A BIOLOGICAL SURVEY OF THE SOUTHERN MOUNT LOFTY RANGES SOUTH AUSTRALIA

2000-2001

BIOLOGICAL SURVEY SOUTH AUSTRALIA

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Fire-blackened trees in Horsnell Gully Conservation Park following a fire in 1965.

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PREFACE

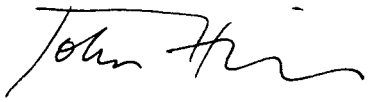
A Biological Survey of the Southern Mount Lofty Ranges, South Australia is a further product of the Biological Survey of South Australia.

The program of systematic biological surveys to cover the whole of South Australia arose out of a realisation that an effort was needed to increase our knowledge of the remaining vascular plants and vertebrate fauna of South Australia and to encourage its conservation.

Over the last 18 years, there has been a strong commitment to the Biological Survey by Government and an impressive dedication from hundreds of volunteer biologists.

By 2015, it is anticipated that the Biological Survey will achieve complete statewide coverage.

The Biological Survey of South Australia will be an achievement for which we can be very proud. We will have substantially improved our knowledge of the biodiversity of South Australia to enable biologists in the future to measure the direction of long-term ecological change. This will greatly enhance our ability to adequately manage nature conservation into the future.



JOHN HILL
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ABSTRACT

The Southern Mount Lofty Ranges (SMLR) Biological Survey study area boundary was defined as the Fleurieu and Mount Lofty Ranges IBRA (Interim Biogeographic Region of Australia) sub-regions. The survey area extends from the Barossa Valley in the north (Tanunda and Angaston) to the southern ocean in the south. The western boundary is formed by the steep western scarp of the Mount Lofty Ranges including Mount Lofty, the highest point (720m), which extends as an elevated plateau to the east, gradually falling towards the south- eastern boundary near Strathalbyn. The study region comprises 6 282 km^2, just 0.6% of the area of South Australia.

The primary aim of the SMLR Biological Survey was to determine the diversity and distribution of biological communities in the region. This was achieved by systematically surveying a range of survey quadrats that represented the biological variation over the study area.

Five surveys, conducted between 1977 and 2000 and comprising 1,177 vegetation quadrats in the survey region, contributed to the floristic analysis. Due to past vegetation clearance patterns, most of the survey quadrats were concentrated in the western two/thirds of the survey region. Survey quadrats were located on both crown and privately owned land. At least one survey quadrat was located in each of the *National Parks and Wildlife Act* reserves in the study region.

Three surveys, conducted between 1995 and 2000 and comprising 157 quadrats, contributed to the vertebrate analysis (these surveys also included vegetation quadrats). The major vertebrate survey fieldwork occurred in three separate periods, from autumn to early summer 2000. The vertebrate survey results were combined with previous records for the region to produce consolidated total species lists for each vertebrate category. Invertebrates were surveyed from 74 quadrats, using macro and micro pitfalls, and some hand collecting.

The total number of survey quadrat records contributed to the Biological Survey Database were: 40 091 vascular plants, 157 amphibians; 2 051 reptiles, 6 518 birds, 2 027 mammals and at least 2 100 invertebrates. These figures exclude opportune records.

Of the 40 091 survey records for plants, 35 920 (90%) were native. Between 992 and 1 227 taxa were recorded (incomplete identification of species prevents a more accurate determination), of which approximately 75% were native. The most commonly recorded plant species were *Xanthorrhoea semiplana* ssp. (Yacca), *Gonocarpus tetragynus* (Common Raspwort), *Lepidosperma semiteres* (Wire Rapier Bush), *Acacia pycnantha* (Golden Wattle), and *Platylobium obtusanglum* (Common Flat-pea). These species are typically "sclerophyllous", a feature that characterises the majority of remnant understorey in the region. The two most common eucalypts recorded were *Eucalyptus fasciculosa* (Pink Gum) and *E. obliqua* (Messmate Stringybark), both being recorded from just over 40% of quadrats. A distant third most common eucalypt was *E. cosmophylla* (Cup Gum) recorded from 22% of quadrats. These three eucalypts are all associated with less fertile soils.

Generally, highest native species diversity was associated with *E. fasciculosa* (Pink Gum), *E. obliqua* (Messmate Stringybark) and/or *E. goniocalyx* (Long-leaved Box) sclerophyll forest and woodlands, these communities averaging from 30 to 40 native species per quadrat. Low native species diversity was most commonly associated with *E. camaldulensis* (River Red Gum), *E. viminalis* ssp. (Manna Gum) and *E. leucoxylon* (SA Blue Gum) savannah woodlands. These communities also contained a very high proportion of weed components, averaging at least 12 weed species per quadrat. The savannah woodlands are generally located on more fertile soils with a grassy understorey, making them susceptible to direct clearance, grazing and weed invasion. Above-average numbers of weeds (namely, six to ten species per quadrat) occurred in drier woodland communities including *E. odorata* (Peppermint Box), *E. microcarpa* (Grey Box), *E. porosa* (Mallee Box) and *Allocasuarina verticillata* (Sheoak) communities.

Four weeds of National Significance were recorded from survey quadrats, namely Blackberry (128 records), Boneseed (97 records), Bridal Creeper (78 records) and Gorse (38 records). The most commonly recorded perennial weed was Rough Cat's-ear followed by African Daisy.

Of the confirmed 753 native taxa recorded from survey quadrats, 236 are rated at least Rare for the Southern Lofty herbarium region. Of these, 105 have a State rating and nine have a National rating. Five species were rated as Nationally Vulnerable: *Olearia pannosa* ssp. *pannosa*, *Glycine latrobeana*, *Prasophyllym pallidum*, *Correa calycina* and *Spyridium coactilifolium,* the latter being the most commonly recorded with 19 records. Of the 13 native taxa

endemic to the Southern Lofty herbarium region, six were recorded from survey quadrats. Of these, *Olearia grandiflora* and *Pultenaea involucrata* are locally common.

Two plant communities surveyed in the study region have been nominated as Nationally Threatened Ecological Communities. These are the swamps of the Fleurieu Peninsula and Peppermint Box (*Eucalyptus odorata*) grassy woodland. The swamps were specifically targeted by two of the surveys included in this Biological Survey report and hence have been comprehensively surveyed. The swamp communities also contain the highest numbers of conservation rated species. Peppermint Box woodlands are very rare in the region and this association was recorded at only one survey quadrat. State threatened plant communities recorded during the survey include *Eucalyptus goniocalyx* (Long-leaved Box) dominated Open Forest, *E. viminalis* ssp. (Manna Gum) Woodland, *E. microcarpa* (Grey Box) grassy Low Woodland, *E. ovata* (Swamp Gum) Low Open Forest and Low Woodland and *E. dalrympleana* ssp. *dalrympleana* (Candlebark) Open Forest.

PATN exploratory data analysis program was used to classify the 585 plant species records from quadrats into 41 groups based on the similarity of their floristic composition. These 41 groups formed 10 main alliances based on similar overstorey species. The vegetation of the South Mount Lofty Ranges, of which the Biological Survey study region forms part, was mapped in 2000. One hundred and fifty two vegetation groups were described for the mapping region, using a combination of survey site data, interpretation of aerial photography, ground-truthing and literature survey. The 152 groups have been summarised into 51 groups for the purpose of the map display according to common dominant overstorey species.

Of the 31 species of native mammals known to reside in the Southern Mount Lofty Ranges (SMLR) at the commencement of European settlement in 1836, only 22 can now be confirmed as currently resident within the region These consist of one monetreme (the Echidna), nine marsupial, three rodent and nine bat taxa. The status of the Platypus (*Ornithorhynchus anatinus*) is uncertain with only a few unverified records in the last 10 years. Of the eight extinct species, seven are marsupials and one is eutherian (placental). The Koala (*Phascolarctos cinereus*) has been introduced to the region and become naturalised. During the survey, a total of 2 027 mammal records of 18 species were made (excluding bats and domestic stock) over 157 survey quadrats.

Eight of the nine resident native bat species, nine of the 14[1] non-bat native resident mammals, and the introduced Koala were recorded at survey quadrats. The eight resident bat species recorded were: Gould's Wattled Bat, Chocolate Wattled Bat, Lesser Long-eared Bat, Large Forest Bat, Southern Forest Bat, Little Forest Bat, Southern Freetail Bat and White-striped Freetail Bat. The other native mammals recorded were: the Bush Rat, Western Grey Kangaroo, Common Ringtail Possum, Yellow-footed Antechinus, Short-beaked Echidna, Swamp Rat, Common Brushtail Possum, Southern Brown Bandicoot, and Western Pygmy Possum. One other, the Euro (*Macropus robustus*) was recorded opportunistically on several occasions during the survey. Of the three mammal species not recorded, the Common Dunnart (*Sminthopsis murina*) and Fat-tailed Dunnart (*Sminthopsis crassicaudata*) are both known to be only peripheral to the region, where no surveying was carried out. The Water Rat (*Hydromys chrysogaster*) relies upon well-vegetated permanent watercourses, a habitat type that is rare in the region and was not surveyed during the survey.

Eight of the nine species of introduced mammals with established feral populations in the region were recorded both at survey quadrats and opportunistically (House Mouse, Fox, Black Rat, Rabbit, Brown Hare, Fallow Deer, Feral Goat and Cat). The remaining species, the Brown Rat (*Rattus norvegicus*) was recorded opportunistically only once during the survey, largely due to its preference for an urban environment on the Adelaide Plains, resulting in a restricted peripheral distribution within the ranges.

The most frequently recorded species was the Bush Rat accounting for about 30% of all mammal records at survey quadrats. The Short-beaked Echidna and Western Grey Kangaroo, however, were recorded at most survey quadrats. The House Mouse was recorded at 70 survey quadrats.

