable; P = threatened species profile completed
Vic FFG Act = Victorian Flora and Fauna Guarantee Act	2 = listed on Schedule 2 as threatened; A = action statement completed
VROTS = Victorian Rare or Threatened Species list	e = endangered; c = restricted colonial breeding or roosting sites; ins = insufficiently known (suspected of being e, r or v); r = rare v = vulnerable;
ACT NC Act = ACT Nature Conservation Act	A = action plan completed e = endangered; v = vulnerable;

Table 10A.4 Amphibian species of the Australian Alps national parks considered significant as rare, vulnerable or threatened

Common name	Scientific name	IIUCN	EPBC Act	ANZECC list	NSW TSC Act	Vic FFG Act	VROTS	ACT NC Act
Spotted tree frog	*Litoria spenceri*	V	E	Cr	e	2	e	
Baw Baw frog	*Philoria frosti*	E	E	Cr		2A		
Southern corroboree frog	*Pseudophryne corroboree*	E	E	Cr	e			
Giant burrowing frog	Helioporus australiacus		V	V	v	2A	r	
Alpine tree frog	*Litoria verreauxii alpina*	V	V	V				
Northern corroboree frog	*Pseudophryne pengilleyi*		V	V	v			vA
Booroolong frog	*Litoria booroolongensis*				e			
Blue Mountains tree frog	*Litoria citropa*						r	
Eastern banjo frog (montane form)	*Limnodynastes dumereli fryii*							

IUCN = World Conservation Union	E = endangered; L = lower risk, near threatened; V = vulnerable
EBPC Act = *Commonwealth Environment Protection and Biodiversity Conservation Act*	E = endangered; O = recovery outline completed; P = recovery plan completed; S = taxon summary completed; V = vulnerable
ANZECC list = Australian and New Zealand Environment and Conservation Council	Cr = critically endangered; E = endangered; V = vulnerable
NSW TSC Act = NSW Threatened Species Conservation Act	e = endangered; P = threatened species profile completed v = vulnerable;
Vic FFG Act = Victorian Flora and Fauna Guarantee Act	2 = listed on Schedule 2 as threatened; A = action statement completed
VROTS = Victorian Rare or Threatened Species list	c = restricted colonial breeding or roosting sites; e = endangered; ins = insufficiently known (suspected of being e, r or v); r = rare v = vulnerable
ACT NC Act = ACT Nature Conservation Act	A = action plan completed e = endangered; v = vulnerable

Table 10A.5 Fish species of the Australian Alps national parks considered significant as rare, vulnerable or threatened

Common name	Scientific name	IUCN	EPBC Act	ANZECC list	NSW FM Act	Vic FFG Act	VROTS	ACT NC Act
Trout Cod	*Maccullochella macquariensis*	E	E O	Cr	e	2A	e/ v	eA
Macquarie perch	*Macquaria australasica*	D	E O	E	v	2	v	eA
Australian grayling	*Prototroctes maraena*	V	V O	V		2	v	
Murray Cod	*Maccullochella peeli*	Cr				2	v	
Two-spined blackfish	Gadopsis bispinosus							vA
Australian bass	*Macquaria novemaculeata*						r	
Climbing Galaxias	*Galaxias brevipinnis*						r	
Flat-headed Galaxias	*Galaxias rostratus*	V					r	
Freshwater Blackfish	*Gadopsis marmoratus*						in d	
Mountain Galaxiid	*Galaxias olidus*						ins	
Dwarf flat-headed gudgeon	*Philypnodon sp. nov.*						ins	

IUCN = World Conservation Union	E = endangered; L = lower risk, near threatened; V = vulnerable
EBPC Act = *Commonwealth Environment Protection and Biodiversity Conservation Act*	E = endangered; O = recovery outline completed; P = recovery plan completed; S = taxon summary completed; V = vulnerable
ANZECC list = Australian and New Zealand Environment and Conservation Council	Cr = critically endangered; E = endangered; V = vulnerable
NSW TSC Act = NSW Threatened Species Conservation Act	e = endangered; P = threatened species profile completed v = vulnerable;
Vic FFG Act = Victorian Flora and Fauna Guarantee Act	2 = listed on Schedule 2 as threatened; A = action statement completed
VROTS = Victorian Rare or Threatened Species list	c = restricted colonial breeding or roosting sites; e = endangered; ins = insufficiently known (suspected of being e, r or v); r = rare v = vulnerable
ACT NC Act = ACT Nature Conservation Act	A = action plan completed e = endangered; v = vulnerable

