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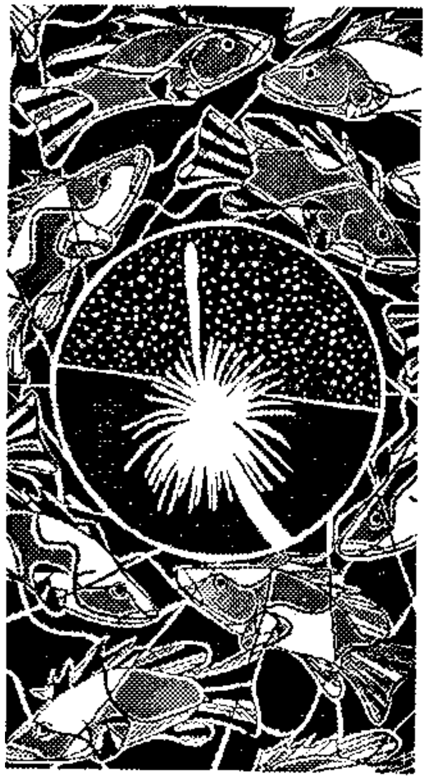
THE EFFECTS OF FIRE ON FAUNA IN THE AUSTRALIAN ALPS NATIONAL PARKS: A DATABASE



A report to the Australian Alps Liaison Committee

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Atlas records from NSW, ACT and Victoria for fauna species found in each of the AANP was made available to us and we gratefully acknowledge this. Dick Cooper from the NSW Bird Atlassers also made additional information available from their database on birds in the NSW Alpine Parks.

Abbreviations

AANP	Australian Alps National Parks
AALC	Australian Alps Liaison Committee
ACT	Australian Capital Territory
ALP	Alpine National Park
AWP	Avon Wilderness Park
BNP	Brindabella National Park
BNR	Bimberi Nature Reserve
DNRE	Department of Natural Resources & Environment
KNP	Kosciuszko National Park
NNP	Namadgi National Park
NPWS	National Parks and Wildlife Service
NSW	New South Wales
SRNP	Snowy River National Park
SRNR	Scabby Range Nature Reserve
Vic.	Victoria

1.0 Introduction

This report and the FIRE AND FAUNA database have been compiled for the Australian Alps Liaison Committee (AALC). The faunal habitat information in the database is based on a fauna-habitat matrix for Kosciuszko National Park (KNP) developed by Woods (1996)_ The database provides information on the effects or possible effects of fire on vertebrates recorded within the Australian Alps National Parks (AANP). Where known, effects of various aspects of fire regimes, fuel reduction activities, and fire suppression techniques on fauna and habitat, are included. Recommendations are made for future research, and an update of the fire and fauna database. A copy of the project brief is appended

1.1 Australian Alps National Parks

The area covered in the database encompasses the AANP including; Namadgi National Park (ACT), Kosciuszko National Park, Brindabella National Park, Bimberi Nature Reserve, Scabby Range Nature Reserve (NS W), and the Alpine National Park, Avon Wilderness Park and Snowy River National Park (Victoria). The Australian Alps National Parks span from near Canberra in the North to the north-east of Melbourne in the South. They contain a great diversity of environments, rare and threatened flora and fauna, and have world heritage values. The AANP do not consist entirely of alpine areas, but also contain large areas of foothills and montane landforms. Elevation ranges from approximately 300m to 2230m. A large number of vertebrate fauna exist in a variety of vegetation/habitat complexes within the AANP.

1.2 Database compilation

A full vertebrate species list for the AANP was compiled using data from State atlas records, published literature, fauna survey reports and anecdotal reports. Sixty one species of mammals, 27 species of amphibians, 46 species of reptiles, and 205 species of birds have been recorded. It is possible that some species have not yet been recorded within the Australian Alps, or that species lists for particular parks are not complete. This is especially relevant for Scabby Range Nature Reserve and Bimberi Nature Reserve where fauna surveys have not been undertaken. Recent and current fauna surveys for the Victorian Regional Forest Agreement in central Gippsland and north-east Victoria may too increase the species list for Victorian parks.

The fauna-habitat matrix (Woods 1996) was reviewed and used to classify habitat for fauna species in the database. The fauna-habitat matrix (Woods 1996) uses broad vegetation community descriptions and specific microhabitat descriptions to classify habitat for species and is based upon those categories used in the Atlas of NSW Wildlife database. It was decided to build upon the Woods matrix (1996) because it was the most comprehensive database developed in terms of relating fauna and broad community/habitat in the AANP available. Most importantly, those vegetation/habitat categories chosen are easily recognisable in the field by inexperienced users. Further categories of habitat based on dominant vegetation were added to encompass all areas within the AANP. An explanation of how habitat-vegetation categories were compared between the States is found in section 2.1.

The known effects of fire on fauna in the AANP are covered in a literature review by Walter (1997) and are reviewed in this document. There is a paucity of information on the effects of fire and fire related activities on fauna and habitat within the Australian Alps. The database covers known effects of fire regimes on fauna and habitat within the Australian Alps, but research findings used in the database have not necessarily been confined to research undertaken within the AANP. In addition research findings from closely related species in other parts of Australia have been used to speculate on possible reactions of fauna to fire in the AANP.

In the Fire and Fauna database, components of the fire regime *including* fire intensity, fire extent, fire season and fire frequency are used to catalogue data on faunal responses to fire. In addition the implications of fuel reduction burning and fire related practices are also examined for fauna species. An explanation of terminology used is found in section 4.1.

1.3 Management applications of the database

The fire and fauna database has been developed in a Microsoft Excel spreadsheet format to allow for ease of use and *manipulation* of data by a range of users. Users of the database are encouraged to add, delete or manipulate the matrix data to suit their needs, provided an original copy is kept intact, Reference material used in the database is listed fully in the reference section of this report. Unreferenced passages within the database are the expert opinion of the database authors, based on current knowledge of faunal habitat requirements and responses of fauna to fire.

The simple format of the database allows users with a wide variety of computing skills to access *information* easily. Users of the database should be aware that the broad-based approach used to cover all areas of the AANP, may not necessarily represent what actually occurs on the ground in specific areas of the

AANP. For example *Pseudomys fumeus* (Smokey Mouse) will not occur in all woodland areas with a heathy understorey. It is therefore recommended that information contained the database be used as a guide, and that users filter information with the appropriate heritage management authorities/experts within their departments.

Fire managers are able to quickly access the data contained in the spreadsheet matrix during times of wildfire suppression and when planning fuel reduction measures. Cross-referencing between fauna, habitat and the likely effects of fire, if known, is possible using the database. Given the known habitat, land managers can easily access information on fauna likely to be present and assess fire *management* options. The fire and fauna database will be particularly useful for land managers *planning* for fuel reduction burning in areas where threatened fauna is known to occur or may possibly occur. With this information, fire management practices can be modified to suit particular species requirements. Research *indicating* particular fire thresholds for fauna should be added to the database as it becomes available.

The lack of *information* on many species found within the AANP in relation to fire is highlighted *in* the database. Both short and long term studies *in* the AANP are desperately needed to establish the effects of fire on fauna and habitat, particularly in terms of fire thresholds for threatened species.

2.0 Faunal-habitat Classification

Faunal-habitat classification is useful in terms of fire management within protected areas. The relationships between fire, fauna and plants is extremely complex, however the responses of fauna to fire are known to operate partially through the response of habitat, particularly vegetation, to fire.

2.1 Comparisons of Broad community/faunal-habitat classification between the States and Territory and use in fire management planning

NSW, Victoria and the ACT each use different vegetation based community and/or habitat descriptors to document fauna records in their respective wildlife Atlas's. An attempt to illustrate relationships between descriptors used in this database (based on Woods 1996) and those used in Victoria and the ACT, is included below, however relationships are not clear-cut. Fire management strategies are based to varying degrees on vegetation alliances by each of the state management agencies.

Table 1. Comparisons of Broad community/Faunal-habitat classification between the States and Territory.

Vegetation complexes within Kosciuszko National Park have been mapped using a variety of tools including LANDSAT (Wimbush *et u1.* 1993). The NPWS fauna species-habitat matrix (Woods 1996) incorporates those vegetation complexes and it is on the Wimbush *el at.* (1993) classification that the vegetation units and associated strategies within the Kosciuszko National Park Fire Management Resource Document (NPWS 1997) have been broadly based. A description of vegetation communities is summarised in the Resource Document (NPWS 1997). The other NSW parks within the Australian Alps group are in the process of developing both general management and fire management plans and classifications of vegetation/habitat have not been finalised at this stage.

Victoria is currently mapping vegetation alliances in terms of Ecological Vegetation Classes (EVC's). EVC's are based on both dominant overstorey and structural components of vegetation, gained from satellite imagery and field nothing. Despite an attempt at gaining state-wide classification, floristic components of particular EVC alliances may vary between regions (Foreman pers comm.). In addition, not all maps of the Victorian Alpine Parks have been finalised, notably those of Avon Wilderness Park and areas within central Gippsland. It is expected that all of these areas will be mapped by the end of 1998, and that Regional Forest Agreement fauna surveys will be completed, allowing for clarification of fauna-habitat relationships. Because the Ecological Vegetation Classes are numerous, Broad

Vegetation Types (BVT's) for the Victorian AANP are listed in Table 1, in an attempt to show the relationship between vegetation types used in Victoria and that used in the database. BVT's are modeled on broad scale land systems and are considerably more simplified than EVC's.

Fire management within the Victorian AANP is not based upon BVT's or EVC's. Each of the Parks and sub-units of the ANP have broad-based fire management guidelines outlined within their management plans, regional fire management plans and the "Code of practices for fire management on public lands" (Department of Conservation and Natural Resources Victoria 1995).

Namadgi National Park has been classified into three broad vegetation community types for fire management. These include *Forest and woodland, Woodland,* and *Grassland.* Forest and woodlands are further defined in terms of dominant overstorey. While a more detailed classification of vegetation has been undertaken for NNP. the Draft Bushfire (Fuel) Management Plan (ACT Department of Urban Services 1997) does not utilise these classes for tire management strategies at present. A need for more research into appropriate fire management for vegetation within the park is recognised in the plan.

2.2 Broad community habitat descriptions

The following definitions of broad community/habitat are modified from those used by Woods (1996) to incorporate all areas within the AANP. Codes used in the database are provided for each habitat description.

Rainforest (RF)

Temperate rainforests within the AANP are dominated by non-sclerophyllous vegetation and often appear as disjunct communities. They are generally restricted to moist east facing gullies in montane areas, but can occur on sheltered mountain slopes and plateaus. Dominant species of the overstorey can include ,*Nothofagus cunninghamii* (Myrtle Beech) and *Atherosperma moschatum* (Southern Sassafras). Acacias such as *Acacia dealbata* (Silver wattle) and *A. melanxylon* (Blackwood) and smaller trees and tall shrubs such as *Olearia argophylla* (Musk Daisy-bush) and *Pittosporum bicolor* (Banyalla) are often present in the mid-strata. Ferns are common in the understorey and ground layers, and a number of graminoids, forbs, epiphytes, climbers and scramblers are generally present. This community is fire sensitive.

Tall Open Forest (TF)

Tall Open Forest is sometimes referred to as wet sclerophyll forest or moist forest. It occurs in moist montane and higher foothill areas and can contain a variety of species in pure or mixed stands, including *Eucalyptus delegatensis* (Alpine Ash), *E. dalrympleana* (Mountain Gum), *E. bicostata* (Victorian Blue Gum) *F.* fastigata (Brown Barrel), *E. radiata* (Narrow-leaf Peppermint), F. *viminalis* (Manna Gum), E *regnans* (Mountain Ash) and *F'. rubida* (Candlebark). The canopy layer is generally in excess of 30m and often taller than 50m. An understorey layer is dominated by shrubs and small trees such *as Bedfordia arborescens* (Blanket-leaf), *Pomaderris aspera* (Hazel Pomaderris), *Acacia dealbata* (Silver Wattle), and *Cassinia aculeata* (Dogwood). A ground layer of ferns, grasses and herbs is usually present.