Three of the current resident mammal species have a threatened status at National or State level,the Southern Brown Bandicoot – Nationally Endangered and State Vulnerable, the Platypus (current existence in SMLR is unconfirmed) – State Endangered and the Koala (introduced to the SMLR) – State Rare

Two hundred and ninety three bird species have been recorded for the study region, including 36 oceanic species and 11 introduced species. This represents 63% of the total bird species recorded within South Australia. One hundred and thirty nine species are considered resident.

One hundred and fifty seven bird species were recorded during the Biological Survey. From the 157 survey quadrats alone, a total of 6518 records of 127 bird species from 49 families and sub-families were recorded. Opportunistic

[1] This figure of 14 current native mammals includes the Platypus whose status is uncertain.

records totalled 1164 records of 136 species representing 53 families or sub-families. These included 30 species not recorded at survey quadrats. The majority of these additional species were water birds, rarely seen at survey quadrats.

Four sub-species are endemic to the SMLR: the Mount Lofty Ranges Southern Emu-wren (*Stipiturus malachurus intermedius*), Spotted Quail-thrush (*Cinclosoma punctatum anachoreta),* White-throated Treecreeper (*Cormobates leucophaeus grisescens*) and Chestnut-rumped Heathwren (*Calamanthus pyrrhopygius parkeri*). However, the SMLR is an "island" of woodland and forest, and is the western extreme of the range of many south-eastern Bassian species, some of which exist as isolated populations in the study region.

Fifty of the bird species recorded for the SMLR have legislated conservation ratings. Twenty of these species were recorded during the survey. In addition, the Mt Lofty Ranges Task Force has identified 37 species in the Mt Lofty Ranges which do not have a legislated conservation rating but which are known to be declining and considered at risk. These include the Brown Treecreeper (recorded at two survey quadrats), the Diamond Firetail and Crested Shrike-tit (recorded from one survey quadrat each), and the Jacky Winter and Restless Flycatcher, which were not recorded at all during the survey.

Forty-two native and two introduced reptile species are currently accepted as being resident in the study region. Of these, 37 native reptiles and both the introduced species were recorded during the survey. Twenty-seven species were recorded at quadrats with the remainder recorded opportunistically. Reptiles were recorded at 150 of the 157 survey quadrats.

Four small skink species were the most frequently and commonly recorded species, comprising 78% of all records. These were the Garden Skink (*Lampropholis guichenoti*), the Three-toed Earless Skink (*Hemiergis decresiensis*), Bougainville's Skink (*Lerista bougainvillii*) and the Eastern Three-lined Skink (*Bassiana duperreyi*). Four reptile species were each recorded at only one quadrat: the Pygmy Copperhead (*Austrelaps labialis*), the Eastern Stone Gecko (*Diplodactylus vittatus*), the Eastern Water Skink (*Eulamprus quoyii*) and the Little Whip Snake (*Suta flagellum*).

Six species recorded from the region have conservation ratings under State or Federal legislation. The highest rated species, the Flinders Worm Lizard, is Nationally Vulnerable and endemic to South Australia; however, it was not recorded during the survey. Cunningham's Skink and the Carpet Python are both considered Vulnerable for South Australia, and both were recorded opportunistically during the survey. The three species rated Rare for South Australia (Olive Snake-lizard, Heath Goanna and Yellow-bellied Water Skink) were also recorded during the survey. South Australian endemic species recorded during the survey were Pygmy Copperhead, Adelaide Snake Lizard and Southern Rock Dtella. Although the Pygmy Copperhead does not have a conservation rating, its distribution is restricted and it is infrequently encountered. The Black Tiger Snake, another South Australian endemic was not recorded, and is rare in the SMLR.

Two species not previously included in the herpetofauna of the SMLR were recorded opportunistically during the survey: the Delicate Skink (*Lampropholis delicata*) and Murray (or Macquarie) River Tortoise (*Emydura macquarii*). The Murray River Tortoise and another species (the Water Dragon) are assessed as being the result of pet escapes or releases, which have established wild populations within the region.

All six of the resident native frog species known to occur in the SMLR were recorded during the survey: the Painted Frog, Marbled Frog, Brown Froglet, Bull Frog, Brown Toadlet and Brown Tree Frog. One hundred and fifty seven frog records were obtained from the survey quadrats, with records being obtained from 66 of the 157 survey quadrats. The Brown Froglet was the most commonly recorded species, followed by the Bull Frog.

Excluding ants, more than 197 species of invertebrates from 86 families were recorded from 74 survey quadrats. The most commonly recorded Orders were Collembola and Coleoptera (Beetles). Thirty-one ant genera were recorded from 95 survey quadrats. Only the *Camponotus* genus was identified to species level, and 13 species were recorded.

The Monitoring River Health Initiative (MRHI), which is a coordinated national river bio-assessment and prediction scheme included 51 sites from the Mount Lofty Ranges. Further work from 1997-1999 involved sampling another 450 test sites as part of the AUSRIVAS (AUStralian RIVer Assessment System) program. This included a further 211 sites from waterways in the Mt Lofty Ranges study area from the Gawler Creek catchment in the north to the Finniss River in the south. An overview of the aquatic macroinvertebrates found at these sites is presented which identifies biodiversity 'hotspots', describes the rare species and gives a summary of the bio-assessment ratings for each site. Some comments are also included about the threats and opportunities to address river health issues in the study area.

Finally a series of conservation management recommendations are provided covering: recommendations for further research/survey work and a brief discussion of the biodiversity conservation challenges ahead for the SMLR.

A mass flowering of Myrtle Wattle in Cleland Conservation Park two years after a fire. (Photo: A. Robinson).

A male Tawny Dragon showing his breeding colours. (Photo: P. Canty).

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ACKNOWLEDGEMENTS

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Funding for the survey was provided by the South Australian Government as part of its Natural Heritage Trust matching funding commitment to the Biological Survey of South Australia. The Northern Adelaide and Barossa Catchment Water Management Board also provided some funding support for sites sampled in the North Para catchment in 1999.

2. Survey Field Staff and Volunteers
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8. Hair-tube Analysis
Nerissa Haby

9. Freshwater Macro-invertebrates
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INTRODUCTION

D. Armstrong[1] and S. Croft[1]

BACKGROUND AND AIMS

In South Australia a program of systematic fauna and flora surveys across the state has been developed and implemented since 1971. This program known as the Biological Survey of South Australia, was established under the auspices of the Biological Survey Coordinating Committee (Foulkes and Gillen 2000). This interdepartmental committee comprises representatives from the South Australian Museum, Planning SA, Environment and Heritage, Plant Biodiversity Centre, SA Research and Development Institute, and Primary Industries and Resources SA. The aim of these surveys is to document the range of biological variation across the state to improve long-term natural resource management.

To date, vegetation only surveys in the Agricultural Zone, have been completed for: the Mt Lofty Ranges (1985), the Mid North (1992), Burra Hills (1994), Yorke Peninsula (1994), Southern Eyre Peninsula (1995), Upper Midnorth (1996), Northern Adelaide Plains (1996), North Eastern Eyre Peninsula (1998) and North Western Eyre Peninsula (1999). Vegetation and vertebrate surveys in the Agricultural Zone have been completed for the South East, Murray Mallee (1990), Western Murray Flats (1992), Kangaroo Island (1989 – 1990), Offshore Islands (1971-1982) and South East Coast (1982-1983). In addition, the same survey methodology has been used for specific surveys concentrating on specialists habitats such as grassy ecosystems and numerous smaller-scale surveys of parks and reserves conducted by various government and non-government organisations.

In the Pastoral Zone, Biological Surveys have been carried out in twelve major regions: Cooper Creek (1983, 1991), Nullarbor (1984), Gawler Ranges (1985), Yellabinna (1987), Stony Deserts (1994-1996), Strzelecki Dunefields (1988 – 1992), Diamantina River area (1994), South Olary Plains (1996), Anangu-Pitjantjatjara Lands of north-western S.A. (1992 – 1996), North Olary Plains (1995), Flinders Ranges (1998- 1999) and Sandy Deserts (1997 – present). Generally the boundaries of these surveys have been based on the environmental regions of South Australia as delineated by Laut *et al*. (1977) and more recently by bioregions (Thackway and Cresswell 1995).

BIOLOGICAL SURVEY OF SA OBJECTIVES

The principal aim of the Biological Survey of South Australia is to systematically sample a variety of sites chosen to represent the range of biological variation over each study area and across the state in order to enhance integrated land management and conservation. A secondary aim is to support, with scientific data, Government strategies for biodiversity conservation and ecologically sustainable development. The specific objectives of the Southern Mount Lofty Biological Survey were:

1. To observe, collect and identify species of plants and vertebrate fauna present in the area by sampling an array of fixed quadrats representing the geographical and biological diversity of the region. In particular the Survey conducted during 2000 was the first systematic survey of vertebrates over the entire study region. The floristic component of this survey supplemented several previous flora surveys within the region.
2. To establish a comprehensive data base of the flora and associated vertebrate communities of the SMLR that is amenable to ecological analyses.
3. To document and classify the patterns of species and communities across the region and their relationship with physical parameters.
4. To evaluate the conservation status of species and communities within the SMLR, as a basis for conservation strategies.
5. To provide the South Australian Plant Biodiversity Centre and South Australian Museum with collections representative of the diversity of plants and vertebrates in the region.
6. To establish a long-term monitoring system and associated database to enable subsequent measurement of environmental change.

BIOLOGICAL SURVEYS INCLUDED IN THIS REPORT

Data from five Biological Surveys has been combined for analysis in this report. Field data for all surveys has been extracted from the Department for Environment and Heritage's Survey database. Full details of these surveys appear in the Methods chapter but in brief the surveys are:

- Mt Lofty Ranges survey, 1985, focussing on high rainfall forests and woodlands (vegetation only)
- Mt Lofty – Private, 1987 - focussing on swamps and other remnants of the southern Fleurieu, and

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also Long-leaved Box communities in the northern Adelaide Hills (vegetation only)

- Mt Lofty – Emu Wren, 1993 -1996 – surveyed only swamps of the Fleurieu Peninsula (vegetation and vertebrates)
- Southern Fleurieu (Scientific Expedition Group), 1997 - 1999 – southern Fleurieu remnants (vegetation and vertebrates), and
- Southern Mt Lofty, 2000 – a range of communities, particularly concentrating on "gaps" in prior surveys (vegetation and vertebrates).