Table 10A.6 Insect species of the Australian Alps national parks considered significant:

Common name	Scientific name	IUCN	EPBC Act	ANZECC list	NSW TSC Act	Vic FFG Act	VROTS	ACT NC Act
Alpine stonefly	*Thaumatoperla flaveola*					2		
Bogong Moth	Agrotis infusa							
Alpine mayflies	*Ameletoides lacusalbinae*							
Stonefly	*Austrocerella hynesi*							
Stonefly	*Austrocerella verna*							
Caddisfly	*Austropsyche bifurcata*							
Rayed Blue Butterfly	*Candalides heathi alpinus*							
Caddisfly	*Chimarra monticola*							
Mayfly	*Coloburiscoides munionga*							
Reduced-wing Stonefly	*Eusthenia venosa*							
Caddisfly	*Helicopsyche tillyardi*							
Kosciuszko Mtn Grasshopper	*Kosciuscola tristis tristis*							
Stonefly	*Leptoperla cacuminis*	V						
Stonefly	*Leptoperla rieki*							
Stonefly	*Leptoperla sp. nr. tasmanica*							
Spotted grasshopper	*Monistria concinna*							
Ground beetle	*Notonomus carteri*							
Ground beetle	*Notonomus kosciuskianus*							
Moth	*Oenochroma alpina*							
Alpine Silver Xenica	*Oreixenica latialis theddora*							
Caddisfly	*Polyplectropus lacusalbinae*							
Metallic Cockroach	*Polyzosteria viridissima*							
Stonefly	*Riekoperia intermedia*					2		
Ground beetle	*Scopodes splendens*							
Moth	*Synemon sp.*							
Caddisfly	*Tasimia atra*							
Mayfly	*Tasmanophlebia lacuscoerulei*							
Mayfly	*Tasmanophlebia nigrescens*							
Ground beetle	*Teraphis crenulata*							
Hairy cicada	*Tettigarcta crinita*							

IUCN = World Conservation Union	E = endangered; L = lower risk, near threatened; V = vulnerable
EBPC Act = *Commonwealth Environment Protection and Biodiversity Conservation Act*	E = endangered; O = recovery outline completed; P = recovery plan completed; S = taxon summary completed; V = vulnerable
ANZECC list = Australian and New Zealand Environment and Conservation Council	Cr = critically endangered; E = endangered; V = vunerable
NSW TSC = NSW Threatened Species Conservation Act	e = endangered; P = threatened species profile completed v = vulnerable;
Vic FFG Act = Victorian Flora and Fauna Guarantee Act	2 = listed on Schedule 2 as threatened; A = action statement completed
VROTS = Victorian Rare or Threatened Species list	c = restricted colonial breeding or roosting sites; e = endangered; ins = insufficiently known (suspected of being e, r or v); r = rare v = vulnerable
ACT NC Act = ACT Nature Conservation Act	A = action plan completed e = endangered; v = vulnerable

Table 10A.7 Invertebrate species of the Australian Alps national parks, other than insects and cave fauna, considered significant

Common name	Scientific name	IUCN	EPBC Act	ANZECC list	NSW TSC Act	Vic FFG Act	VROTS	ACT NC Act
Murray River crayfish	*Euastacus armatus*	V						vA
Freshwater crayfish	Euastacus crassus	E						
Freshwater crayfish	*Euastacus woiwuru*							
Spider	*Sternodes castaneous*							
Mountain Earthworm	*Graliophilus montkosciuskoi*							
Mountain Earthworm	*Graliophilus woodi*							
Kosciuszko Funnel Web Spider	*Hadronyche sp*							
Wolf Spider	*Lycosa kosciuskoensis*							
Wolf Spider	*Lycosa musgravei*							
Wolf Spider	*Lycosa summa*							
Peripatus, Velvet worms	Onychopohora - *Peripatoides leuckartii*							