Open Forest (OF)

Also often referred to as Dry sclerophyll forest. Overstorey species include Eucalyptus *dives* (Broad-leaf Peppermint), *E. radian* (Narrow-leaf Peppermint), F. *dalrympleana* (Mountain Gum), E. *viminalis* (Manna Gum), *F. mannifera* (Brittle Gum) and *E. macrorhyncha* (Red Stringybark). Structural diversity often exists in
middle and understorey layers, common components include *Cassinia aculeata* (Dogwood), *Platylobium formosum* (Handsome Flat-pea), and *Pteridium esculentum* (Bracken). A high number of shrubs, graminoids and forbs are generally present.

Woodlands (WD)

Woodlands generally occur on dry north-western slopes on the tablelands, or in rain shadow areas within the AANP. A number of alliances exist and at times it is difficult to differentiate between woodlands and open forest. Lowland woodland overstorey species can include *Eucalyptus melliodora* (Yellow Box), *F. bridgesiana* (Apple Box), *E. goniocalyx* (Bundy or Long-leaved Box), *E. microcarpa (Grey* Box), £. *polyanthenios* (Red Box), *E. macrorhyncha* (Red Stringybark), and F. *camaldulensis* (River Red Gum). Montane woodland overstorey species can include *Eucalyptus pauciflora* (Snow Gum). *F. rubida* (Candlebark). *F. dalrympleana* (Mountain Gum), *F. viminalis* (Manna Gum), *F.. mannifera* (Brittle Gum) F. *camphora* (Mountain Swamp Gum), and *F. radiata* (Narrow-leaf Peppermint). Rainshadow woodland can consist of a *Eucalyptus albens* (White Box) and *Callitris glaucophylla* (White Cypress Pine) alliance. Sub-alpine Woodlands are treated separately (see below).
Mid and understorey components of woodlands are commonly sparse and consist of leguminous shrubs such as Acacias and Peas. The ground layer is generally dense consisting of grasses and forbs.

Sub-alpine Woodlands (SAW)

Woodlands generally between 1400 - 1.850 metres and consisting primarily of *Eucalyptus pauciflora* (Snow Gum), *E,. niphophila* (Snow Gum), *E..stellulata* (Black Sallee) and *F. perrinianna* (Spinning Gum). Snow Gums are fire sensitive and coppice regrowth is evident in many stands in the AANP. Sub-alpine woodlands generally have either a heathy to shrubby understorey in regenerating burnt areas (seral woodland), or a grassy understorey in their climax state.

Alpine Community (ALP)

Includes Tall Alpine Herbfields, Short Alpine Herbfields, Sod Tussock Grasslands, Feldmark, Valley Bogs and Raised Bogs. Common plants in Alpine communities include *Celmisia, Poa, Danthonia, Epacris, Craspedia, Ranunculus, Gentianella, Euphrasia, Helichrysum, Brachycome, Podolepis, Senecio, Wahlenbergia* and *Carex*
- sp. Sphagnum bogs and fens are an important component of this community for some fauna species, and are discussed further in section 4.6.3 of this report.

Grassland (GRD)

Temperate grasslands are located in dry areas of the AANP. These grasslands often overlap with some woodland areas, forming open woodlands with a grassy understorey. Common grasses include *Danthonia sp., Poa sp., Stipa* sp., and *Themeda* sp., with forbs such as *Geranium* sp. and *Wahlenbergia* sp. (Bluebells) present. Alpine grasslands and frost hollow grasslands are not included in this community as they are a component of the alpine community.

Heath (HTH)

This does not include alpine and subalpine heaths (see below). Heaths within the AANP apart from those in alpine and subalpine areas are generally not dominant community types. They occur most often as an understorey component of open forest or woodland, however small areas of heath complexes exist, usually where soil nutrients are low and fire is a factor.

Alpine/subalpine Heath (ASH)

This classification includes heaths in both the alpine and subalpine zones. Subalpine heaths may possibly be termed subalpine woodlands in many classification schemes, when in association with Snow Gums. Heath is often further classified by the dominant shrub species and structure, and a number of common alliances exist. depending on climatic and topographic conditions. Species common to heath include, *Kunzea ericifolia, Oxylobium alpestre* (Alpine Oxylobium), *Oxylobium elliplicum* (Common Oxylobium). *Bossiaca foliosa* (Leafy Bossiaea), *Podocarpus lawrencei* (Mountain Plum-pine), *Grevillea australis* (Alpine Grevillea). *Phebalium sp., Richea continentis* (Candle Heath). *Epacris .sp., Hovea sp.* and *Prostanthera cuneala* (Alpine Mint-bush). It is likely that significant modification of heaths in the AANP have occurred through grazing and fire.

Riparian (RIP)

Refers to vegetation adjacent to streams and waterways. This vegetation type can be a combination of any of the above structural forms although it is generally moist. Examples include montane riparian thickets with an overstorey of *Leptospermum grandifolium* (Mountain tea-tree), and *Leptospermum myrtifolium* (Swamp tea-tree). Overstorey eucalypts can include *Eucalyptus viminalis* (Manna Gum), E. *rubida* (Candlebark), E. *globulus* (Blue Gum), and *F. dalrympleana* (Mountain Gum), and E. *camaldulensis* (River Red Gum).

Swamp (SWP)

Swampy areas exist where the water table rises to or above the ground level. This category includes ephemeral swamps and permanent swampy areas, and poorly drained areas. Semi aquatic vegetation is often present, including reeds, rushes, and sedges. Overstorey species need to be tolerant of inundation and may include *Eucalyptus ovata* (Swamp Gum) E. *camphora* (Mountain Swamp Gum) and E. *camaldulensis* (River Red Gum). This category does not include bogs and fens found in the alpine community (see above).

Stream or river (SR)

Includes any river, creek or stream flowing within the AANP, and can overlap with any of the community types mentioned above.

Freshwater lake (FL)

Includes both natural and artificial lakes within the AANP. Rock outcrop (RO)

Can be in all vegetation communities mentioned above. Includes boulderfields, blockstreams, scree slopes, granite tors, cliffs, and other generally rocky areas.

Cave (CA)

Either formed in limestone karst areas, or from other geological processes, (e.g. weathering in granite/sandstone). May also encompass human-made tunnels and mine shafts.

Urban (UR)

Highly disturbed and generally built up areas, including ski resorts and other towns.

2.3 Microhabitat descriptions

Microhabitat descriptions generally follow that, or are a combination of those microhabitat codes used in the Atlas of NSW Wildlife, as used by Woods (1996). They are included in the database to further filter habitat requirements of fauna species within each of the broad habitat types. Those used in the database include:

TC Tree canopy. Includes upper, mid and lower canopy of trees.
TK On trunk. On the trunk of trees. DT In dead tree (stag)
HI In tree hollow SH Shrub layer
HE Heath. Includes heathland vegetation and heathy understorey vegetation.
IG In grass. As well as in reeds.
GR On ground
LG Log. Includes in, on, or under logs, and in crevices in logs
RO Rock Includes on or under rocks.
UB Under bark
IS In soil
LB In burrow
IW In water
EW Edge of water.
IL In litter
IC In cave. Includes mines.
SN Sand. Beaches on river banks and lake edges
BO Alpine and Subalpine Bogs

2.4 Vulnerable Period

An indication of the vulnerable period for each fauna species is included in the database, and while this usually coincides with the breeding period, this is not always the case. Vulnerable period may differ in species that inhabit a different habitat in the breeding season than at other times for example. Scheduled fauna may be vulnerable at all times. The vulnerable period indicated in this database does not relate specifically to fire, but if a species is particularly vulnerable to fire, this is outlined in other sections of the database.

3.0 Understanding fire regimes as a basis for management

Understanding the effects of fire regimes on fauna is an important requisite for managing this component of the system over time In turn, it is useful for managers to understand the nature of fire regimes and how they have changed over time. The term fire regime encompasses variation in the frequency, intensity, season and type of fire (Gill 1975). Because intensity within a fire event varies with location, each "point" has a particular fire regime. In this discussion we will ignore the "type" of fire because peat fires are very unusual, although they can have important local and regional effects in some geographic areas (Good 1973). Natural (non-human) fire regimes are determined by a number of factors such as fuel dynamics, climate and vegetation. Cheney (1976) noted that "holocaust fires" tended to coincide with a relatively short burst of extreme weather conditions. On the south coast of New South Wales for example, records indicate a severe fire season, related to the incidence of drought and strong, hot, westerly or northwesterly winds, occurs on average once in seven years (Duggins and Saunders 1978). Around Port Macquarie in Northern NSW a severe fire season is expected once in 12 years (FCNSW 1993). The fire season there usually extends from September to December when the combination of low rainfall, high temperatures and strong westerly winds can create the conditions under which severe fires can develop. Gill and Moore (1990) provide long-term fire weather analyses for Moruya, Nowra, Nerriga, Canberra and Honeysuckle Creek, areas where forests are found close by. They demonstrated that the weather under which severe fire may occur can vary between locations in terms of both mean and extreme values.

Naturally, not all areas bum during severe fire seasons and fires can occur in between these seasons. The use of plant species biology to estimate patterns of fire across the landscape suggests a range of fire regimes occur. In wet sclerophyll forest in eastern Australia, catastrophic fires sufficiently intense to kill trees are thought to occur infrequently. Ashton (1981) considers wet sclerophyll forests can tolerate severe fire every 1, 2 or 3 centuries. Barker (1991), using age-class information, estimated that fires in the tall open forests around Goonmirk Rocks in eastern Victoria occurred at intervals of approximately 100 years. Ellis and Thomas (1988) suggested high intensity fires in these wetter forests occur once every 80-100 years in Tasmania, and Mackowski (1984) once every 280 years in north-eastern NSW.

In contrast, dry sclerophyll forests are fire-prone and highly flammable (Christensen et *al.* 1981), so bum more frequently than the wetter forests under the natural fire-regime. The exact fire regime in these forests, however, is difficult to elucidate. Vines (1974), investigating the relationship between the occurrence of fire and climatic cycles, suggested the natural frequency of "serious" fires in dry sclerophyll forest in southeastern Australia is approximately 13 years. This represents a regional figure, not the return frequency at one site. Average estimates of fire regimes should be treated with some caution as they will exhibit considerable variation from place to place.

It is well established that the fire regime can have important influences on many ecosystem patterns and processes, for example, on plant species composition (Bell and Loneragan 1985: Dickinson and Kirkpatrick 1987; Nieuwenhuis 1987; Clark 1988; Noble 1989; Bradstock 1990; Fensham 1990; Cary 1992). Superimposed on the natural regimes described above are those associated with human activity. In order to characterise the nature of fire regimes over time we will refer to historical, present and future fire regimes.

3.1 Historical fire regimes

A number of lines of evidence, many of which are circumstantial, are used for determining historical fire regimes, both pre- and post-European, in south-eastern Australia. These include palynological investigations, archaeology, geomorphology, folklore, ethnohistory, historical documentation and studies of fire-scars and post-fire growth pulses on trees.

3.1.1 Pre-European fire regimes

Although there has been much debate about the nature of pre-european fire regimes, the season, frequency, distribution and extent of these fires remain largely conjectural (Gill 1977). Jones (1969) introduced the concept of 'Fire-stick farming` stating that at the time of ethnographic contact, and probably for tens of thousands of years before, fires were systematically lit by Aborigines and were an integral part of their economy. Aborigines utilised fire in many aspects of their lives although there has been some lively debate about the extent and effects of this burning (Jones 1969; Hallam 1975: Nicholson 1981; Horton 1982; Clark 1983; Hallam 1985; Bowman and
Brown 1986; Gell and Stuart 1989; Benson & Redpath 1997).