Notable exceptions to surveys not included in the analysis are grassy ecosystems and coastal vegetation (both are the subject of separate reports: namely Robertson 1998 and Oppermann 1999).

BIODIVERSITY PLANS AND INTERIM NATURAL RESOURCE MANAGEMENT PLANS

Concurrently with this Biological Survey report the above documents are being independently prepared. These documents aim to summarise all natural resource information and values with the aim of providing biodiversity management strategies. Species and also regions of high conservation value are highlighted. Consequently this report and the above reports are complementary and do not duplicate material to any degree.

THE PHYSICAL ENVIRONMENT

STUDY AREA BOUNDARY AND DESCRIPTION

IBRA Sub-regions

The area described as the Southern Mount Lofty Ranges (SMLR) for the purpose of this survey may generally be described as all the hills and ranges of the Mount Lofty Ranges south of the Gawler River. The precise boundary is delineated by two IBRA[1] sub-regions as follows:

- All of the Fleurieu IBRA sub-region of the Kanmantoo Bioregion and
- All of the Mount Lofty Ranges IBRA sub-region of the Flinders Lofty Block **less** the area which includes urban land on the Adelaide plain.

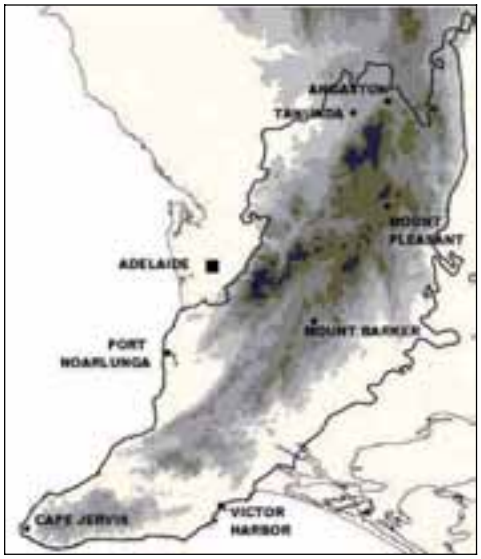

Figure 1.
SMLR study area boundary.

Fleurieu IBRA sub-region

"This sub-region is predominantly an undulating to low hilly upland with steeper marginal ranges and hills. A laterized surface occurs on the Fleurieu Peninsula and becomes increasingly dissected northward to where only a few remnants survive as rounded crests and summits with mottled yellow duplex soils. The lowest lying areas are within the Inman Valley where soft glacial and fluvio-glacial deposits have been lowered more quickly than the surrounding sedimentary rocks." (Blason and Carruthers in prep.)

The southern Fleurieu Peninsula area is a plateau with an average altitude of 350m above sea level, dissected by steeply descending creeks with an average rainfall of 850mm per annum.

Very little native vegetation remains in the northern half of this sub-region.

Mount Lofty Ranges IBRA sub-region

The Barossa Valley is the lowest area in this sub-region and represents a structural basin. The rest of the sub-region consists of hilly uplands on sandstone and shale with northerly trending strike ridges and dissected lateritic tableland remnants (Blason and Carruthers in prep.)

The vegetation of the Mt Lofty Ranges IBRA sub-region is summarised in Blason and Carruthers (in prep.) as follows. Woodlands and forests, "commonly dominated by *Eucalyptus obliqua* (Messmate Stringybark) and *E. baxteri* (Brown Stringybark) are found in higher rainfall areas on deep, lateritic soils. Shallower or sandy soils support *E. fasciculosa* (Pink Gum), *E. cosmophylla* (Cup Gum) and in the northern part of the region *E. goniocalyx* (Long-leaved Box). *Eucalyptus leucoxylon* (SA Blue Gum) dominates the woodlands on podzolised soils in the lower rainfall areas, *E. viminalis* ssp. *cygnetensis* (Rough-barked Manna Gum) dominates the wetter and cooler woodlands and *E. odorata* (Peppermint Box) characterises drier sites. Eucalypts give way to *Allocasuarina verticillata* (Drooping Sheoak) in the most arid woodlands and in coastal situations on shallow rocky soils."

Environmental Associations

The above IBRA sub-regions have been delineated from Laut *et al*. (1977) who mapped South Australia in terms of Environmental Associations. These are smaller mapped land units than IBRA sub-regions, and represent a particular combination of landforms.

The SMLR survey area consists of all 20 Environmental Associations within the Peninsula Uplands Environmental Region (one of three regions that constitute the Mount Lofty Block Province). In addition, Rosedale, the most southerly of the Environmental Associations of the Mid-north Wheatlands Environmental Region is also included within the SMLR survey area, as it is south of the Gawler River and contains significant areas of remnant native vegetation, including Sandy Creek Conservation Park. Appendix I contains descriptions of the environmental associations occurring in the Fleurieu

[1] Interim Biogeographic Regions of Australia (IBRA) sub-regions are distinctive landscapes with characteristic patterns of landforms, soils and vegetation (Thackway and Cresswell 1995). Australia has been divided into 354 IBRA sub-regions.

and Mt Lofty Ranges sub-regions. Their locations are shown in Figure 2.

Figure 2.
Location of Environmental Associations occurring within SMLR study area boundary (refer Appendix I for description of codes).

Geology, Geomorphology and Soils
Comprehensive accounts of the region's geology, geomorphology and soils are in the *Natural History of the Adelaide Region* (Twidale *et al*. 1976) and will not be repeated in detail in this report. However, the general topography of the ranges is concisely summarised by the following brief extract from Adamson and Osborn (1924):

"Inland to the east of the city, the Mount Lofty Range rises with rather steep slopes to a general height of about 1,500 feet (460m), Mount Lofty, 2334 feet (720m) being the highest point. While it is possible to speak of a western face to the Mount Lofty Range near Adelaide, on the eastern side the summit generally extends as an elevated plateau which has a gradual fall towards the Murray River." "The crest of the main Mount Lofty Range lies near to the western face. It consists of a complex of ridges separated by valleys, some of which have steep and rocky sides. These valleys form an intersecting series and run in varied directions. The ridges between may be broad and flat-topped or rather narrow, but for the most part the general outlines are smooth and somewhat rounded, not rugged."

Corbett and Whitelock (1977), Long (1999) and Blason and Carruthers (in prep.) also have summaries of the region's geology and topography. Long's (1999) report includes a map showing catchment boundaries. The geology of the Fleurieu Peninsula region, in particular, is described in the Draft Management Plan for the Parks of the Fleurieu Peninsula Region (National Parks and Wildlife Service 1985).

BIOGEOGRAPHIC VALUES
Even prior to European settlement the SMLR was a virtual island of woodland and forest, isolated by the waters of the Southern Ocean and Backstairs Passage to the south and Gulf St Vincent to the west, and the drier more open woodland and mallee habitats on the plains to the north and east. It is in effect an outlier of the Bassian biogeographic region that encompasses the sclerophyll woodland and forest areas with an average annual rainfall in excess of 500mm, of the south-east and south-west of the Australian continent. Within the SMLR, many plant and vertebrate species exist as populations isolated from the greater areas of their natural distribution in the southeast of the continent. Several species of plants are endemic to the region. The extensive clearing of forest and woodland in the SMLR, for pastoral and agricultural purposes, since European settlement has increased this isolation. It has also fragmented what was once one "island" into many smaller islands.

The SMLR survey region covers an area of 6,282 square kilometres. This represents 0.6% of the total area of South Australia and a mere 0.08% of Australia. The small size of the region is of particular significance in relation to the relatively large number of species of both fauna and flora recorded within it, many of which exist as isolated populations.

Human Population
Using figures from the Australian Bureau of Statistics (ABS) 1996 population census, there are an estimated 340,000 inhabitants in the study area. Many are concentrated in the Southern Vales and southern suburbs of Adelaide, in the low rolling hills to the west of the Willunga scarp and south of Marino/Hallet Cove to Sellicks Beach, where 177,000 (52%) of the region's population lives. The high population densities coincide with very little remnant vegetation.

Local Government Areas and Soil Board Districts within the Southern Mt Lofty Ranges are described in Long (1999) and Blason and Carruthers (in prep.).

Natural Resource Values
The SMLR is the "back yard" to metropolitan Adelaide, which has a population of 1,046,000 (1996 Census, ABS). As such, it acts as the main natural water supply catchment for the city, contains some of the most intensive agricultural and horticultural resources found within the State and is the primary source of land-based outdoor recreational opportunities for the residents of Adelaide. The Integrated Natural Resource Management Plan for the Mount Lofty Ranges and Greater Adelaide Region (MLRIINRMG, in prep.) elaborates upon these values.

Land Clearance and Current Perceptions of the SMLR

Probably due to the study region's proximity to the city, the fauna, flora and unique biodiversity values of the region are generally taken for granted by residents of both the city and ranges. Much of what was believed to be common knowledge of many of the vertebrate wildlife species of the region prior to this survey was not substantiated when data from the Department for Environment and Heritage (DEH) and South Australian Museum (SAM) data bases were examined.

The view of the relatively well vegetated hills face from the Adelaide Plains which is observed as the backdrop to the city itself, gives the false impression that the biodiversity values of the SMLR are far more intact than is actually the case. The hills face zone comprises a number of almost contiguous parks including: Ansteys Hill Recreation Park, Black Hill, Morialta, Horsnell Gully and Cleland Conservation Parks, and Belair National Park (Figure 3). The steepness of the hills face zone rendered it unsuitable for cropping and in most cases even for grazing. Whilst having been extensively quarried, the steep escarpment has been relatively undisturbed when compared to the remainder of the SMLR.