IUCN = World Conservation Union	E = endangered; L = lower risk, near threatened; V = vulnerable
EBPC Act = *Commonwealth Environment Protection and Biodiversity Conservation Act*	E = endangered; O = recovery outline completed; P = recovery plan completed; S = taxon summary completed; V = vulnerable
ANZECC list = Australian and New Zealand Environment and Conservation Council	Cr = critically endangered; E = endangered; V = vulnerable
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ACT NC Act = ACT Nature Conservation Act	A = action plan completed e = endangered; v = vulnerable

Table 10A.8 Fauna confined to the caves of Kosciuszko National Park, or there and very few other localities

INSECTS		
Family Blephariceridae	After a survey of 130 caves in NSW and literature review, this family was recorded only at Yarrangobilly.	1 (see below)
Cavernotettix montanus	In a survey of 130 caves in NSW and literature review, this species was recorded only in two caves at Cooleman Plain and four caves at Yarrangobilly.	1
Family Ptiliidae	After a survey of 130 caves in NSW and literature review, this family was recorded only at Yarrangobilly.	1
Pseudonemadus sp.	After a survey of 130 caves in NSW and literature review, this species was recorded only at Yarrangobilly.	1
Teraphis cavicola	Occurs at Yarrangobilly; draft nomination prepared for listing as Vulnerable in NSW.	2
Teraphis sp. Nov.	After a survey of 130 caves in NSW and literature review, this species was recorded only at Yarrangobilly.	1
OTHER INVERTEBRATES		
? Heterias sp.	After a survey of 130 caves in NSW and literature review, this species was recorded only in two caves at Cooleman Plain and one other cave.	1
Achaeranea extrilidum	After a survey of 130 caves in NSW and literature review, this species was recorded only in two caves at Yarrangobilly and one other cave.	1
Class Symphyla	After a survey of 130 caves in NSW and literature review, this class was recorded only in two caves at Cooleman Plain, three caves at Yarrangobilly and three other caves.	1
Engaeus cymus	In a survey of 130 caves in NSW and literature review, this species was recorded only at Yarrangobilly.	1
Ferrisia sp.	In a survey of 130 caves in NSW and literature review, this species was recorded only at Cooleman Plain.	1
Genus nov. near *Laetesia* sp. Nov.	After a survey of 130 caves in NSW and literature review, this species was recorded only at Yarrangobilly.	1
Glacidorbis hedleyi	In a survey of 130 caves in NSW and literature review, this species was recorded only at Cooleman Plain and Yarrangobilly.	1
Holonuncia recta	After a survey of 130 caves in NSW and literature review, this species was recorded only at Cooleman Plain and Yarrangobilly.	1
Icona sp nov	A spider troglobite known only from one juvenile specimen from River Cave (Yarrangobilly). No other troglobitic spiders are known from caves in the Australian Alps despite their apparent suitability as glacial refuge areas.	2
Icona sp.	This troglobitic species is confined to one cave at Yarrangobilly and has been proposed for listing under the *Threatened Species Conservation Act*	JI
Ixodes sp.	After a survey of 130 caves in NSW and literature review, this species was recorded only at Yarrangobilly.	1
Neoniphargus sp.	In a survey of 130 caves in NSW and literature review, this species was recorded only at Cooleman Plain.	1

Table 10A.8 Fauna confined to the caves of Kosciuszko National Park, or there and very few other localities