Most discussions of the pre-european period equate the fire regime with Aboriginal burning patterns. However, the impact of Aboriginals on the natural (nonhuman) fire regime would have been variable in space and time and would not have applied equally across Australia (Clark 1983; Hallam 1985; Gell and Stuart 1989). For convenience, when the literature uses 'Aboriginal' instead of 'pre-european' we have adopted the same terminology. It is important to note that much of the work on the. effects of Aboriginal burning on vegetation is restricted to grasslands, open-scrub and open-woodlands (Nicholson 1981), not forests. Several lines of evidence will be presented in an effort to elucidate pre-european fire regimes in the forests of eastern NSW.

Hughes and Sullivan (1981), on the basis of geoarchaeological investigations in eastern Australia, argued that Aboriginal fire regimes in the late Holocene led to episodic erosion and deposition at rates which greatly exceeded those under natural firing. They confined their hypothesis to the hilly landscapes with dry sclerophyll forest, suggesting that the 'systematic, episodic burning' of eucalypt forest/woodland by Aborigines removed the ground cover more frequently than natural fires and was the major cause of landscape instability (erosion). They later acknowledged (Hughes and Sullivan 1986) that their main study may not signify anything more than disturbance at a very local scale. Other authors (Young *et at* 1986: Prosser 1987) have argued that the apparent clustering of charcoal in the last few thousand years may be arbitrary, and be related, for example, to the destruction of older carbon. Gell and Stuart (1989) also raise a number of questions about the use of geomorphic evidence to detect and interpret the use of fire by Aborigines.

One of the pioneering works in the application of palynology to the question of. Aboriginal burning was by Singh *et al.* (1981). The discussion of the antiquity of Aboriginal burning, inferred from pollen and charcoal samples from a core from Lake George, southeastern NSW, is most relevant. The first evidence of open eucalypt woodlands, along with significantly greater amounts of charcoal, was dated to 120,000 BP (the last interglacial). It was suggested that Aboriginal people may have caused and maintained these changes over time by the use of more frequent and less intense fires than under 'natural' conditions (Singh *et al.* 1981).

There has been an ongoing debate about the interpretation of the pollen core at Lake George (Clark 1983; Wright 1986; Head 1989). Clark (1983) suggested that uncertainty about the dating and the coarseness of the sampling scheme 'allows nothing to be said with certainty about fire history' and that there are alternative explanations for the inferred changes. Wright (1986) also questioned the dating of the core and revised the age of the change-over to woodlands from 120,000 to 60,000 years BP.

Dodson (1986) investigated several Holocene pollen sequences from the Goulburn area in the southern tablelands of NSW. A considerable degree of variability was evident in the sequences but it appeared that eucalypt woodlands or open forest with a grassy understorey had been dominant for the last 9,300 years. He argued that fires were frequent but that there were no clear trends in their impact on vegetation. At Barrington Tops in NSW, Dodson *et at* (1986) noted that fire became more important after 3,000 BP and was thought to have contributed to the contraction of the wetter forest types in the area. However, these authors were unable to attribute such firing to Aborigines due to lack of archaeological data (Head 1989).

Clark (1983) identified a number of methodological questions that needed to be addressed before pollen analysis could be expected to document evidence of Aboriginal burning. For example, unless fine-resolution techniques were utilised, only broad-scale (in time and space) fire patterns could be elucidated. Green *et at* (1988) have since demonstrated that fine-resolution paleaoecology (single year sampling) is potentially a useful tool in determining fire history.

Gell and Stuart (1989) integrated evidence from fine-resolution palynological studies and archaeological and ethnohistoric records to explore the history of human settlement, lire and vegetation in the Delegate River Catchment of East Gippsland, Victoria. This is one of the few detailed studies carried out in a more densely forested landscape, especially in eastern Australia. They concluded that the pre-contact fire regime was one of infrequent, intense fires, that probably raged during the late summer months of irregular drought periods. They considered it unlikely that the number of Aborigines in the area was as large as elsewhere in Australia and so their impact upon the natural fire regime was similarly less.

Another avenue for investigating historic patterns of fire frequency is tree-ring studies. These attempt to age the fire scars or post-fire growth pulses on trees using either wood cores or tree cross-sections for analysis. The latter technique is more reliable, but not always possible or desirable as the tree must be felled. Forest fire histories using these methods can be made at the levels of a region, a site or at the individual tree level. However, one has to be careful about making generalisations from individual sites as not all forests have experienced the same level of burning (Banks 1989). Low intensity fires are less likely to scar trees so may leave no trace. These techniques have limited usefulness for providing an understanding of preeuropean fire regimes due to the lack of older trees with a complete history (i.e. intact heartwood) In addition, most of the work has been conducted in the sub-alpine areas of south-eastern Australia (Banks 1989) where distinct growing seasons occur.

Banks (1990), using tree fire-scar data, studied fire history in a wet sclerophyll forest dominated by *Eucalyptus fastigata* and a dry sclerophyll forest dominated *by E. sieberi* on the top of the escarpment in Glenbog State Forest, south-eastern NSW. This represents one of the few studies in lower altitude forests in NSW. The fire history for the *E. fastigata* stand spanned 400 years and showed a progressive change to more frequent fires in recent decades, Prior to c. 1835 the apparent average fire free period was 24.5 years (range 6 - 43 years), to 11.7 (range 9 - 16 years) for the period 1835 to 1870, and after 1870 was only 8 years (range 2 - 16 years).

In the early period of European settlement, observations were made of fire patterns in general. and the Aboriginal use of fire in particular. This era falls into the 'folklore' phase of Banks (1989), which he described as 'a mixture of facts and fantasy usually expressed in proportions most likely to satisfy the occasion and narrator'. Indeed, studies using historical sources are plagued by uncertainties and should be interpreted with care.

Currently, most ethnohistorical observations related to burning practices come from south-western Australia, northern and central Australia and Tasmania (for reviews see Hallam 1985; Gel] and Stuart 1989). From her work in south-western Australia, Hallam (1985) suggested that in general, open country was subject to more frequent (but less intense) fires than forest or scrub and that firing was a function of forest productivity and the size and needs of Aboriginal populations. However, much of the evidence for these patterns (Appendix in Hallam 1975) makes it difficult to draw firm conclusions about the fire regime at any one location. Lamont and Downes (1979) estimated fire frequency using floral remnants on grass trees on a site in Western Australia apparently occupied by Aborigines. They found a low incidence of fires in the 150 years prior to European settlement and concluded that either Aborigines caused fewer fires than reported by Hallam (1975) or that the specimens they studied were not representative of fire regimes for the area.

There are relatively few ethnohistorical observations from the forested landscapes of south-eastern Australia. In Jones' (1969) treatise on 'fire-stick farming', the only reference to NSW was the comments of an explorer (in 1848) on the park like nature of the savanna woodlands of central and western NSW, and the potential role of the use of fire by Aborigines in its maintenance. Sullivan (1982), in an ethnohistorical study of the Aboriginal "age of forests south of Sydney, found very limited evidence for the use of fire by Aborigines. While there is archaeological evidence of Aborigines occurring throughout eastern NSW (Lampert 1971; McBryde 1974; *Byrne* 1982; Feary 1988), reliable estimates of their population densities are difficult to derive, particularly in the rugged terrain and densely forested landscape in south-eastern Australia (Feary 1988, Gell and Stuart 1989).

In summary, the pre-european fire regime was due to a complex mix of fires started by lightning and fires ignited by Aborigines. The true source of these fires is often difficult to determine. Many of the I lines of evidence used to document preeuropean fire regimes, especially in southern Australia, are of necessity indirect and are open to a number of interpretations (Clark 1983; Head 1989). There is very little evidence documenting the pre-european fire regimes in the tableland and coastal forests of eastern New South Wales. For example, Head (1989), reviewed the pollen and charcoal evidence for prehistorical impacts on Australian vegetation, and identified only four major palynological studies in south-eastern Australia that specifically examine pre-european fire patterns. While there are suggestions that fires were less frequent and more intense in forests than in woodland habitats, and that

r. Aborigines did not appear to burn much in the uplands and wetter forests (Head 1989), we can say very little about the timing, frequency or intensity of fires in eastern NSW prior to European settlement.

3.1.2 Early European phase

A number of sites in south eastern Australia provide pollen and charcoal evidence of the frequency and/or intensity of burning since European settlement (Head 1989). These include the fine-resolution study by Green *et al.* ()988) at Bega Swamp and studies on the southern tablelands by Singh and Geissler (1985) and Dodson (1986). Gell and Stuart (1989), in the Delegate River area of Victoria, noted charcoal peaks in the pollen record in the 1850s and 1890s, and the persistence of high charcoal levels until around 1939/1940. The charcoal was thought to indicate increased levels of burning and corresponded with the most active mining and prospecting periods in the region, as well as regular burning that was typically associated with grazing activities. Wakefield (1970), based on his own observations and acquaintances with Braziers, calculated a fire frequency of 3-4 years in dry sclerophyll forests in East Gippsland resulting largely from the activities of graziers. Pyne (1991) also noted the widespread and frequent use of fire by early pastoralists, primarily to encourage 'green pick'.

Banks (1989). based on fire-scar information, recorded a marked increase in apparent fire frequency with the arrival of European pastoralists and prospectors in the sub-alpine forests of NSW. For example, along the ridge top of the Brindabella Range fires were recorded almost every year from the 1890s to the 1960s, although the exact frequency varied between sites. A fire frequency of 2-3 fires per decade with the arrival of Europeans was also noted by Banks (1990) in his fire-scar studies of trees in E *sieberi* and *E. fastigata* dominated forests in Glenbog State Forest, south-eastern NSW. A similar pattern was found in a study of the dynamics of White Box *(Eucalyptus albens)/White* Cypress Pine *(Callitris* spp.) forests of in the Snowy River Valley (Pulsford *et aL* 1992). Tree-ring dating of the Cypress pines showed an increase in fire frequency with the arrival of Europeans and their grazing animals in the early 1840s. Between this date and 1900 fires occurred about every 6 years (range 3 - 11), but the frequency declined after 1910 and then again after 1940 (Pulsford *et al.* 1992). In contrast, a study of post-fire growth pulses in E. *sieberi* forest in east Gippsland (Woodgate *et al.* 1994) found no evidence of increased fire frequency after European settlement, emphasising the localised nature of this evidence.

3.2 Present day fire regimes

Largely because of the widespread wildfires of 1939, and the crisis of World War II, a major restructuring of fire policy occurred in southeastern Australia in the early 1940s (Gell and Stuart 1989; Pyne 1991). Therefore, this section discusses patterns of fire from this time until the present.

Some of the factors determining fire regimes can be manipulated by land managers such as frequency of ignition and fuel quantity. The capacity to manipulate Fire regimes has led, for example, to the use of frequent, low *intensity* 'fuel reduction' fires by land *management* agencies. Widespread use of the practice began in NSW in 1967 when aerial ignition techniques were introduced (Pyne 1991). The frequency of burning under fuel reduction burning varies from region to region. In the Eden Management Area in southeastern NSW the aim is to bum areas at 4-7 year intervals (FCNSW 199t). However, because it is only safe to burn under a narrow range of environmental and climatic conditions, potentially not all areas would be burnt at this frequency. In the Kempsey Wauchope Management area in Northern NSW three broad zones have been derived for fire management purposes. The frequency of fuel reduction burning in these zones varies from 3-4 year intervals in areas with high fire hazard rating to approximately 10 year intervals in the low fire hazard area (FCNSW 1993). Areas within a high fire hazard, for example, are those close to human settlement or surrounding hardwood plantations and tend to consist of the drier forest types.

Areas covered by single prescribed litter fires vary between 150 and 200 ha for ground-ignition and 6 - 8000 ha are not uncommon for aerial ignition (Cheney 1978). Within any one year the total area burnt by prescribed fire can be tens of thousands of hectares (Kirkpatrick et al. 1990).