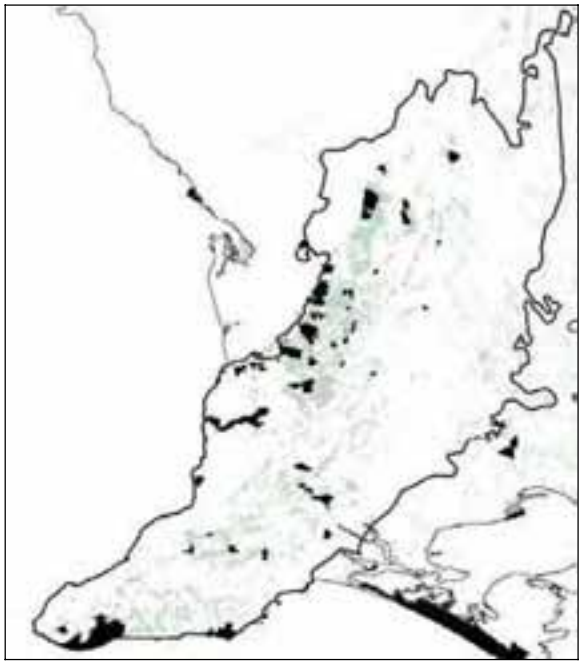

Figure 3.
Location of National Parks and Wildlife Act Reserves (black shading) and remnant vegetation (grey shading) within study area - showing concentration of reserves along western scarp.

This forested backdrop to the city, however, is relatively narrow. Beginning at the eastern edge of the suburbs at the base of the hills, it varies in width from about 5km to nearly 10km in the area immediately south of the Torrens Gorge. To the north and south of this screen are lower rolling hills that were cleared for agriculture many years ago and in some cases more recently for housing.

Much of the remainder of the hills, which are not under native vegetation, are also low rolling hills and wide valleys, which have mostly been used for grazing. Although grazing has not generally necessitated broadacre clearance of woodland and forest, it has reduced the majority of understorey plants and a portion of the overstorey trees. Roadside trees and scattered remnant mature trees in paddocks help to give a parkland impression, generally aesthetically pleasing, but provide little suitable habitat for native wildlife. Travelling through these areas by road may create the impression that large areas are better vegetated than they actually are. Examination of aerial photographs quickly exposes this two-dimensional view as false.

Remnant Vegetation

Vegetation clearance and forest utilisation began with the first European settlers (Williams 1974). The once large areas of grasslands and grassy woodlands covering the foothills and the eastern hills were generally cleared first. Most of the remaining less favourable sites were cleared after World War II.

Of the approximately 13% of the study region which remains uncleared, the majority is on nutritionally poor upland soils, sand or in areas of steep terrain, all of which were unsuitable for agriculture. The dominant eucalypt woodland or forest type reflects this clearly. Most of the remnant vegetation is dominated by Stringybarks (*Eucalyptus obliqua* and *E. baxteri*), Pink Gum (*E. fasciculosa*) and Long-leaved Box (*E. goniocalyx*), which are usually found on the poorer quality soils.

The smooth-barked "gums", River Red Gum (*E. camaldulensis*), SA Blue Gum (*E. leucoxylon*), Manna Gum (*E. viminalis* ssp. *viminalis*) and Candlebark Gum (*E. dalrympleana*) occur on more fertile loamy soils, and are generally confined to scattered trees and isolated small remnants. The understorey has often been removed by grazing and converted to grassland dominated by introduced species.

This has also been the fate of the majority of what is regarded as the intact native areas of "gum". These, usually SA Blue Gum dominated areas, have generally had the larger specimens logged out, have had the understorey grazed at some time and are mostly on steep slopes (e.g. Morialta, Blackhill and Montacute Conservation Parks). The smooth-barked eucalypt remnants tend to be highly weed infested (e.g. South Para Reservoir) or have major recreational pressures and facilities (e.g. Belair National Park and Mark Oliphant Conservation Park).

In general throughout the study region, the remnant areas contain relatively small trees, below 10 –15m

tall. Areas where Stringybarks, Pink Gums and Long-leaved Box exceed this height do exist, but at that height they are usually on better than average soils for the species

The pattern of valley clearance leaving only ridge top remnants is clearly evident when viewing aerial photography or remnant vegetation mapping for the region (Fig. 4). Extensive logging, firewood cutting and increased frequency of large-scale fires have further compromised the ecological value of these remnants. These activities have effectively removed much of the dead fallen and standing timber, or forest "furniture", which is an important habitat component for many vertebrate species.

Figure 4.
Much of the remnant vegetation of the SMLR has been cleared or partially cleared, leaving a matrix of remnant vegetation, horticulture and residential buildings. The steeper slopes and ridge tops generally retain natural vegetation. (Photo: J. Turpin)

Today, there is virtually no vegetation in the SMLR which not been altered since European settlement (authors' personal observations). Much of the remaining woodland and forest is regrowth. In 1831, on making the first European ascent of Mount Lofty, Captain Collett Barker commented on the size of the trees on the summit, including one with a girth of approximately five metres (Robinson 1978). When crossing the SMLR in 1837, Robert Cock described two Stringybark trees near the summit of Mount Lofty with a circumference of 36 and 40 and a half feet (Hyde 1999). That trees approaching the size of these exist anywhere within the SMLR today is doubtful. Their absence is indicative of the changes within the region since European occupation.

Much of the eastern side of the region which was originally SA Blue Gum (*E. leucoxylon*) and River Red Gum (*E. camaldulensis*) Open Woodlands with grassy understoreys, or Grassland and Irongrass (*Lomandra* spp.) communities. This area, however, has been so heavily modified by agriculture and grazing that very few areas of intact habitat exist that are sufficiently large to survey using the Biological Survey of SA methods. Early Europeans travelling through on journeys of exploration commented upon the suitability of this area for pasture (Hyde 1999). Figure 5 illustrates the concentration of survey sites in the western half of the study region. In the eastern areas of the region, therefore, SA Museum records were relied upon as the principal source of vertebrate information.

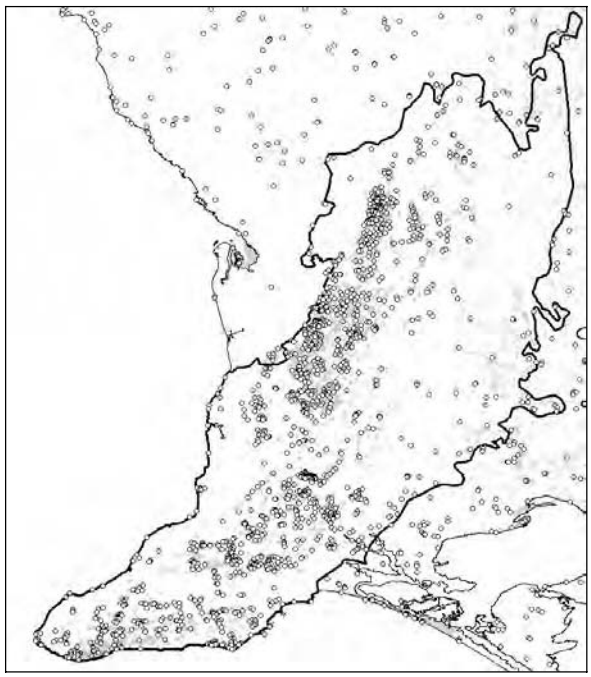

Figure 5.
Location of vegetation survey sites within study area, showing concentration of sites in western half of SMLR.

Fragmentation of Vegetation
As discussed above, the remaining vegetation is highly fragmented. The following information is extracted from Blason and Carruthers (in prep.). Of the remaining vegetation in the Mount Lofty Ranges Region (as defined in Blason and Carruthers in prep.):

- 10% occurs in 2281 blocks between 1 to 10 ha
- 25% occurs in 905 blocks between 10 to 100 ha
- 20% occurs in 93 blocks between 100 to 500 ha
- 8% occurs in 11 blocks between 500 to 1000 ha
- 37% occurs in 12 blocks greater than 1000 ha

These statistics are elaborated upon in Table 1.

Table 1.
Size distribution of native vegetation blocks in Mt Lofty Ranges INRM (source: Carruthers and Blason in prep.).

Block size range (ha)	Number of Blocks	Blocks as % of Total Numbers	Estimated Area (ha)	Area as % of Total Vegetation
1 – 10	2,281	69	9,360	10
10 – 100	905	27	22,780	25
100 – 500	93	3	18,660	20
500 – 1000	11	<1	7,340	8
>1000	12	<1	33,220	37
TOTAL	3,264	100	91,360	100

Figure 6.
Most remnant vegetation patches in the SMLR study region are less than 10 ha, and often with a degraded understorey. Photo shows remnant vegetation patches near Victor Harbor, a highly cleared district. (Photo: A. Robinson)

SURVEY LOGISTICAL DIFFICULTIES
Although relatively small in area and close to facilities, logistically the SMLR is a difficult region in South Australia to undertake a Biological Survey. In addition to the fragmented nature of the remnant vegetation areas, there is an intricate road network, multiple landowners, both private and Government, a massive amount of fences and locked gates, and complex topography forming a variety of natural access barriers.

Further division of the SMLR into three sub-regions
The study area was divided into three sub-regions based on broad variations in climate and habitat. This was to improve logistical management but also to facilitate data interpretation. The sub-regions are:
Southern Barossa/South Para: Gawler River, south to the Torrens River.
Adelaide Hills: Torrens River south to latitude 35^0 $11^{'}$ (this equates to the southern-most limit of the Onkaparinga River).
Fleurieu Peninsula: Latitude 35^0 $11^{'}$ (ie southerly point of Onkaparinga River) to the south coast of the Fleurieu Peninsula.

These subdivisions are shown in Figure 7 and the dominant structural formations within these areas are shown in Table 2.

Table 2.
Dominant structural formations within the three sub-regions within the SMLR study area.