INSECTS		
Family Blepharidae	After a survey of 130 caves in NSW and literature review, this family was recorded only at Yarrangobilly.	1 (see below)
Cavernotettix montanus	In a survey of 130 caves in NSW and literature review, this species was recorded only in two caves at Cooleman Plain and four caves at Yarrangobilly.	1
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Teraphis sp. Nov.	After a survey of 130 caves in NSW and literature review, this species was recorded only at Yarrangobilly.	1
OTHER INVERTEBRATES		
? Heterias sp.	After a survey of 130 caves in NSW and literature review, this species was recorded only in two caves at Cooleman Plain and one other cave.	1
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Class Symphyla	After a survey of 130 caves in NSW and literature review, this class was recorded only in two caves at Cooleman Plain, three caves at Yarrangobilly and three other caves.	1
Engaeus cymus	In a survey of 130 caves in NSW and literature review, this species was recorded only at Yarrangobilly.	1
Ferrisia sp.	In a survey of 130 caves in NSW and literature review, this species was recorded only at Cooleman Plain.	1
Genus nov. near *Laetesia* sp. Nov.	After a survey of 130 caves in NSW and literature review, this species was recorded only at Yarrangobilly.	1
Glacidorbis hedleyi	In a survey of 130 caves in NSW and literature review, this species was recorded only at Cooleman Plain and Yarrangobilly.	1
Holonuncia recta	After a survey of 130 caves in NSW and literature review, this species was recorded only at Cooleman Plain and Yarrangobilly.	1
Icona sp nov	A spider troglobite known only from one juvenile specimen from River Cave (Yarrangobilly). No other troglobitic spiders are known from caves in the Australian Alps despite their apparent suitability as glacial refuge areas.	2
Icona sp.	This troglobitic species is confined to one cave at Yarrangobilly and has been proposed for listing under the *Threatened Species Conservation Act*	JI
Ixodes sp.	After a survey of 130 caves in NSW and literature review, this species was recorded only at Yarrangobilly.	1
Neoniphargus sp.	In a survey of 130 caves in NSW and literature review, this species was recorded only at Cooleman Plain.	1

Olois pictus	After a survey of 130 caves in NSW and literature review, this species was recorded only at Yarrangobilly.	1
Paralaoma sp.	In a survey of 130 caves in NSW and literature review, this species was recorded only at Yarrangobilly.	1
Textricella sp.	In a survey of 130 caves in NSW and literature review, this species was recorded only at Cooleman Plain.	1
Thasyrea lepida	After a survey of 130 caves in NSW and literature review, this species was recorded only at Yarrangobilly.	1
Note:	Bats and their resultant guano are a very important determinant of the type and abundance of cave fauna. The decline in numbers and distribution of bats in NSW caves has had far reaching, but completely unquantifiable, effects on invertebrate communities.	1

1 Eberhard, S and Spate A, 1995, Cave Invertebrate Survey: Toward an Atlas of NSW Cave Fauna, Copyright Dept Urban Affairs and Planning and the Australian Heritage Commission

2 NSW NPWS, 2000b, Yarrangobilly Management Unit Kosciuszko National Park Karst Area Management Plan (draft), NSW NPWS

JI Jo Ingarfield pers.comm.

Attachment 10B Fauna of Victoria and New South Wales

Table 10B.1 Number of threatened fauna taxa in the Victorian alpine bioregion

Number of taxa		VROTS									Threatened (c,e,v)
Flora or fauna	**Division name**	**x**	**c**	**e**	**v**	**l**	**i**	**k**	**r**	**Total**	
Fauna	Mammals		2	5	2	1	1			11	9
	Birds		1	7	8	1	2			19	16
	Reptiles		2		3	1				6	5
	Amphibians		2		1					3	3
	Fish		1	1			1			3	2
	Invertebrates				5		4		5	14	5
Fauna total			8	13	19	3	8		5	56	40

VROTS = Victorian Rare or Threatened Species list
c = restricted colonial breeding or roosting sites; e = endangered; v = vulnerable

Table 10B.2. Number of taxa in each IUCN category and vertebrate class that are included on the Advisory List of Threatened Vertebrate Fauna in Victoria, 2002 version (% of listed taxa).

IUCN Category	Fish	Amphibians	Reptiles	Birds	Mammals
Number of taxa assessed	28	17	49	165	63
XT	0	0	0	0	10 (22)
RX	3 (12)	0	1 (3)	1 (1)	10 (22)
CR	7 (28)	6 (40)	9 (26)	10 (12)	5 (11)
EN	5 (20)	2 (13.3)	11 (31)	25 (30)	11 (24)
VU	5 (20)	2 (13.3)	6 (17)	48 (57)	8 (18)
DD	5 (20)	5 (33.3)	8 (23)	0	1 (2)
NT	3	1	12	41	14
Total listed on advisory list (excluding NT)	25	15	35	84	45
Number of taxa listed under FFG Act	23	9	26	63	33

CR = critically endangered; DD = data deficient; EN = endangered; NT = near threatened; RX = regionally extinct; VU = vulnerable; XT= extinct.