As well as the intentional lighting of Fires for management purposes, there are a number of other sources of fire_ Duggins and Saunders (1978) listed the following as probable sources of fires in the coastal and tableland regions of NSW between

1967-197;: burning-off, reignition from burning off operations for grazing and land clearing, lightning, campfires, roadside carelessness, waste disposal, vehicles and machinery, incendiarism and 'other'. By far the largest percentage of fires was caused by escapes from both legal and illegal burning-off operations. An analysis of the causes of fire from 1971 to 1988 in the Kempsey and Wauchope Management Areas around Port Macquarie also identified burning-off on adjoining private property or leasehold land as a major cause of fire, causing approximately 70% of fires in State Forests (FCNSW 1993).

The systematic recording of fires has only recently received attention (Banks 1989). For example, fire history records for the Brisbane Water National Park near Sydney date from 1960, but records prior to 1964 are considered unreliable (Bradstock 1985 cited in Cary 1992). However, the ability to characterise fires is improving at a number of levels including the measurement of the characteristics of individual fires and the mapping of large-scale fire patterns using remote sensing (Graetz *et al.* 1992). Only with accurate recording can the actual fire regime at any one site be reliably characterised.

Factors affecting fire patterns include sources of ignition, vegetation type, fuel characteristics and climate - all of these exhibit marked spatial and temporal variability. Fires from 'natural' sources such as lightning tend to occur during summer in eastern NSW, coinciding with periods of low rainfall, low humidity and high temperatures which affect fuel and fire characteristics. Severe fire seasons which are often correlated with the incidence of drought and strong, hot, westerly winds, can occur every 7 - 12 years, depending on location. However, the frequency and intensity of fires at any one site will also be related to factors such as the flammability of the vegetation, local topography and sources of ignition. For example, under a natural regime the moister forests often found on sheltered slopes may bum less frequently, but at a higher maximum fire intensity, than the drier forests occurring on ridge-tops and exposed slopes.

4.0 Fire Regimes and implications for faunal diversity

Achieving biodiversity conservation through the management of fire is often constrained by the emphasis on other objectives of fire management, and by a lack of ..knowledge of fire thresholds for flora and fauna species (Bradstock *et al.* 1995). ,.Knowledge of fire thresholds for species in the AANP is scant, is more likely to be known for flora than fauna, and most likely to be known for the dominant overstorey species. While it is recognised that managing a community by using fire thresholds for the dominant overstorey species only is not ideal, very little information exists to support a change in management practices in most parts of the AANP. In addition, fire thresholds are often based on frequency of fire rather than other aspects of the fire regime such as intensity, season and fire extent, reflecting a lack of historical data on those variables. It is for these reasons that inflexible fire management regimes are often imposed upon public lands. Fire management practices, particularly prescribed fuel reduction burning, have come under increased scrutiny, mainly because the effects of fire on biota are largely unknown.

4.1 Terminology used in the Fire and Fauna database

The following terms are widely recognised and have been used in the database to allow for a clarification of research findings for fauna from specific aspects of fire.

Fire Intensity

Fire intensity generally refers to energy output per metre of fire front and is determined by variables such as fuel, topography and climate (Whelan 1995).

Fire Season

Refers to the season in which a fire event occurs. Within the AANP fuel reduction burning is generally carried out in the Autumn months, and wildfire is most prevalent in Summer.

Fire Extent

Fire extent or patchiness is primarily related to heterogeneity in the fire landscape, particularly to fuel loads and distribution, but also to vegetation type, spatial patterns of previous fire, and seasonal and climatic conditions at the time of fire (Whelan 1995).

Fire Frequency

Fire frequency refers to time between consecutive fires and is dependent upon fuel productivity and the frequency of ignitions (Whelan 1995).

4.2 Fuel reduction techniques

Fuel reduction methods are examined in reference to their effect on fauna and faunal habitat where known. These techniques include prescribed burning, grazing, slashing, pruning, mulching, and herbicide application.

Some fuel reduction techniques such as slashing or mowing further fragment habitat, and removal of even small areas of native vegetation may prove to be an impediment to movement of some species of native animals reliant on dense cover. Further clearing along road edges, where the road already is a significant barrier to movement of some vertebrates, are of particular concern.

In laboratory trials, frog species have been shown to be effected by herbicides containing glyphosphate, with the surfactant present in herbicides thought to be responsible for the toxic effects (Bidwell & Gorrie 1995). Certain surfactants can cause damage to the gill membranes explaining why tadpoles were found to be more susceptible than adult frogs in those trials (Bidwell & Gorrie 1995).

Fuel reduction using prescribed fire has come under scrutiny because the effects on biota are largely unknown. Prescribed burning generally occurs in different seasons and at different frequencies and intensities to that of naturally occurring fire in southern Australia, and this may have an effect on plant species composition and structure, and subsequently on faunal assemblages in those areas subject to intensive fuel reduction activities.

4.3 Fire suppression techniques

Wildfire suppression techniques and related activities are critiqued in the database in terms of their effect on fauna and faunal habitats if known. These techniques include construction and maintenance of fire access tracks, helipads and water-points,
construction of fire lines using heavy machinery or hand tools, firebombing, backburning, burning-out, use of foams and retardants, moping up techniques such as tree felling, and rehabilitation methods.
The impact of fire related infrastructure such as poorly maintained roads may lead to erosion and sediment input into streams. Increases in water turbidity and sedimentation pose a significant threat to stream fauna, especially invertebrates, upon which predators, such as native fish rely (DNRE 1997).
The use of chemical retardants is highly controversial as the effects upon flora and fauna, particularly aquatic fauna are poorly understood. The high concentrations of retardant used in fire bombing tends to be destructive to vegetation (Loane & Gould 1986). Again it appears to be the surfactant contained within the retardant that is the cause of concern. Fire management authorities within the AANP prefer to avoid the use of retardants in or close to riparian areas, as it is thought to be damaging to aquatic fauna.

4.4 Effect of fire on fauna & faunal habitat

As with vegetation, fires can affect animals both directly and indirectly. Animals may die from a variety of causes including smoke inhalation and heat, starvation after the fire, or predation. However, the major effect of fire on animals is through changes to their habitat and the availability of food, shelter and breeding sites. Consequently, an understanding of the life history and habitat requirements of animal species is essential to understand their responses to fires (Friend 1993). The spatial relationship of burnt to unburnt vegetation has also been identified as important for the post-fire dynamics of animals.
Rates of animal mortality will depend on a number of factors including fire intensity and extent, and the mobility of the animals concerned. In a mild fire, birds and mammals can easily avoid the flames whereas in severe fires such as in Hobart (1967) and Nadgee (1972) many birds and mammals were killed (Recher 1981). However, even in fires like that at Nadgee, many individuals were able to escape death by sheltering in holes and burrows, by taking refuge in less severely burnt
gullies or by doubling back into burnt areas (Recher *et a1.* 1975). Species that reside in tree canopies, and with limited mobility such as the koala *Phascolarctos cinereus,* are more likely to be killed during a high intensity fire_ Species that have burrowing habits such as some amphibians and reptiles (Friend 1993) have considerable resilience to fire, being able to shelter underground during the passage of the fire. All animals forced to move on the ground during or soon after the passage of a fire may be subject to damage to their feet and outer-body if they tread or fall on to embers.
Immediately after a fire, shelter and food can be scarce for many animals so they may succumb to predation or starvation (Recher et *al.* 1975; Recher and Christensen 1981; .Friend 1993). The most important effect of fire on animals is not that individuals are killed, although this could be serious if populations were small or isolated, but the resultant change in habitat quality (Recher 1981). The timing of fires in relation to breeding cycles, and the size of the fire in relation to the home range of species will also influence the population dynamics of animals after a fire.

One of the more comprehensive studies of animal responses to fire in the forests of NSW, with both pre- and post-fire data, was undertaken in the dry sclerophyll forests of Nadgee Nature Reserve (Newsome *et at* 1975). The authors recommended that more work be conducted on the effects of pockets of unburnt vegetation on survival of fauna, the re-invasion of burnt habitat, and the interrelationships of the flora and fauna. Almost twenty years later we still have few empirical data on the importance of the patchiness of fire for fauna, especially in the forests of eastern Australia. Fox and McKay (1981) monitored species of small mammals at Myall Lakes National park in open eucalypt forest regenerating from fires that had occurred from one month to nine years, previously. The abundance of small mammals was related to changes in vegetation, which itself was strongly influenced by the fire regime. More recently, responses of animals to fires in forest ecosystems in NSW were reported from studies conducted near Bega, on the south-coast of the State (Lunney 1987; Lunney and Ashby 1987; Lunney *et al.* 1987; Lunney and O'Connell 1988;
Lunney *et al.* 1991). This work examined the effects of logging and fire on lizards, small mammals, large herbivores and possums and gliders. In general these papers concluded that unburnt areas, especially in gullies, and a mosaic of growth stages of vegetation, were important for fauna. Calling (1991) reviewed the ecological effects of prescribed burning on the mammals of southeastern Australia, concluding that the use of frequent, low-intensity fires in autumn will eventually eliminate the dense forest understorey required by many native animals. In addition, Tolhurst *et al.* (1992) have published the initial results of an experimental study of the effect of low intensity fires on a range of biota in dry-sclerophyll forest in west-central Victoria. It was observed that unburnt patches were important for the recovery of local populations of, at least, small mammals such as *Rattus fuscipes* and *Antechinus agilis* and reptiles, after fire.

Responses of birds to fire are strongly linked to responses of habitat, particularly the recovery of vegetation and food sources such as invertebrates. In the Eden district, fire had a greater impact on numbers of individuals than numbers of species in burnt areas of open forest and tall open forest (Recher et *al* 1985). The
number of Brown Thombill, Striated Thornbill, White-throated Tree-creeper, and Grey Fantails were loner in recently burnt habitats. In tall open forest, however, Musk Lorikeet, Yellow-faced Honeyeater, Yellow-tufted Honeyeater, White-naped Honeyeater and Spotted Pardalote were more abundant in burnt areas than in unburnt areas, possibly as a result of an increase in carbohydrates such as lerp and manna in burnt plots. The insectivorous Rufous and Golden Whistlers were possibly more affected by the changed structure of the forests after burning than by changes in insect abundance. Golden Whistler numbers decreased, attributed to limited opportunities for foraging in the markedly altered shrub layer. Rufous Whistler, which favours open habitat, increased in abundance in burnt open forest but not tall open forest (Recher et al. 1985).

Often what is known about the ecological effects of fire is limited to a description of changes to species at points on the ground. This information is difficult to extrapolate to populations spread across the landscape (Bradstock *el al.* 1995). In addition, positive responses of fauna to recently burnt areas often represent opportunistic behaviour rather than representing any specialisation to fire regimes (Calling & Newsome 1981).

4.4.1 Mammals

The effect of fire on mammals in the AANP has been detailed in a literature review by Walter (1997). Mammalian community responses to fire appear to be largely dependent on habitat re-establishment after fire. Fire-related activities such as fire-line construction and felling of burning stags during mopping up, may also impact upon habitat components, however the effect of fire related activities on mammals has v_et to be studied.

Components of the fire regime are particularly important for those mammals reliant upon dense understorey. In south-eastern Australian forests, occasional high intensity wildfire in spring or summer encourages the perpetuation of a dense understorey, whilst autumn fuel reduction (frequent and low intensity) fire may reduce and eventually eliminate the dense understorey (Calling 1991). Because of changes to structural components of their habitat, repeated seasonal burning may have a significant impact on small mammal populations due to their well-defined breeding season and natural seasonal population fluctuations (Humphries & Tolhurst 1992). With changes in cover, and the necessity to move over burnt areas to find food, increased predation of small mammals immediately following fire may also impact upon populations. However, the relationship between season and intensity of fire and the effects on understorey habitat is not clear-cut, and is likely to vary depending on many other factors such as climate and herbivory following burning.

Arboreal mammals are likely to be most effected by fire if it is intense and extensive, because of changes to the availability of suitable tree hollows for den sites, and a reduction in food availability. Individuals of territorial species such as the Yellow Bellied Glider *(Petaurus australis)* may have difficulty finding suitable unoccupied habitat following fire, if fire has destroyed the integrity *of* habitat in their home range.