Structural Formation	Sub-region		
	Southern Barossa	Adelaide Hills	Fleurieu
Stringybark Forest/Woodland		✔	✔
Stringybark and Pink Gum Low Woodland – on poor soils, usually ridges or hill tops		✔	✔
Long-leaved Box, Stringybark species and Pink Gum Low Woodland – on poor soils on ridge and hill tops, north of Torrens Gorge	✔	✔	
SA Blue Gum Woodland, occasionally with some River Red Gums	✔	✔	✔
Larger water courses with narrow corridors of Manna Gum		✔	✔
Swamps (mainly in Fleurieu district) including Swamp Gum		✔	✔
Grey Box – hills face slopes with open grassland		✔	
Pink Gum/Native Pine woodlands on laterite or sand	✔		
Coastal mallee (Newland Head)			✔

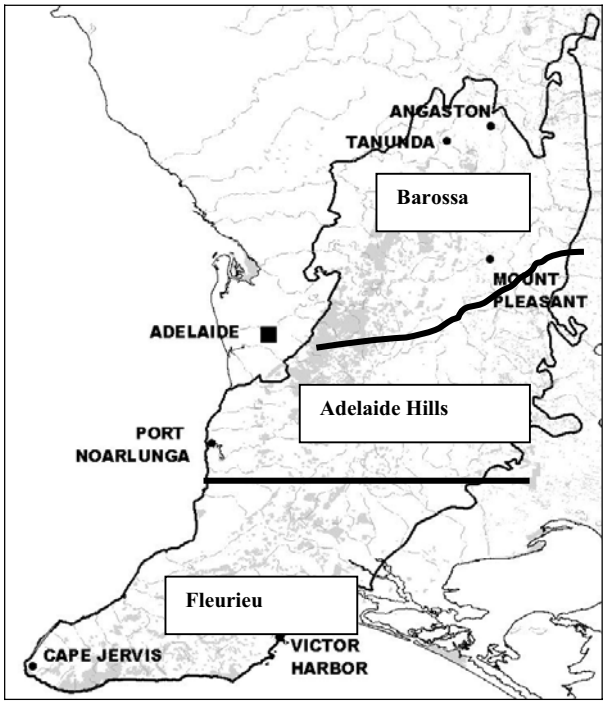

Figure 7.
The three sub-divisions within SMLR study region.

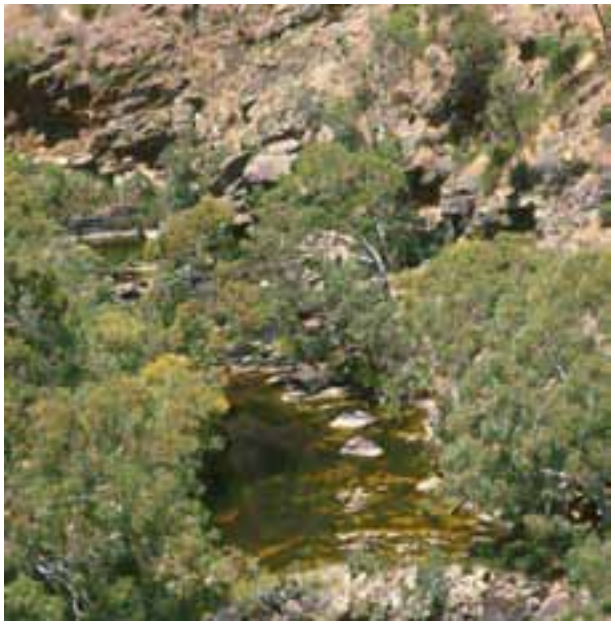

Figure 8.
The Onkaparinga River forms the southerly boundary between the Adelaide Hills and Fleurieu sub-regions. The photo shows River Red Gum lining the banks. (Photo: A. Robinson).

CLIMATE

The major climate throughout the Mount Lofty Ranges consists of a temperate pattern with a hot, dry summer and moderately wet winter on the slopes of Mt Lofty and associated ranges (Schwerdtfeger 1976).

Mount Lofty (720m) and associated ranges create significant orographic rain for about 8 months of the year, resulting in some of the highest winter rainfall averages in the State. Substantial cloud cover, enhanced by orographic uplift, may extend non-continuously well into spring over the ranges. This causes overall solar radiation totals to be much less than areas on the Adelaide Plains. The drop in temperature with altitude, supplemented by the extended cloud cover lowers average temperatures by up to several degrees Celsius less than temperatures on the plain.

There is a considerable variation in rainfall, and to a lesser extent temperatures within the SMLR study area, mainly due to topography and altitude. The mean height of the main ridges of the Mt Lofty Ranges is approximately half that of the main peak (Schwerdtfeger 1976). In the Adelaide Hills sub-region (Fig. 7), annual precipitation rises steadily from 600mm to over 1000mm along ridges which run approximately east to west (Specht 1972). Records from 1972 – 74 indicated the mean annual rainfall in the vicinity of Mt Lofty Summit approached 1,600 mm, approximately four times the rate that falls on the Adelaide Plains near the coast at Port Adelaide (Schwerdtfeger 1976). Some parts of the ranges average 600 mm/month during winter, with occasional thunderstorms in summer adding sudden downpours of up to 100 mm/day.

Similarly, there are great variations in rainfall in the Fleurieu Peninsula sub-region. The rainfall, in general, increases with altitude ranging from about 400mm in the east near the mouth of the River Murray up to nearly 1000 mm on the south-western plateau.

Within the Barossa sub-region, there are similar variations in rainfall, with some of the driest northern areas experiencing 300mm annual rainfall and the wetter areas averaging about 900mm annual rainfall.

In contrast to the cool, wet winters within the SMLR region, summer is characterised by long periods of dry conditions, during which time the evaporation rate may approximate 200 mm/month (Schwerdtfeger 1976). Most summer rain is in the form of thunderstorms. During the drier spring and summer months tall trees on the highest ridges may frequently capture cloud droplets even when it is not actually raining.

Local topographic variations also cause variations in weather eg deep gullies and valleys experience greater shading and cooler temperatures. Aspect strongly influences evaporation (and hence soil moisture). The following quote from Specht (1972) illustrates the influence of aspect and rainfall within the ranges:

> "Three species of *Eucalyptus* are common on soils developed from phyllite ridges. Where annual precipitation is 60 – 70 cm, *E. odorata* (Peppermint Box) occupies the north-facing slopes while *E. leucoxylon* (Blue Gum) occurs with *E. odorata* on the south-facing slopes. Between 70 and 80 cm annual precipitation, *E. leucoxylon* is common on both sides of the ridges, but is found only on north-facing slopes when the annual rainfall lies between 80 and 100 cm; *E. viminalis* (Manna Gum) then occupies the south-facing slopes."

Table 3 illustrates the range in average annual rainfalls received within the study area:

Table 3.
Annual temperature and rainfall averages for selected locations within study region.

Location	Avg. Rain-fall (mm)
Mount Kitchener, Hundred Moorooroo, east of Tanunda, Angaston	600[1]
Altona, Hundred Barossa, near Lyndoch and Tanunda	600[1]
Pimpala Road, Hundred Barossa, Between Sandy Ck, Lyndoch and Williamstown	600[1]
Pewsey Vale and Wirra Wirra Peaks, Hundred Barossa	900[1]
Watts Gully Road, adjoining Warren CP	700[1]
Barossa, South Para and Warren Reservoirs	700[1]
Humbug Scrub, Hundred Para Wirra	700[1]
Mount Gawler	750[1]
Cromer, Hundred Para Wirra	350[1]
Deep Creek, Hundred Onkaparinga	950[1]
Basket Range, Hundred Onkaparinga	900[1]
Langhorne Creek, south-eastern Fleurieu Peninsula	390[2]
Mt Jagged, south-west Fleurieu Peninsula	963[2]
Stirling West	1165[3]
Morphett Vale	575[3]
Mount Pleasant	670[3]

[1] = Wells (1976)
[2]= National Parks and Wildlife Service
[3] = Adamson and Osborn (1924)

PREVIOUS BIOLOGICAL RESEARCH

VEGETATION

There have been numerous vegetation studies and surveys of the SMLR – most specialising in particular habitats or locations.

Lange (1976) provided a resume of major vegetation studies of the SMLR "from earliest investigations and conditions to the present day". Lange noted that the accumulated knowledge describing and classifying the region's vegetation was marked by a varied approach and lack of continuity. Major accounts of vegetation of the region are:

Adamson and Osborn's (1924) *The Ecology of the Eucalyptus forest of the Mount Lofty Ranges* (*Adelaide District*)*, South Australia*. Lange (1976) noted that "After half a century their pioneering paper still is used as a main source of information about Adelaide Hills vegetation…". Adamson and Osborn (1924) divided the vegetation into three formations:

1. Stringybark (sclerophyll) Formation, including *Eucalyptus obliqua* forests. These forests occurred at rainfalls greater than 750mm, mostly on ridges and hills and on shallow soils, formed from quartz.
2. Savannah Woodland Formation, including *Eucalyptus leucoxylon* and *Eucalyptus odorata.* Savannah woodland formation occurred at rainfalls of 400-900mm, mostly on soils derived from non-silicious rocks.
3. Red Gum Formation, including *Eucalyptus camaldulensis* and *Eucalyptus viminalis* ssp. *viminalis* in the valleys and lower slopes.

Swamps were recognised but not described by Adamson and Osborn (1924).

Wood's (1937) *The Vegetation of South Australia,* was the first attempt to describe the vegetation of all of South Australia and this account "greatly augmented" the paper of Adamson and Osborn (Lange 1976).

Crocker and Wood (1947) outlined historical influences in accounting for the occurrence, composition and characteristics of plant communities now present in South Australia.

Papers by Jessup (1946), Specht and Perry (1948) and Specht *et al*. (1961) included an emphasis on the relationships between soil and vegetation.

Specht's (1972) *Vegetation of South Australia* provided one of the most comprehensive accounts of Adelaide regional vegetation *(*Lange 1976).

Other specialised studies since 1976

Wells (1976) described and assessed 20 vegetation remnants of the north-central Mount Lofty Ranges, along with conservation recommendations.