4.4.2 Reptiles

Research into the effect of fire on reptiles has shown different species benefited by different fire regimes, with the inference that a range of fire regimes is needed to conserve reptilian fauna (Russell-Smith 1995). Despite no studies having been undertaken on the effects of fire on reptiles within the AANP, studies from other areas on reptiles found within the AANP, may provide some insight into these effects. :.The responses of reptiles to fire is likely to be through the response of vegetation to fire and the impact of fire on critical habitat components such as leaf litter and fallen timber (Walter 1997).

Newsome *et al.* (1975), using animal tracks to census numbers, recorded a decline in the number of tree goannas *(Varanus varius)* after a fire in Nadgee Nature Reserve. Apart from this study, and those by Lunney *et al.* (1991) and Tolhurst *et al.* (1992), there have been few investigations of the *effect* of fire on reptiles in forests in eastern Australia. The above authors observed that different species of reptile responded differently to fire. The response was related to the nature of the fire and the habitat requirements of the reptiles.

An indirect way of examining the effect of fires on reptiles is to characterise habitat use by reptiles. how fire changes these parameters, and how these changes may affect populations of reptiles. In a brief review of studies on habitat preferences of forest reptiles, Brown and Nelson (1993) reported that forest reptiles depend on differing degrees of insolation (solar penetration to the ground stratum), cover, litter depth and moisture. They concluded that the identification of a single habitat variable as a predictor of reptile abundance or occurrence was not possible, at least in the Eucalyptus regnant forests in Victoria. Similarly, Friend (1.993) reported no consistent relationship between successional stage and reproductive and dietary patterns of reptiles in mallee-heath ecosystems. Therefore it may be necessary, in the first instance. to stud% the responses of individual species of reptiles to fire.

4.4.3 Amphibians

Fire is thought to influence the distribution of some species of frogs through the effects on habitat, principally vegetation (Walter 1997). The effect of fire on riverine frog habitat is likely to be related to components of the fire regime, particularly fire intensity, or to fire related activities, and be a response to consequences such as increased sedimentation, eutrophication, pollution and loss of stream side vegetation. Siltation of wetlands resulting from vegetation disturbance has been found to decrease both frog numbers and diversity (Ferraro & Burgin 1993). Fire may disrupt breeding and affect breeding opportunities of species of amphibians if the above consequences prevail, and is more likely to have this affect if intense, extensive, and occurs at a time when that particular species is breeding. Species that are most vulnerable include those that require habitat of limited availability and consist in isolated populations, for example the Baw Baw Frog *(Philoria frost!)* has been adversely effected by ski resort development, road construction and cattle grazing on the Baw Baw plateau (Ferraro & Burg in 1993). The Spotted Tree Frog *(Litoria spenceri)* is likely to be most vulnerable to intense fire occurring in early summer, if rainfall following fire leads to increased runoff of debris and nutrients into streams.

4.4.4 Birds

The effects of fire on birds in the AANP is largely unknown (Walter 1997). Research elsewhere in Australia has exhibited the diverse response of birds to fire. Long-term research is desperately required to clarify the effect of various components of the fire regime on both avifauna and habitat in the AANP.

Fire and fire related activities can impact on avifauna in a variety of ways. Loss of mature vegetation from fire may affect hollow-nesting species (Green & Osborne 1994). Food sources for a number of species such as honeyeaters may be affected by too frequent burning and a subsequent loss of species such as grevilleas and banksias (Lupica pers. comm.). Waterways may be effected by increased sedimentation, erosion of banks and loss of streamside vegetation, and these alterations have the potential to impact upon species such as Latham's Snipe *(Gallinago hardwickii).*

The response of birds during and soon after a fire appears to depend to some extent on fire intensity. In low to moderate intensity fires there have been several observations of birds easily avoiding fire and returning to areas they occupied before the burn within a number of days (Recher and Christensen 1981). During high intensity fires. birds may be killed by heat and suffocation or caught in the strong winds generated by the flames. Immediately following such fires, bird numbers usually decrease (Christensen *et al.* 1985). Unburnt patches provide important resources for birds. Following the Nadgee fire, many previously abundant birds were

restricted to small unburnt patches or the less affected vegetation along creeks (Recher and Christensen 1981).
As with other fauna, the impact of fire on birds will depend on their requirements for food, shelter and breeding sites. Species occupying the lower vegetation strata are therefore likely to be most affected by the changes in vegetation structure caused by fire (Calling and Newsome 1981; Recher and Christensen 1981). Christensen *el al.* (1985) suggested that fire intensity is the major factor determining the effect of fire on birds in the sclerophyll forests of Australia through its effect on habitat structure. Following fire of low to moderate intensity, a rapid recovery in both numbers and species composition is generally observed, whereas the recovery process after more intense fires is usually slower. Inn comparison, Rowley and Brooker (1987)
in a study of Fairy Wrens *(I Malurus splendens)* in heathland found the birds survived a widespread intense wildfire remarkably well, a result attributed to site tenacity and the timing of the fire. It is apparent that a range of fire, habitat and life-history characteristics will influence the responses of birds to fires.
Insectivorous birds are influenced by changes in their prey resource after fire (Wooller and Calver 1988). After a low-intensity fire in dry sclerophyll forest in south-western Australia, Wooller and Calver (1988) found that there were few changes in species composition of the assemblage but that the abundance of the 6-8 most numerous and relatively sedentary species of birds was approximately halved. Analysis of the faeces of insectivorous birds collected after the fire, indicated that they ate proportionally more ants and fewer beetles; suggesting a change in the relative abundance of prey as a result of the fire. There have been suggestions that delays in the recovery of invertebrates after intense fires may be largely responsible for the slower recovery of birds following such fires (Christensen *et al.* 1985). The effect of fire on populations and species of invertebrates, however, is poorly known.

4.4.5 Fish

The effects of fire on fish are largely unknown. Aquatic systems are affected by increased sedimentation and increased runoff following wildfire (Brown & Millner 1988) and fire related activities such as fire break and track construction. Erosion is promoted by grazing, used as a fuel reduction technique in some areas of the AANP. Grazing may also lead to changes in structure and composition of riparian vegetation and thereby indirectly affect aquatic fauna through changes to habitat. For example overhanging vegetation may be important for shelter and breeding sites for some species. Trampling or grazing of vegetation overhanging streams may limit the number of sites available for fish and other aquatic fauna to shelter and breed in. Fish are not included in the database at this stage, however, as more information becomes available on distribution and fire effects, including this information into the database would be beneficial.

4.4.6 Invertebrates

Fire heats the soil and may consume much of the litter on the ground. In doing so it may kill a high proportion of soil and litter invertebrates (Recher and Christensen 1981). Apart from data provided in Campbell and Tanton (1981), and Greenslade and Rosser (1984), detailed studies in the forests of eastern Australia on the response of invertebrates to fire have only recently appeared in the literature (Neumann and

Tolhurst 1991, Collett *et al.* 1993). Much of our information on the responses of invertebrates to fire comes from studies in the forests of Western Australia (Springett 1976, 1979; Abbott 1984; Majer 1985; Christensen and Abbott 1989). Considering the importance of invertebrates to the dynamics of forest ecosystems (Campbell and Tanton 1981) it is surprising that more work has not been conducted in eastern Australia. Serious problems with sampling and identification, however, have hampered studies on invertebrates (Campbell and Tanton 1981; Christensen and Abbott 1989).

Work on the effect of low-intensity prescribed fires in dry sclerophyll forest in west-central Victoria indicates that the timing (season) of fire was important for some invertebrate taxa (Neumann and Tolhurst 1991). Population levels of earthworms decreased after burning in spring but not after a fire in autumn. This study only assessed the effects of one fire, whereas Collett *et al.* (1993) investigated the effects of two low-intensity fires on invertebrates in the litter/upper soil layer. The two fires were lit in spring, within three years of each other. Earthworms took longer to recover than the Collembola after each fire (Collett *et al.* 1993). The authors concluded that both fires induced a decline in the decomposer cycle in the study area as Collembola and Earthworms are important and dominant among litter decomposers in some forests. However, these studies did not sample individual species, focusing instead on groups of species such as epigeal arthropods (those living within the litter surface) and earthworms. The responses of individual species to low-intensity fires in these forests remain unknown.

A review of the research emanating from Western Australia concluded that, in general, soil and litter invertebrates recorded an immediate decrease in total numbers following a fire (Christensen and Abbott 1989), However, current data suggest that the patterns of recovery after fire between species and groups are highly variable and unpredictable. This is perhaps not surprising given the number of differences that may occur between studies such as the nature of the fires- the invertebrate population levels preceding the fire and the post-fire conditions. Campbell and Tanton (1981) noted that the pattern or rate of recolonisation of burnt areas will also be influenced by the aerial movement of small litter insects. They found that the number of invertebrates protected under large woody debris during a fire was related to the dimensions of the log, its stage of decay and the depth of accumulated litter about the log prior to burning.

The number of small flying insects, and foliage dwelling insects which are both important food resources for birds, may be affected by fire. Recher *el al.* (1985), in a study in the forests around Eden, found that while insects were more abundant on the foliage of post-fire vegetation, the smaller amount of foliage on the burnt plots may have meant the total numbers were lower in the burnt area. Nonetheless, invertebrate prey may be more conspicuous in the post-fire environment. It is evident that much more research is required, especially at the species level, on the effects of fires on invertebrates.

4.4.7 Faunal succession and population dynamics

There is little information on the succession of faunal communities following fire. Most studies of vertebrates are autecological in nature. Research of broader assemblages of animals in specific areas however, consistently relate resource availability to community structure of sympatric vertebrates. This faunal succession

will depend on the successional processes of vegetation following fire, although the two processes are not independent.
Data on the nature of faunal succession after fire are primarily limited to studies of assemblages of small mammal populations, particularly rodents. Various authors suggest that the size of these animal populations may drop immediately after fire. There then appears to be a reasonably consistent and predictable successional sequence of small mammals following fire, at least in dry sclerophyll forests and associated heath (Calling and Newsome 1981; Recher and Christensen 1981). These patterns appear related to shelter, diet and reproductive patterns of the different animal species (Friend 1993). Studies on succession in forest ecosystems in eastern NSW have focused on the drier forest types (Newsome *et a/.* 1975; Fox and McKay 1981). Newsome *et al.* (1975) monitored 20 vertebrate species for two years after the fire and reported a major invasion of House Mice *(Mus musculus domesticus)* after the fire and possibly a minor one by Dusky Antechinus *(Antechinus swainsonnii).* Populations of medium sized marsupials recovered quickly. Due to a change in the predatory habits of dingoes, population numbers of large herbivores did not increase over the two years of the study. Fox and McKay (1981) also recorded the highest population densities of house mice within the first year post-fire, then a rapid decrease in population numbers. They also found the maximum population densities of small mammals species ranged from I year post-fire for New Holland Mouse *(Pseudomys novaehollandiae)* to in excess of 8 years for Bush Rat *(Rattus fuscipes),* a pattern also reported by Norton (1987a, 1987b) in dry and wet eucalypt forest and associated coastal heath in north-eastern Tasmania.

4.4.8 Refugia and unburnt patches

The contribution of "refugia", unburnt patches of vegetation, and vegetation mosaics to the survival of fauna during fire and the recolonisation of an area after fire has been mentioned frequently in the literature (Christensen and Kimber 1975; Newsome *et at* 1975; Recher and Christensen 1981; Fox and McKay 1981; Lunney 1987; Christensen and Abbott 1989; Catling 1991; Whelan and Muston 1991; Tolhurst *e(al.* 1992). However, there have been few empirical studies in forested ecosystems in eastern Australia examining the importance of a mosaic of burnt and unburnt patches for fauna (Gill and Bradstock 1994)- In order to achieve this, one would need to consider the size, shape (Gill 1986) and spatial arrangement of vegetation or habitat patches in the forest mosaic, and why these features were important. Attributes such as whether the understorey and/or overstorey were burnt within a patch may also require consideration (Williams *et a.* 1994),

4.5 Threatened fauna species - implications for fire management

This section outlines the responses of threatened vertebrate fauna species to fire and suggests options for management of those species and the habitat on which they depend, in relation to fire and fuel management within the AANP.

4.5.1 Mammals

Mountain Pygmy Possum (Burramys parvus)

Burramys parvus is found in alpine and subalpine zones and favors a habitat consisting of boulderfields and rock scree associated with Mountain Plum Pine *(Podocarpus lawrenceii)* (Broom & Mansergh 1989). Broom and Mansergh (1989) indicate that the vegetative component of the habitat of the Mountain pygmy possum is extremely sensitive to fire and that absolute protection from fire is required.

Smoky Mouse (Pseudomys fumeus)

In the AANP, Smoky Mouse is found in montane and sub-alpine woodland, and open forest areas with a heathy understorey component. Cockbum (1995) suggests that because the heathy vegetative understorey is generated by fire, this species may be dependent upon post-fire succession for its continued survival. However, the Smoky Mouse requires careful monitoring because it occurs in small isolated populations susceptible to successional changes in vegetation patches (Menkhorst 1995c).

The Smoky Mouse feeds on leguminous seeds, berries of epacrids, insects, including Bogong Moths, and the fruiting bodies of fungi (Cockburn 1995). Because of its reliance on these food resources which are not available year round in all habitats utilised by this species, a critical period between September to November can occur and may lead to a temporary decline in the local population (Cockburn 1995). Depending on extent, fire during this period may be detrimental to the survival of local populations of this species.

Broad Toothed Rat (Mastacomys fuscus)

In the AANP, the Broad Toothed Rat generally inhabits moist montane sedgelands, grasslands and heathlands above 1400m, often along drainage lines. They are herbivorous, feeding mainly on stems and leaf tissue from plants in the Gramineae and Cyperaceae families, but also on bark seeds and fungi (Menkhorst 1995d). Because of their reliance on wetter habitat, the threat to this species from fire is limited, however still should be considered, as it may compound the effects of habitat reduction. Fire related activities such as fire line construction and track building should be avoided in areas of known occurrence.

Koala (Phascolarctos cinereus)

In the AANP, Koalas inhabit eucalypt forests and woodlands of the tablelands, preferring species such as Manna Gum and Swamp Gum. While they can tolerate low intensity fires, Koalas are particularly susceptible to wildfire as they find it difficult to escape and their food resource may be destroyed resulting in starvation (NSW NPWS 1997). Habitat fragmentation, from fire and fire related activities, is a concern for the survival of populations within the AANP.

Spot-tailed Quoll (Dasyurus maculatus)

In the AANP, The Spot-tailed Quoll has been recorded from many forested habitats including rainforest. In addition, several records exist from the dry rainshadow White Cypress Pine Woodlands in the upper Snowy River area (Mansergh 1995)_ Optimum conditions for both foraging and den sites are in old-growth forest (Scotts 1991). Habitat destruction is the main cause of concern for this territorial species which occupies a large home range. The Spot-tailed Quell is an opportunistic carnivore and scavenger, eating birds, mammals, carrion and arthropods (Mansergh 1995). Habitat fragmentation from fire and reduction in prey items following fire may effect this species. This species uses hollow logs as den sites, which may be destroyed during high intensity fire events (NSW NPWS 1997). Their preferred habitat of old-growth forests is of particular concern in relation to edge effects of fire. Fuel management in areas surrounding old-growth forest should be aimed at protecting_ this resource.

Brush-tailed Phascogale (Phascogale tapoatafa)

Brush-tailed Phascogales favor open dry sclerophyll forests. often with little understorey, where they nest in tree hollows with a small entry (Menkhorst 1995i). They are largely arboreal and feed primarily on arthropods, supplemented with nectar and occasionally larger prey. With all males dying following the breeding season (July-November), and a normally low population density, they are susceptible to population crashes following intense fires (Menkhorst 1995i). The main effects are likely to be from changes in tree hollow availability, a reduction in the main food sources, increased likelihood of predation, and habitat fragmentation. Catling (1991) suggests that the Brush-tailed Phascogale may be advantaged by frequent low intensity fire because of the simplification of forest structure. Research is required to clarify the relationships between the Brush-tailed Phascogale, habitat, and fire regimes in the AANP.

Yellow-bellied Glider (Petaurus australis)

The Yellow-bellied Glider inhabits tall moist mature sclerophyll forests, and are likely to be most effected by fire if it is intense and extensive, because of changes to availability of suitable tree hollows for den sites and a reduction in food availability. Wildfire can reduce the availability of all food types except sap, impacting on food supplies in the short term (Goldingay & Kavanagh 1991). This species is territorial, lives in small family groups, and occupies a large home range, and as such may have difficulty finding suitable unoccupied habitat following fire, if fire has destroyed the integrity of habitat in their home range. Increased exposure to predation, and reduced opportunities for dispersal because of habitat fragmentation, is also of concern following fire.

Common Wallaroo - eastern race *(Macropus robustus robustus)*

The eastern race of the Common Wallaroo (AML *r. robustus)* occupies small home ranges comprising dry open woodlands and rocky ridges (Menkhorst 19951). They feed on grasses and forks, and on improved pasture if available, but rarely forage more than 200m from shelter (Menkhorst 19951). Their main threats are likely to be from predation and habitat destruction, and isolated populations such as the population near Suggan Buggan are especially vulnerable. Wildfires can temporarily reduce grasses for feeding, although may provide green-pick in the medium term. Depending on components of the fire regime, alterations to vegetation structure can occur, which could impact upon the habitat of this species. This can include the replacement of a climax grassy understorey with that of a thick shrub layer. Predation may be an important factor to consider if the Wallaroo is forced to move large distances from shelter in order to feed following fire. Further investigations into the effects of fire on this species and their habitat are required.

Long Footed Potoroo (Polorous longipes).

Several mycophagous mammals, including endangered species such as the Longfooted Potoroo *(Potorous longipes)* occur in native forests in eastern Australia. The habitat of these species can be significantly influenced by wildfire and prescribed fire. Taylor (1991) for example, suggested that fire is integral to relationships among plants, fungi and bettongs. Taylor reported that the Tasmanian Bettong *(Bettongia gaimardi),* a small ground-dwelling marsupial, foraged intensively for sporocarps of certain hypogeal (below ground) mycorrhizal fungi in forest sites shortly after fire. However, research by Johnson (1997) indicates that frequent fire could reduce the abundance of many of the fungi eaten by *B. gaimardi,* and that a fire free period of at least 10 years between burning, and use of small patch bums which allow animals to more between suitable habitat should be investigated Scotts and Seebeck (1989) found that *P. /ongipes* had disappeared from a location which had not been burnt for 20 years. They suggested that the establishment of a dense grass cover may have hindered the species search for hypogeal fungi. Evidence to date suggests that gaps in the ground cover are necessary for successful foraging of hypogeal fungi by mycophagous mammals (Scotts and Seebeck 1989).

Mycophagous mammals are potentially important agents in the dispersal of hypogeal fungi which have been shown to enhance plant growth through nutrient and water uptake from the soil. Presently however, the autecology of mycophagous mammals is poorly known and the extensive use of fire as a means to manipulate habitat is considered inappropriate (Claridge 1992).

Soil moisture is an important factor in sporocarp abundance, with increasing soil moisture leading to an increase in sporocarp production (Bennett & Baxter 1989; Claridge *et al.* 1993; .Green *et al.* in press). Fire may reduce leaf litter cover and expose the soil to drying, thus effecting sporocarp production.

Dogs and Red Foxes are significant predators of Long-footed Potoroo (Brown & Triggs 1990). Following fire the Long-footed Potoroo may be required to forage in cleared areas with little protection from patches of vegetation, making them more vulnerable to predation. In addition, access for Dogs and Red Foxes into the normally densely *vegetated* areas inhabited by the Long-footed Potoroo, is increased immediately following fire.

Changes to vegetation structure, increased edge effects on habitat, and habitat fragmentation from fire are all concerns for this species. Identification and management of threatening processes to allow this species to maintain secure and viable populations, is required (DCNR 1994).

Brush-tailed Rock Wallaby (Petrogale pencillata)

Habitat of the Brush-tailed Rock Wallaby includes rocky slopes, gorges and cliffs in dry sclerophyll forests. Although this species eats a wide variety of plant material, it is possible that floristic changes associated with altered fire regimes have reduced food availability to the extent that habitat is now less than optimum (Menkhorst 1995e). Fire also increases habitat fragmentation, and thus may further jeopardise populations within the AANP. Populations of Brush-tail Rock Wallabies have been decimated by predation by foxes_ Fire related activities such as construction of roads and fire-breaks can lead to increased penetration of predators into Brush-tailed Rockwallaby habitat.

Common Bent-wing Bat (Miniopterus schreibersii)

The Common Bent-wing Bat breeds and roosts in caves, mine shafts and tunnels. They feed high in, or above the canopy, primarily on moths, although other flying insects are also taken. (Menkhorst & Lumsden 1995a). Following high intensity fire and canopy scorch, insect prey normally found in the tree canopy may need to alter their habitat utilisation. and can move onto the ground to forage (Whelan 1995). The
resulting reduction in prey availability for canopy feeders following high intensity wildlife may temporarily force this species to travel further distances in search of prey or forage in different habitats, exposing them to increased predation.
Fire is implicated in disturbance to karst areas. The Common Bent-wing' Bat requires caves of specific temperatures at different times during the breeding season, whist raising young, and for over-wintering, thus limiting the number of caves suitable for habitation. Research is required to ascertain if alterations to cave integrity from fire impact upon this species. Fire related activities such as construction of roads or dozer constructed fire-breaks, need to be avoided, or carefully monitored in karst catchment areas to minimise impacts on this species.

Eastern False Pipistrelle (Falsistrellus tasmaniensis)

Eastern False Pipistrelle demonstrates a preference for wet habitats, particularly riparian and high rainfall areas. They have been recorded roosting in tree hollows nest boxes and caves. The insect prey is usually captured around or just below the tree canopy (Menkhorst & Lumsden 1995b). A reduction in prey following high intensity wildlife that affects the tree canopy, may temporarily force this species to travel further distances in search of prey, and expose them to increased predation. Fire may effect availability of tree hollows and could temporarily limit roosting sites. Edge effects on wet and riparian vegetation are increased by frequent fuel reduction in adjacent areas (Walter 1997), and this may further limit suitable habitat for this species. Mopping up activities following wildfire and fuel reduction burning, such as tree felling, can impact on availability of roosting sites.
As with the Common Bent-wing Bat, research is required to ascertain if alterations to cave integrity from fire impact upon this species. Fire related activities such as construction of roads or dozer constructed fire-breaks, should be avoided, or

carefully monitored in karst catchment areas, to minimise potential impacts on this species.

45.2 Reptiles

Alpine Oak Skink (Cyclodomorphus praealtus)

The Alpine Oak Skink occurs in alpine areas between 1600-2100m in open shrubland with a thick cover of tussock grass (Green & Osborne 1994). Little is known of the requirements of this species and research into these requirements, including the effects of fire, is warranted, particularly as this species appears to be dependent upon ground-layer vegetation for shelter.

Heath Monitor (Varanus rosenbergi)

The Heath Monitor occupies a wide range of habitats from dense forest areas to open grasslands (Green & King 1993; Cogger 1994). Its distribution in south-eastern Australia however, is limited and has only been recorded within NNP in the AANP. The diet is almost entirely carnivorous, and includes mammals, insects, reptiles, birds and amphibians. This species home range size depends upon habitat characteristics such as availability of prey, and is likely to be large in NNP. Research is required to ascertain the effects of fire, particularly extensive high intensity fire, on prey availability and foraging success of this species. Low intensity fuel reduction burning is not thought to be a threatening process, however changes to habitat from frequent fire may effect prey availability in the long term, particularly as the population appears to be isolated.