Lamprey and Mitchell (1979) provided a detailed account of the vegetation of the Fleurieu Peninsula.

Mitchell *et al.* (1981) surveyed remnant vegetation and wetlands in the central and north-eastern Mt Lofty Ranges.

Green (1994) investigated the ecology of the central Mt Lofty Ranges.

Hyde (1999) described and mapped pre-European vegetation and described remnant vegetation of the Bremer Barker Catchment. Hyde, in turn outlines previous botanical studies for this Bremer Barker Catchment (in the south east of the SMLR), including: Boomsma (1948), Hyde 1993, 1995, 1996), Crawford (1997) and the Bremer Barker Catchment Group (1996).

Biological Surveys listed in the Department for Environment and Heritage's Survey Database

Included in this Biological Survey vegetation analysis for the SMLR are five separate surveys, of which the most extensive was conducted in 1985 and comprised over 600 quadrats. Details of all five surveys, which comprise this analysis, are outlined in the Methods chapter.

In addition to the above five surveys included in this report, a number of other surveys conducted within the SMLR region are listed in the Department for Environment and Heritage's Survey database (Table 4). These include surveys conducted on behalf of the former councils of Happy Valley, Stirling and Noarlunga. A series of surveys were conducted in Adelaide Hills parks in the late 1970's: Kyeema CP, Belair NP, Para Wirra CP, Morialta CP, Cleland CP and Horsnell Gully CP. These surveys sampled vegetation and vertebrate fauna over a range of plant communities. Only the flora data has been entered into the Survey database. Some of these survey sites have now been incorporated in Survey 117, "Southern Mt Lofty".

FAUNA

Prior to the Southern Mt Lofty Biological Survey, conducted in 2000, there had been no systematic survey of fauna for the SMLR. However, research on particular mammal species in the Mt Lofty Ranges has been quite extensive. Long (1999) provided the following list of researchers: Paull (1995), Alexander *et*

al. (1978a,b,c), Aslin *et al.* (1981) Carne *et al.* (1997), Marshall *et al.* (1995), Regel (1995), Sanderson and Kirkley (1998) and Scott (n.d.). Long (1999) also notes that Field Naturalists Journals are another source for mammal notes with most of the SA Mammal Club field trips documented. Further details of historical and current fauna research are provided in the Results chapter.

Table 4.
Summary of flora and fauna surveys conducted in the SMLR study area, where data resides in Department for Environment and Heritage databases.

Survey Name (and number) appearing in survey database	Date	Type of Survey	Conducting organisation/individual
Mt Lofty (5)	1985	Vegetation	D Goodwins, DTUPA
Mt Lofty Ranges (32)	1981	Vegetation	S. Kinnear, DTUPA
Kyeema CP (33)	1977	Vegetation	A. Robinson, DEHAA
Belair NP (34)	1978	Vegetation	A. Robinson, DEHAA
Para Wirra CP (35)	1978	Vegetation	A. Robinson, DEHAA
Morialta CP (38)	1977	Vegetation	A. Robinson, DEHAA
Cleland CP (36)	1988	Vegetation	A. Robinson, DEHAA
Horsnell Gully CP (37)	1977	Vegetation	A. Robinson, DEHAA
Happy Valley DC (56)	1992	Vegetation	M. Robertson, DEHAA
Stirling D.C. (57)	1993	Vegetation	C. Crawford, Adelaide Hills Council
Noalunga Christies Creek (65)	1994	Vegetation	P. Green, DC Onkaparinga
Noarlunga Field Creek (70)	1994	Vegetation	P. Green, DC Onkaparinga
Lofty Block Grasslands (83)	1995	Vegetation	M. Robertson, DEHAA
Coastal Dune and Clifftop (82)	1994	Vegetation	D. Fotheringham, DEHAA
Mt Lofty Emu-wren (52)	1996	Vegetation	R. Taplin, T.Littlely, P. Lang, DEHAA
Southern Fleurieu Peninsula (97)	1997	Vegetation & Fauna	D. McKenzie, Scientific Expedition Group
Fleurieu Roadside Vegetation (93)	1996	Vegetation & Fauna	M. Hyde
Temperate Grasslands (46)	1991	Vegetation	M. Hyde
Private Collections (42)	1987	Vegetation	R. Taplin and D. Murfett
Grassy Woodlands (54)	1993	Vegetation	M. Hyde
Private Collections (47)	1982	Vegetation	M. Hyde

METHODS

S. Croft[1]

The surveys included in this report collectively form part of the Biological Survey of South Australia. In general, methods are consistent with the methodology outlined in the following manuals:
Guide to a Native Vegetation Survey Using the Biological Survey of South Australia. (Heard and Channon 1997), and:
Guidelines for Vertebrate Surveys in South Australia: using the Biological Survey of South Australia (Owens 2000).

However, the vegetation surveys included in this report date from 1977 and incorporate a number of variations and/or additions to the "standard' Biological Survey methods.

Aims, quadrat selection, field methods and data analysis are outlined separately for vegetation, vertebrates and invertebrates.

VEGETATION

Five surveys comprise the vegetation component of the biological survey. Although each survey recorded floristic composition within defined quadrats, the aims, quadrat size and data recorded varied between surveys. Table 5 shows the dates, scope and number of quadrats within each survey.

Table 5.
Vegetation surveys included in SMLR study analysis.

Survey Number	Survey Name	Dates of Surveys	Type of Survey	Quadrats within study area	Quadrats outside study area
5	Mt Lofty	1/5/85 to 13/12/91	Vegetation	609	19
42	Mt Lofty - Private	8/1/87 to 29/7/91	Vegetation	292	34
52	Mt. Lofty – Emu Wren	Various dates between 1/10/93 to 31/3/94; and Oct. to Dec. 1996	Vegetation	50	3
97	Southern Fleurieu (Scientific Expedition Group)	14/1/1997 to 1/3/1999	Vegetation and Vertebrates	34	0
117	Southern Mt Lofty	1/11/77 to 10/5/01 (most quadrats surveyed in spring of 1999 and 2000)	Vegetation and Vertebrates	192	0
			Total	**1177**	**56**

[1] Biodiversity Survey and Monitoring Section, Science & Conservation Directorate, Department for Environment and Heritage, GPO Box 1047, Adelaide 5001.

The location of survey quadrats is shown in Fig. 5.

VEGETATION SURVEY OBJECTIVES, STUDY AREAS AND SITE SELECTION

The details of each survey are outlined below and the differences between surveys are summarised in Table 6.

Survey 5 (Mt Lofty)

Objective: To classify and map communities in the South Mount Lofty Ranges as part of a fire management system. High fire hazard communities, especially high rainfall forests and woodlands with a heath understorey were targeted. No coastal, wetland or grassland sites were sampled.

Study Region: Mount Lofty Ranges, south of the Gawler 1:50,000 map sheet to the coast and east as far as Goolwa in the south and Barossa in the north.

Site Selection: Based on an even geographical spread of sites. Selected within areas having tree or shrub cover. No coastal sites selected. Stratified sampling techniques were used to gain maximum variation.

Survey 42 (Private)

Objective: To record base-line data for remnant vegetation of:

- Southern Fleurieu Peninsula, targeting high rainfall Stringybark forest with a heath understorey,
- North-east of Adelaide, targeting Pink Gum, *Eucalyptus fasciculosa* – Long-leaved Box, *Eucalyptus goniocalyx* forest with a dry heath understorey (500 – 750mm rainfall), and
- Wet creekline and peat bog swamps of southern Fleurieu Peninsula

Study Region: Southern Fleurieu Peninsula and Adelaide hills northeast of Adelaide, including Kersbrook – Williamstown area.

Site Selection: Quadrats were located entirely within one aspect and plant community, and avoided disturbance and edge effects. Quadrats were numbered sequentially PC (for Private Collectors) and quadrat numbers were between 765 and 1100, inclusive.

Survey 52 (Mt. Lofty – Emu-wren)

Objective: To determine the vegetation structure and composition of Southern Emu-wren habitats. Compare swamps that have records of Emu-wrens present against those without Emu-wrens.

Study Region: Southern Fleurieu Peninsula, bounded by Yundi in the north and Cape Jervis in the south, west by the coast and east to the mouth of the Finniss River.

Site Selection: Quadrats were located within swamps providing existing or potential Emu-wren habitat. Site nomenclature follows Heard and Channon (1997).

Survey 97 (Southern Fleurieu (SEG))

Objective: To assess biodiversity of road reserves on the Southern Fleurieu Peninsula to assist in management of these road reserves.

Study Region: Southern Fleurieu Peninsula.

Site Selection: Quadrats were selected on both developed and undeveloped road reserves. Quadrat names were based on the first three letters of the 1:50,000 mapsheet and quadrats were numbered sequentially in an anti-clockwise direction.

Survey 117 (Southern Mt. Lofty Ranges)

Objective: To survey vegetation types and also National Parks and Wildlife Act reserves, inadequately surveyed by prior surveys within the Southern Mount Lofty Ranges.

Study Region: The area is bounded by Gawler River to the north, where the Ranges meet the Murray plain in the east, the Southern Ocean in the South and St Vincent's Gulf to the west.

Site Selection Criteria: Survey 117 has combined three separately conducted surveys:

- 81 quadrats comprised a series of 7 vegetation surveys conducted in Adelaide Hills parks in the late 1970's: Kyeema CP, Belair NP, Para Wirra CP, Morialta CP, Cleland CP and Horsnell Gully CP.
- 9 quadrats conducted by the NCSSA
- 102 quadrats coordinated by the Department for Environment and Heritage in 2000

The following comments relate to the latter mentioned 102 quadrats. Site selection for survey 117 avoided the more specialised areas of habitat surveyed during surveys 52 and 97, swamps and mainly smaller areas of privately owned remnant native vegetation in the Fleurieu District. Based on remnant vegetation mapping for the region, the survey quadrats were selected using the following broad criteria.