4.5.2 Amphibians

Green and Golden Bell Frog (Litoria aurea)

Green and Golden Bell Frogs are usually found in or close to water, or in very wet forest, woodland or shrubland areas, often under debris (Cogger 1994). They breed in summer, and tadpoles are located in lakes, dams and swamps, with still water (Hero *et al.* 1991). Fires during the breeding season may effect breeding success if extensive loss of cover occurs, and water bodies are degraded. Fire related activities such as construction of fire lines with earth moving equipment and the use of foams and retardants are potential threats to this species and should be avoided at sites of known occurrence. Further research into the effect of fire and fire related activities, on this species is required.

Spotted Tree Frog (Litoria spenceri)

The Spotted Tree Frog inhabits rocky fast moving streams in both wet and dry forests (Hero *et al.* 1991; Cogger 1994). They are often found basking on boulders mid stream, and also utilise streamside vegetation. Fire or fire related activities that destroy riparian vegetation and effect water quality through increased sedimentation

may impact on this species. Walter (1997) suggests riverine frog habitat can be effected by frequent fuel reduction fire in adjacent areas, as it can eliminate the graduation from riparian to dry forest. The remaining riparian vegetation is then more susceptible to fire.
The use of chemical retardants in catchment areas inhabited by the Spotted Tree Frog has the potential to detrimentally effect this species. Research into the effects of chemical retardants on biota is urgently required.

Blue Mountains Tree Frog (Litoria citropa)

This frog inhabits rock' rivers or streams in heath and wet and dry sclerophyll forests and woodlands (Hero *et al.* 1991; Cogger 1994). It shelters under rocks and in rock crevices and breeds in permanent and semi-permanent pools in spring and summer (Cogger 1994). As with other frogs that normally reside in damp habitats normally protected from fire, fire and fire related activities have the potential to indirectly effect this species. Further research is required into the effects of fire on this frog.

Large Brown Tree Frog (Litoria littlejohni)

Very little published information on this newly recognised species exists. It has been found in a limited area of damp forest in the SRNP. Further research into the distribution and habitat of the Large Brown Tree Frog is required in order to speculate on any effects fire and fire related activities might have on populations of this species.

Alpine Tree Frog (Litoria verreauxii ssp. alpina)

The Alpine Tree Frog is found in alpine bogs, fens and streams (Hero *et al-* 1991; Green & Osborne 1994). Breeding begins in December, and eggs are attached to submerged vegetation. The diet of this frog consists of small invertebrates, including beetles, flies, spiders and the larvae of moths (Green & Osborne 1994). Fire that effects alpine vegetation (especially surrounding bogs and fens) may have an impact on this species because of sedimentation, and loss of protective cover around breeding sites. A reduction in vegetative covet around breeding sites may expose the water body to greater temperature extremes. This has been shown to effect the survival of eggs and tadpoles in other frog species (Ferraro & Burgin 1993). Loss of vegetation cover can also expose this species to predation. Summer wildfire is likely to be particularly detrimental. Disturbance to breeding sites form fire related activities such as fire break construction- should be avoided. The use of chemical retardants in fire fighting may also effect this species and further research is required to ascertain this.

Southern Corroboree Frog (Pseudophryne corroboree)

The Southern Corroboree Frog is found predominantly at altitudes between 1300 and 1770m (Green & Osborne 1994). Breeding occurs between late December and early January in wet grassland. sphagnum bogs, or wet heathland. Adult frogs spend the non breeding season in adjacent woodlands or dry heathlands (Osborne 1991, Green & Osborne 1994). The food primarily consists of ants, beetles, mites and springtales (Green & Osborne 1994). They are likely to be more at risk from fire outside of their breeding period, as areas they inhabit at this time are more susceptible to fire (Green pens. comm.). Fire in these drier habitats can reduce leaf litter and ground debris, under *which* this species shelters. Fire related activities, such as vehicle use, and activities that intercept and reduce water flow into breeding sites, can effect breeding habitat, and should be avoided. Osborne (1991) warns against the use of controlled burning in Corroboree Frog habitat.

Northern Corroboree Frog (Psuedophryne pengellii)

The Northern Corroboree Frog is restricted to areas with small semi-permanent pools and seepages (Green & Osborne 1994), in the north section of KNP and in NNP. Activities that reduce water flow into breeding sites are potentially detrimental to the breeding success and continued existence of this species. Sediment run-off from roads and associated weed invasion is of concern in some areas of Northern Corroboree Frog habitat (Osborne 1991). As such, fire management in areas surrounding the habitat of this species should be carefully regulated. As with other frog species, the effect of fire retardants are unknown, but potentially damaging, and should be avoided.

Giant Burrowing Frog (Heleioporus australiacus)

This frog inhabits wet and dry forests and woodlands. Tadpoles are laid in water filled burrows, or in damp vegetation in ditches, dams and streams (Hero *et a!.* 1991). Little detailed knowledge of ecology or specific habitat requirements of this species are available (Gillespie 1990). They are thought to breed during summer and autumn (Cogger 1994), and fires during the breeding season have the potential to effect breeding success, through changes in vegetation cover, and drying of breeding sites.

4.5.3 Birds

Regent Honeyeater (Xanthomyza phrygia)

The Regent Honeyeater inhabits shrubby eucalypt woodlands and open forests. Other habitats, for example riparian gallery forest are also vital to the survival of this species (Oliver 1997). They are nomadic in their search of seasonally fluctuating food supplies, which consist of nectar, insects, manna and lerp. Oliver (1997) suggested that the focus of research needs to be on post breeding movements in autumn and winter, in order to uncover new habitats and resources, which may be the limiting factors in the survival of this species. Grazing as a fuel management tool is not recommended in areas of suitable habitat for the Regent Honeyeater, as this can suppress regeneration of trees, such as *Eucalyptus albens* (White Box), and E. *melliodora* (Yellow Box), vital for the continued survival of this species. Relationships between fire and the habitat used by this species require investigation.

Grey Falcon (Falco hypoleucus)

Habitat of the Grey Falcon includes grasslands, low woodlands, acacia scrub and timbered watercourses (Garnett 1992; Olsen 1995). They are widely distributed in Australia, but are not common. They feed on small birds, reptiles and small mammals. Breeding occurs between July and November, however there are no known accounts of this species breeding within the AANP. Nests are constructed in the tops of tall trees. Habitat fragmentation is a likely cause of decline in their breeding range, and habitat destruction continues to be the main threat to this species (Garnef 1992; Olsen 1995). Fire has the potential to disrupt foraging patterns and effect breeding success of this species, because of the effects on major prey species, although further research is required to ascertain this.

Square-tailed Kite (Lophoictinia isura)

The Square-tailed Kite is a summer migrant to southern regions of Australia and a rare visitor to the AANP. They are a specialist predator of the canopy feeding primarily on nestling birds, eggs, insects and reptiles (Gamett 1992; Olsen 1995). They mainly utilise timbered watercourses when inland, preferring coastal forests, woodlands and gullies (Olsen 1995)- Wildfire may temporarily increase food availability as prey is flushed from habitats (Whelan 1995), however if fire is intense and canopy scorch prevalent, foraging opportunities may be reduced for this species in the short term. As this species utilises timbered watercourses, protection of these areas from any detrimental effects of fire should be considered.

Glossy Black Cockatoo (Calyptorhynchus lathami)

The Glossy Black Cockatoo is usually associated with Allocasuarina/Casuarina woodlands, and feed almost exclusively on the seeds of those species (Gamett 1992). They nest in hollows in large eucalypts. While the main threat to this species has been habitat fragmentation and land clearing, any fire that significantly reduces their food source and the abundance of suitable nesting sites is a threat to this species.

Swift Parrot (Polytelis swainsonil)

The Swift Parrot breeds in Tasmania and migrates to south-eastern mainland Australia for the winter (Cayley 1990; Simpson & Day 1996). Nomadic on the mainland, this species follows the flowering of winter-flowering eucalypts, where it feeds on nectar, scale-insects and caterpillars. Like other nomadic species, the Swift Parrot relies upon the maintenance of suitable habitat over a wide range for its survival. Depending on the regime, fire can have effects on the flowering of eucalypts, invertebrate abundance, and on regeneration of suitable feed trees. Frequent fuel reduction fire in areas of suitable habitat should be closely monitored to ensure the habitat of this species is not further limited.

Turquoise Parrot (Neophema pulchella)

The Turquoise Parrot frequents grassland areas bordering forests, especially along ridges, mountain slopes and creeks. They feed on the seeds of grasses and herbaceous plants in grasslands, and require a mosaic of habitats for a year round food supply (Quinn 1997). They nest in the hollow of a tree, or a tree stump, usually between August and December. Nesting sites are highly susceptible to the effects of wildfire (Quinn 1997). and fire during the breeding season may significantly affect their breeding success. Because this species relies on seeds of native grasses for a large proportion of their diet, fire management in grassland areas should take the requirements of Turquoise Parrots into consideration. Summer wildfire for example can affect food availability coinciding with he caring of young (and consequent decreased mobility of adults). Depending on the effects of other variables of the fire regime, particularly extent, on habitat loss, fledgling success may be decreased. Mosaic patch burning of grasslands for protection and regeneration of habitat requires further investigation in the AANP.

Powerful Owl (*Ninax strenua*)

The Powerful Owl occupies wet and dry forests and woodlands, and shows a preference for undisturbed areas. Nests are usually in large eucalypt hollows, and the main prey is medium sized mammals, including the Greater Glider, Yellow-bellied Glider, Common Ringtail Possum and Sugar Glider (Kavanagh 1991; Gannett 1992). High intensity fires may effect the availability of mature eucalypts with hollows suitable for nesting, and thus may be detrimental to this species in some areas. While the main prey items taken by the Powerful Owl in the period immediately following
fire are often further exposed by fire, fire that reduces prey availability in the medium term may impact on populations.

Sooty Owl (*Tyto tenebricosa*)

Preferred Sooty Owl habitat is wet gully areas in tall wet old-growth forest with a dense understorey, although they have been found in dryer forest types including montane woodlands (Loyn *et al.* 1998). In north-east Victorian forests, Sooty Owls appeared to favour sites with many dead hollow bearing trees, and a dense middle storey containing *Acacia dealbata* (Silver Wattle), *A. melanoxylon* (Blackwood), *Bedfordia arborescens* (Blanket-leaf) and Treeferns (Loyn *et al.* 1998). Their preferred habitat is vulnerable to both prescribed and unplanned fires (Gannett 1992). Fuel reduction activities in areas surrounding Sooty Owl habitat should be avoided, or planned so as to minimise edge effects.

Masked Owl (*Tyro novaehollandiae*)

The Masked Owl is predominantly a species of forests and forest margins, including wooded watercourses. The bulk of prey items consist of terrestrial mammals up to the size of rabbits, although some arboreal prey is taken. Because the Masked owl feeds in a variety of habitats, it is likely that only extensive fire will impact on foraging success. Nesting is usually in tree hollows within *tall* forest or riverine forests, and fire, particularly if intense, may effect the availability of suitable hollows.

Pink Robin (Peso ca rodinogaster)

The Pink Robin frequents heavily timbered mountain ranges and gullies in spring and summer, and moves to more open areas in autumn. This species usually feeds in low dense cover on terrestrial and flying insects. They build a cup shaped nest between October and December around 1m above the ground. Fires during this period can effect the breeding success of this species, because of reduction in cover and the resulting increased likelihood of predation. Extensive fire that leaves few refuges is likely to be more detrimental than patchy fire, particularly as this species *rarely* moves very far from the nest to feed during the breeding period. Frequent low intensity burning may reduce understorey habitat, and thus breeding and foraging opportunities for this species.

Olive Whistler (Pachycephala olivacea)

The Olive Whistler is found in tall wet forests, rainforests, woodlands and alpine heaths, where they feed on insects and seeds. They inhabit thick shrubs, usually nesting and foraging within 3 metres of the ground. They nest in spring and summer, and fire at this time can potentially interrupt breeding, and reduce foraging opportunities, by removing undergrowth. In addition, fire may expose nests to predation. While wildfire can encourage the growth of a shrubby understorey, frequent fuel reduction fire may reduce the amount of shrubby undergrowth available for habitat. Following the breeding season, the Olive Whistler becomes nomadic.