- To be concentrated within the larger intact patches of remnant vegetation, with a view that this would improve the possibility of sampling in the most complete ecosystems. This resulted in quadrats concentrated on land managed by National Parks and Wildlife South Australia (NPWSA), Forestry SA and SA Water. However, privately owned remnants (including Heritage Agreements) were also surveyed.
- Quadrats should be proportionately representative of the vegetation associations present.
- Quadrats should be reasonably spatially distributed across the survey area.
- Quadrats should be accessible within a reasonable distance by vehicle.
- At least one quadrat should be located in each NPWSA reserve, where possible and practical.

Vegetation survey quadrats were not always tied to fauna quadrats. Quadrats were numbered using the method described in Heard and Channon (1997).

Table 6.
Details of quadrat size and floristic recording methodology for each vegetation survey.

Survey Number	Size of quadrat	Methodology	Photo-points Established
5	10m x 10m	All species recorded. The three dominant species from each stratum (overstorey, shrub and grass/sedge) were scored using a relative percentage cover. Later converted to Braun Blanquet cover/abundance using quadrat photographs.	No
42	10m x 10m	All species recorded. Three dominants overstorey species were recorded and their relative percentage cover (not Braun/Blanquet), foliage height and depth. Plants species names were recorded under trees, shrubs >0.25m, shrubs <0.25m and grasses/herbs. The structure of each vegetation layer was recorded according to Specht's (1972) classification. Only unidentified species were collected for later identification and herbarium vouchers.	No
52	10m x 10m (or $100m^2$ configuration if 10m x 10m not suitable)	All species recorded along with a Braun/Blanquet cover abundance score. Overstorey heights and canopy cover not recorded.	No
97	30m x 30m (some quadrats adjusted to 20m x 45m)	Heard and Channon (1997)	No
117	30m x 30m	Heard and Channon (1997)	Yes

VEGETATION DATA MANAGEMENT
Table 7 shows data available in electronic form for each quadrat for each vegetation survey.

Table 7.
Data available for each quadrat for the five vegetation surveys included in the SMLR region Biological survey analysis.

Variable	5 (Mt Lofty)	42 (Private Collections)	52 (Emu-wren)	97 (Southern Fleurieu – SEG)	117 (Southern Mt Lofty)
Plant species	✔	✔	✔	✔	✔
Location - description	✔	✔	✔	✔	✔
Latitude and longitude	✔	✔	✔	✔	✔
Elevation	✔	✔	✔	✔	✔
Aspect	✔	✔	✔	✔	✔
Landform pattern description and landform description			✔	✔	✔
Surface strew size and strew cover description			✔	✔	✔
Slope			✔	✔	✔
Vegetation Structural Formations			✔	✔	✔
Braun/Blanquet score for each species			✔	✔	✔
Overstorey and understorey dominants			✔	✔	✔

Structural information and dominant species cover codes for Survey 5 (515 quadrats) has been entered into a Database spreadsheet, and analysed manually for the purpose of this report.

At the time of writing, only species present has been entered electronically for Survey 42. Species lists for each quadrat were analysed manually to determine overstorey, shrub and ground cover species present.

VEGETATION DATA ANALYSIS

The quadrat-based data for vegetation was analysed using PATN exploratory analysis software (Belbin 1994). Because cover/abundance information was not in electronic form for survey 5 and 42 (totalling 901 of the 1177 survey quadrats), the analysis was based on species presence/absence data only. This analysis clustered the quadrat species presence/absence data into groups based on similar floristic composition.

The PATN analysis procedure used was as per Brandle (2001). The results display a dendrogram of similarity between quadrats. The dendrogram can be cut off at any level of dissimilarity to display a desired number of groupings and should be cut off where the vegetation types represented by the quadrats in these groupings reflect ecologically meaningful groups (Robertson 1998). The purpose of the classification is to identify vegetation types in which many species commonly and repeatedly occur together due to particular environmental factors.

The PATN analysis software was also used to produce the [Observed frequency – Expected frequency]/Expected frequency (O-E/E) index values for each species by group. This index is an adaptation of the Chi-squared formula. The Expected frequency for a species in a particular category is determined by dividing the sum of frequencies within one category (ΣX) by the total of the sums of all categories ($\Sigma\Sigma X$), multiplied by the sum of the frequency for the species in all categories (ΣY), ie $\Sigma X/\Sigma\Sigma X*\Sigma Y$.

VEGETATION MAPPING

The area defined for mapping of the South Mount Lofty Ranges was the eleven 1:50,000 mapsheet boundaries from Vincent, Barossa and Gawler in the north to Cape Jervis, Torrens Vale, Encounter and Goolwa in the south. The northern boundary extends south from Tanunda (34.5 degree latitude) and Thompsons Beach and west from Kaiserstuhl Conservation Park (139 degree longitude). It is bounded on the west by St Vincent Gulf and south by the coastline and Lake Alexandrina. Within Lake Alexandrina the islands of the Murray Mouth Reserves were included.

Floristic vegetation mapping in the South Mt Lofty Ranges involved the identification of native vegetation from interpretation of 1:40,000 colour aerial photography taken in 1996, 1999, and 2000. Areas less than 1 hectare was generally not mapped. Within the mapping region larger scale mapping for small areas has since been completed that in some cases may have identified blocks of vegetation less than 1 hectare.

The mapping process was conducted prior to the floristic analysis presented within this report. The mapping project area extends to adjacent plains and coastal zones not within the Fleurieu and South Mount Lofty IBRA boundaries used for the analysis. The initial list of vegetation groups used for the mapping were derived from a vegetation analysis (PATN) conducted in 1986 from Biological Survey sites within the high rainfall zone of the Mount Lofty Ranges. This analysis provided an initial list of 40 vegetation groups for mapping. Vegetation sites surveyed since 1986 within the mapping region have extended the knowledge of vegetation communities within the region.

Further research of the literature provided vegetation details on a block basis. Of particular use were Davies (1982), Neagle (1995), numerous National Parks and Wildlife SA (NPWSA) management plans, heritage agreement and NPWSA reserves that provided lists of vegetation associations within blocks of vegetation. Roadside vegetation mapping existed for some roads and native species identified along a road was a guide for the adjacent blocks of vegetation.

Vegetation information found in the variety of sources indicated above was interpreted to provide an initial list of vegetation groups. All vegetation information was transcribed on reference maps beside the relevant blocks of native vegetation or the vegetation survey sites to aid in the vegetation interpretation process. Using stereo pairs of colour aerial photographs, viewed through a stereoscope, the vegetation was mapped extrapolating out from each site. Extrapolation relied heavily on the recognition of the textural (height, canopy size and spacing) and tonal (foliage colour) qualities characteristic to vegetation groups at a known location and any identifiable landform, soil and surface stone characteristics. This information was extrapolated into surrounding vegetation where no information was available. The vegetation was mapped with one vegetation type identified within an area. Boundaries between different vegetation associations were mapped onto mylar film. The cadastre, roads, drainage and forestry reserves boundaries were used as the reference base for the mapping.

In the identification of native vegetation from colour aerial photography some rare plant community types may not be adequately represented due to the difficulty in their detection from the imagery. The most under represented plant communities are grasslands, sedgelands/reedbeds, swamps, coastal shrubland vegetation and some less common or extensively cleared woodlands and open forest communities.

To aid the mapping process field checking was conducted where possible. The field checking was

limited to one day spent on a mapsheet and involved visual assessment of roadsides, NPWSA parks and reserves accessible to 2WD vehicles and distant observations from roadsides of vegetation within private land. Field checking was particularly useful for recognising and mapping rarer communities or areas where no vegetation information was available.

Larger scale mapping that existed within the mapping region has been incorporated without appropriate scaling. These included mapping of Morialta and Black Hill Conservation Parks using 1995 1:5,000 and 1:10,000 colour aerial photography, Kaiserstuhl Conservation Park using 1994 1:5,000 colour aerial photography, Mt Osmond reserve using 1:5,000 colour aerial photography and Hindmarsh island and surrounding islands using 2001 1:20,000 colour aerial photography. All these mapping projects involved extensive field checking. The Hindmarsh Island mapping was not always able to be assigned one vegetation group to a block. In these cases two floristic groups, in order of dominance and included an estimate of percent cover has been ascribed to the block. This is generally referred to as a mosaic. These project-based updates have followed the principles of the original mapping methods.

The vegetation data is stored and maintained as part of the Environmental Database of South Australia (EDBSA) by the Environmental Information Division, DEH.

VERTEBRATES & INVERTEBRATES

SURVEY SITES AND SUB-REGIONS

One hundred and fifty seven survey quadrats from three surveys (Table 8) were surveyed for mammals, reptiles, amphibians and birds. Figure 9 shows the location of survey quadrats. Appendix II provides vegetation and selected physical parameter details for each survey quadrat.

Table 8.
Surveys included in vertebrate analysis for SMLR, and number of survey quadrats.

Survey No.	Survey Name	Year	Number of quadrats from which vertebrate data recorded
117	Southern Mt. Lofty Ranges	2000	111
52	Mt. Lofty – Emu-wren	1993 - 1996	12
97	Southern Fleurieu (Scientific Expedition Group)	1997-99	34
			Total = 157

The SMLR survey area was divided into three sub-regions of "Barossa", "Adelaide Hills" and "Fleurieu" (Fig. 7). These show variations in the general climate and habitat types, and can be roughly separated on the following basis:

- Barossa: Gawler River south to the Torrens River.
- Adelaide Hills: Torrens River south to an east-west line through the most southerly portion of the Onkaparinga River
- Fleurieu: from the east-west line through the most southerly portion of the Onkaparinga River to the south coast.

Summaries of these surveys and their objectives are outlined below.

Southern Mt. Lofty Ranges survey (No. 117)

Of the 111 quadrats surveyed for vertebrates, 102 were undertaken by the Department for Environment and Heritage (DEH) Biodiversity Survey and Monitoring Section in the year 2000. The 102 quadrats were surveyed over three separate periods:

- 31 quadrats in the Fleurieu District in early autumn (between 20th February and 3rd March).
- 33 quadrats in the southern Barossa District and northern Adelaide Hills in mid-spring (between 22nd October and 3rd November).
- 38 quadrats in the remainder of the Adelaide Hills at the end of spring/early summer (between 26th November and 8th December).