Latham's Snipe (Gallinago hardwickii)

Latham's Snipe breeds in Japan and migrates to Australia for the southern summer. They frequent river flats, swamps and marshes, and are a regular component of the alpine fauna in summer, foraging in fens, bogs and wet grasslands (Green & Osborne 1994). They feed on insects and other aquatic life. While not likely to be a major threat, fire that impacts habitat may limit foraging opportunities for this species.

4.6 Habitat of special consideration

The following section briefly outlines habitat of special consideration not adequately covered in other areas of this report. The effects of fire and fire related activity on these habitat types has relevance to fauna, including a number of threatened species.

4.6.1 Karst.

A number of karst areas exist within the AANP and a review of the significance of these Karst areas is covered by Spate and Houshold (1988). "The stable environments found in caves can sometimes lead to the development of specialised ecosystems which often act as refugia for invertebrate faunas" such as cave spiders and beetles (Spate & Houshold 1988, p208). Caves ate also significant in that they provide important habitat for several bat species in the AANP, including the Common Bent-wing Bat *(Miniopterus schreibersii)*. Caves in the New Guinea Ridge area of the Snowy River National Park, for example, are one of only a few over-wintering sites for *Miniopterus schreibersii* in south-eastern Australia (DCNR 1993). Karst is prone to the impact of fire through a number of mechanisms, primarily through effects on hydrology. Catchments associated with limestone areas need to be managed for both water quality and for rates of flow, as changes to either or both of these components can effect karstification processes (NSW NPWS 1997). Intense fire, for example, can result in spalling of limestone, enhancing erosion in limestone areas (NSW NPWS 1997). Fuel reduction and fire suppression activities such as dozer activity, removal of vegetative cover, and use of retardants, as well as smoke and ash can change the solution properties of water and alter the hydrological regime (NSW NPWS 1997). Fire has been implicated as a causative agent for alteration in cave microclimate (NSW NPWS 1987). Fire management in these areas must take into account the effects of fire and fire related activities on karst systems.

4.6.2 Old growth forest

Old growth forest is particularly susceptible to altered fire regimes. Fauna dependent upon habitat characteristics such as mature hollow bearing trees found in old-growth are thus threatened by any change to habitat integrity, and this needs to be taken into consideration when planning fuel reduction and fire suppression activities in these areas.

Management aimed at ensuring the survival of threatened fauna dependent on old-growth forest, which includes Sooty Owl *(Tyro tenebricosa),* is likely to ensure the survival of less sensitive species. It has been suggested that habitat management based on requirements of target fauna species such as the Sooty Owl will in the short term be successful in maintaining species richness and diversity (Kavanagh 1991; Sutton 1991).

4.3 Sphagnum bogs and fens

Sphagnum bogs and fens are important components of the Alpine Complex. Alpine and subalpine bogs generally occur on valley bog peat and are characterised by a cover of sphagnum moss. Burning by graziers to encourage• growth of grasses, grazing, and bushfire has impacted greatly on bogs and surrounding vegetation in the AANP (Green & Osborne 1994). Fauna species that rely on bogs include the Broadtoothed Rat, Northern Corroboree Frog, and the Southern Corroboree Frog.

Fen is characterised by permanent surface water. The sedge, *Carat gaudichaudiana is* the dominant vegetation in fens. A number of animals utilise fens including skinks, snakes, frogs and birds. In summer the migratory Latham's Snipe forages in fens, and the Corroboree Frogs, and Alpine Tree Frog breed in fens (Green & Osborne 1994). Fens can dry out if there is disturbance which influences drainage (Osborne 1991). Erosion and subsequent siltation of fens, from fire and fire related activities would be expected to impact on breeding sites of Corroboree Frogs.

4.6.4 Temperate grassland

Temperate grassland only exists in small areas within the AANP below 1100 metres. Very small areas of this grassland remain in unmodified condition (Good 1992). While use of fire as a management tool in grasslands may be beneficial to flora, it may also create conditions that favour weed invasion. Fire and grazing appear to be the main threats to this community. Small differences in fertility, for example, can cause major differences in floristic composition in grasslands (Motts & Groves 1994). Deliberate use of fire should aim to conserve biodiversity. A number of reptiles in the AANP utilise this community, including *Varanus rosenbergi* (Heath Monitor). Research to ascertain the effects of fire on this community is urgently required.

4.7 Conclusions

Different species of animals have different habitat requirements, and hence will be differentially affected by fires. Even within a genus, the responses of species to fire can differ markedly. For example, Braithwaite (1987) concluded that in the wet-dry tropics of Northern Australia a range of fire regimes was necessary to maintain assemblages of lizards; some species are sensitive to even a single fire, while other species are tolerant of, or indifferent to fire. Nonetheless, responses may be predictable given sufficient knowledge of life-history characteristics (Friend 1993). Variation in fire frequency, season, intensity and the area burnt will influence the availability of habitat, and the quality of that habitat for fauna. However, scientific understanding of the response of species to fires is limited. This limits the extent to which the use of fires as an ecosystem management tool is predictable such that any potentially undesirable outcomes (in terms of detrimental impacts on fauna) can be avoided.

Fire regimes may affect many fauna including rare and vulnerable species, arboreal species, folivores, omnivores and insectivores. The responses of fauna will vary, perhaps significantly, depending on a number of factors including the timing of the fire (e.g. seasonality) and the natural variability of the local forest environment for the animal species of concern. Some areas of habitat act as significant core areas for fauna, where the fire regime experienced by the site is favorable for the species or assemblage of species of interest. Since the location and functional significance of such core areas are typically poorly known, careful monitoring is required if the persistence of populations and assemblages of species over time under specified fire regimes is to be ensured.

5.0 Recommendations

5.1 Research

Research aimed at exploring the relationships between fire, habitat and fauna (especially threatened fauna) in the AANP is urgently required. Whelan (1995) suggests that long-term experiments designed to assess the effects of fire regimes on population dynamics of a range of animal groups should be established. Furthermore, the relative importance of food, cover and predation as factors controlling post-fire animal populations requires further investigation (Whelan 1995).

Fuel reduction burning and fire related activities have the potential to impact on fauna and faunal habitat, and research is required into these aspects of fire management. The potentially detrimental effects of foams and fire retardants on biota especially should also be considered.

Mosaic patch burning for conservation purposes is one area that has received attention of late, and investigations into mosaic burning in the AANP could provide management with useful information.

In addition, basic research contributing to baseline data of fauna species, particularly threatened species, and information on changes and status of populations of threatened fauna is required for management purposes. Full fauna surveys, which include information on the distribution of fauna species, are required for areas of the AANP such as Bimberi Nature Reserve. Information on habitat and dietary requirements and on foraging methods is needed for many faunal species.

5.2 Schedule for update

This database should be updated by each state conservation agency as new information becomes available. it is suggested that the AALC undertake a general review of the additions made by database users in each state/territory within 5 years. This general review will allow new findings of scientific research in each state to be considered for the management of fauna and critical habitat in relation to fire, in other reserves in the AANP. Updating of the database should include a review of Victorian EVC mapping and RFA reports from data collected in the Victorian AANP.

This general review could also report on progress in meeting recommendations outlined in each state/territory's policy documents particularly in terms of current fire management planning. An update of the Victorian Regional Fire Management Plans are required in the next year, for example, and new guidelines and approaches for management of fire in areas of the AANP may change.

Management plans and fire management plans for Brindabella National Park, Bimberi Nature Reserve and Scabby Range Nature Reserve will be completed within the next 4 years and further information gained from baseline data collected in these areas could be incorporated into the database.

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Personal Communications

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Green, K. NSW NPWS, Jindabyne.
Lupica, P. NSW NPWS, Queenbeyan.

ANNNEXURE A: PROJECT BRIEF

Fire and Fauna

1. SCOPE

The initial phase of this project reviewed the literature in relation to the effects of fire on the fauna of the AANP's. The knP findings of the review were that little specific information was published on AANP fauna, and the effect of fire on habitat was likely to be the key determinant in assessing the effects of fire on fauna.

The current project aims to extend this by compiling a matrix of fauna species in relation to AANP habitat types (forest, woodland, shrublands, grassland, wetland, caves, etc) and predicted behaviour (e.g- home range, mobility, etc), and documenting `expert' recommendations as to how best critical habitat can be rapidly identified, assessed and protected in the fire planning process.

This project will draw on the existing expertise of AANP and other agency staff, and it is expected that recommendations for management of habitat in wildfire situations may also be drawn.

The work will be carried out by the Johnstone Centre

Peer scientist advice will be sought from Dr Ken Green (NPWS Fauna Conservation Officer- Snowy Mountains Region)

2. STUDY AREA

The project will be cared out to encompass the geographic range of the parks and reserves covered in the AALC MOU, ie: Namadgi National Park, Brindabella National Park, Bimberi Nature Reserve, Scabby Range Nature Reserve, Kosciuszko National Park, Snowy Rver National Park, Alpine National Park and the Avon Wilderness Park.

3. TASKS

In liaison with the Service contact officer:

(i) Review the current NPWS fauna species-habitat matrix (Woods, 1997);

(ii) Obtain fauna species lists and habitat information from relevant areas of the AANP agencies.

(iii) Using the published literature, available verified data and expert opinion, compile a master list of the fauna species of the AANP's;

(iv) Using the master list and the published literature, available verified data and expert opinion, extend the NSW/KNP species/habitat matrix to cover all AANP reserves. This task will require identifying, where possible, the likely/predictable effects of fire. The information is to be recorded on a suitable database (NSW information currently in MS-EXCEL);
(v) Summarise literature/expert opinion/best management practice in relation to protection of critical fauna habitat when planning for, or during, fire events;
(vi) Prepare a project report detailing the methods, assumptions, findings and management applications of the system, and a schedule for its update and review.

4. REPORTING & TIMESCALE

4.1 Progress Reports

Report monthly on progress of the brief in terms of:

a) budget expended;
b) tasks/project components completed; c) problems encountered; d) claims for payment submitted.

4.1 Interim Report

Submit 2 copies of Draft Report documenting the Tasks (i)-(vi) above to the Service contact officer by C.O.B Friday 8th Mac 1998.

4.2 Final Report

Submit 2 copies of the ::-.al report, one bound, one unbound (incorporating comments received on the draft report) to the Service contact officer by C.O.B. Friday 5th June 1998.

5. QUALITY PLAN

(i) The methodology data analysis and recommendations of the study will be subjected to rev '.v by a suitably qualified (scientific) peer at agreed stages of the study;

(ii) The Contractor will maintain liaison with the NPWS contact officer according to an agreed schedule. The purpose of this liaison is to discuss the progress of the project, any difficulties encountered or any new developments relating to the project:

(iii) The Contractor will give 7 days faxed notice to contact staff at AANP Field locations before carrying out field work, and will carry out any instructions given by Agency staff in relation to access or other field issues.

(iv) The Contractor will provide brief progress summaries to the contact officer on a regular basis, as agreed in relation to completion of project components;

(v) Notice of any inability by the Contractor to meet timetabled dates will be communicated to the NPWS, Jindabyne at least 7 working days in advance of that date.

7. ADMINISTRATION

Liaison will be kept with the nominated contact officer at NPWS Jindabyne District Fire Unit. The Service will provide what field assistance it can reasonably make available to the Contractor, if required. This assistance will be established in liaison between the Contractor and the contact officer.

8. PAYMENT

Fund payment will be made in three instalments, subject to completion of the tasks to the satisfaction of the contact officer(s).

Payment 1. 20% on signing of this Agreement
Payment 2. 40% on receipt of the satisfactory draft report and database Payment 2. 40% on acceptance of the final report and database

9. INTELLECTUAL PROPERTY

All data obtained and presented by this project will remain property of the Australian Alps Liaison Committee and its agencies. The Contractor may use the data to prepare publications, where this is agreed With the NPWS and AALC.