An additional nine quadrats in the southern Barossa District were surveyed between the 23rd and 27th September 2000 by the Nature Conservation Society (NCS), for the South Para Biodiversity Plan. The majority of these quadrats were originally selected for the DEH survey, and consequently the data collected was included with the DEH survey number 117.

The intention in setting the timing of the survey of the three sub-regions was to facilitate comparable climatic conditions at the time of sampling. The general weather pattern within the region is for cooler, wetter conditions in the Fleurieu District in the south grading to warmer drier conditions to the north in the southern Barossa District. However, the higher altitude in much of the Adelaide Hills or central sub-region modifies this pattern, resulting in it drying out later in the year. Hence the timing of sampling of the two northern sub-regions is reversed. This was considered important as access to many of the survey quadrats was along four-wheel drive tracks, suitable for use only in dry conditions. Unfortunately, the average weather conditions did not prevail in 2000 and the Fleurieu district, expected to be at its driest in late summer-early autumn, received as much as 100mm of rain in some

areas during the survey period. Fortunately only one of the intended survey quadrats had to be abandoned as a result. An unexpected benefit was the high number of frog records obtained for the area. In addition, temperatures were below average during the sampling periods in the other two sub-regions later in the year.

Seven of the survey quadrats in the Adelaide Hills sub-region were long term monitoring quadrats originally established during the late 1970's and early 1980's to assess post bush-fire regeneration of fauna and flora. Four of these quadrats were in Cleland Conservation Park and three in Horsnell Gully Conservation Park. All standard sampling other than the usual trapping effort was carried out at these quadrats. Trapping data used was from the last trapping event of the post fire research, carried out in 1998.

Quadrats selected for survey 117 (including nine NCSSA quadrats) avoided specialised areas covered during surveys 52 and 97, namely swamps and mainly smaller areas of remnant vegetation in the Fleurieu district.

Mt. Lofty – Emu-wren survey (no. 52)
The 12 quadrats from the Nature Conservation Society of SA (NCSSA) Survey of the Fleurieu Peninsula Swamps (Survey No. 52), conducted from the 5th to the 9th of December 1996 were also included in the vertebrate analysis.

Southern Fleurieu survey (Scientific Expedition Group) (no. 97)
Thirty-four roadside quadrats of the Southern Fleurieu Peninsula surveyed by the Scientific Expedition Group were included in the vertebrate analysis. These quadrats were surveyed over separate visits to the area in November 1997, and March, May, August and October 1998.

HUMAN RESOURCES
Survey 117 (Southern Mt Lofty) required field involvement by approximately 70 biologists, equally divided between paid staff and volunteers. There were two groups of usually six people, in the field at a time, over three, two-week periods, for a total of six weeks field time.

SITE SELECTION CRITERIA
As discussed under vegetation methods above, quadrat selection for survey 117 avoided the more specialised areas of habitat surveyed during surveys 52 and 97, swamps and mainly smaller areas of privately owned remnant native vegetation in the Fleurieu District. Quadrats were selected within larger intact patches of remnant vegetation. At least one quadrat was located in each National Parks and Wildlife Act reserve, where possible and practical.

SURVEY METHODS - BIOLOGICAL SURVEY OF SA TECHNIQUES
At each quadrat vertebrates were surveyed using the Biological Survey of South Australia method (Owens 2000). This included the following techniques:

Reptiles and small mammals were surveyed using a single fenced pitfall line, 50m long and comprising six pitfall traps ten metres apart with each pit 15cm in diameter and 40cm deep. A separate line of Elliott traps and two cage traps was run in association with each pitline, about 20m away. Each quadrat was surveyed for 4 days and 4 nights.

Mammals and reptiles were also recorded by active searching of the area surrounding the trap-line for individuals or signs such as identifiable diggings, scats, tracks, bones or even scratches on trees were noted. In some cases material was collected or photographed for later confirmation. Spotlight searches were made for 20 to 30 minutes each night at the majority of survey quadrats.

The majority of bird records from each quadrat were made during a concentrated effort of approximately two hours at the prime activity times for birds (one hour in the early morning and another in the late afternoon). This was supplemented by additional observations, particularly of less frequently encountered species during the four day trapping period. These secondary observations were particularly relevant in obtaining records of nocturnal species during spotlighting. Opportunistic observations of significant species were also collected during reconnaissance trips within the region, and when travelling between survey quadrats during the survey.

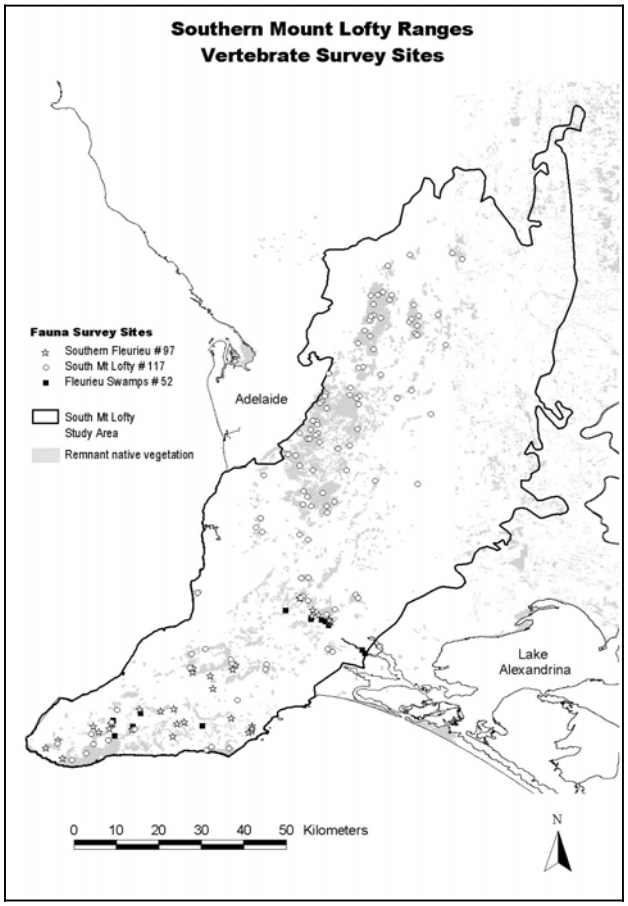

Figure 9.
Location of vertebrate survey quadrats within SMLR study region.

All information was recorded on standard data sheets and included location, method of capture or sighting, microhabitat, numbers of individuals and weight for small mammals.

Fauna encountered outside the specified quadrats were recorded as "opportunistic" sightings on separate data sheets. These records enabled compilation of a more thorough inventory of the biota (especially reptiles) of each area, including species' use of smaller or more heterogeneous habitat types not surveyed by quadrats. Opportunistic records, many in the form of road kills, collected while travelling between survey quadrats during the survey, provided important additional data for the larger mammal and reptile species.

BATS
Although some quadrat based and opportunistic bat trapping was carried out during the survey, information on bats within the region is largely based on the records of the South Australian Museum. A systematic approach to collection of records on this group is largely outside the scope of the Biological Survey of South Australia.

However, in addition to the Biological Survey, a bat survey of the Mount Lofty Region was conducted during the summer 2001/2002, by local residents using ANABAT bat detectors. This survey was organised by the South Australian Museum, the Natural Resources Centre, the Upper River Torrens Landcare Group and the Barossa Catchment Group. Thirty-one quadrats were surveyed for one to three nights and over 15 000 echolocation calls recorded (T. Reardon, pers. comm. 2002).

HAIR TUBE SAMPLING – MAMMALS
In an attempt to provide additional information on mammal species, hair tube sampling was carried out at 100 of the 111 survey sampling quadrats (Appendix IV). Nine of the excluded quadrats were surveyed by the Nature Conservation Society (NCS) survey in the Southern Barossa sub region during September 2000 where hair tubes were not installed. A further two quadrats in the Mount Bold Reservoir Catchment Reserve were excluded as they were on boggy ground along watercourses. In such situations pitfall trapping was impractical and as the pitfall line scar was used to assist in relocating the hair tubes (see below) they were not installed at these two locations.

The hair tube consisted of a 20cm length of 5cm diameter PVC pipe, with two pieces of 2-3cm double sided adhesive tape attached inside and parallel to both ends. Bait was contained in aluminium fly screen mesh in the center of the tube. A hole drilled through the centre of the tube enables a nail or pin to be passed through the tube and the bait parcel to secure the tube in place on a tree or on the ground and hold the bait in place. Hair samples were "captured" when mammals attempted to access the bait. At the time of installation of the standard trap line at each survey quadrat, four hair tubes were located at each of 100 quadrats. These were located, one on the ground and one on a tree, and one at each end of the pit trap line. These were then retrieved four to five weeks later and any hair samples collected and where possible identified, using the methods described in Brunner and Coman (1974). Some taxa are more easily identified than others from hair analysis (Lobert *et al*. 2001) and some taxa are more likely to lose hair when investigating a tube than others.

Some minor discrepancies occurred in the numbers of hair tubes set at each quadrat. Two of the four tubes set at sites in Mount Gawler North Native Forest Reserve (NFR) and Onkaparinga Gorge National Park either could not be relocated. Two sets of hair tubes were inadvertently set at the survey site in Cudlee Creek Conservation Park. Despite these anomalies, the overall effort was still 400 hair tubes set over 100 sites.

OTHER SOURCES OF RECORDS
South Australian Museum records: These records were extracted in 1999. The records of the South Australian Museum were a critical source of information on extinct species in the region. They also provided information on several species that now exist in heavily modified habitat, which was not considered suitable for sampling using the established biological survey approach. This applies particularly to the

heavily cleared eastern side of the ranges, and the hills face zone north of the city of Adelaide.
The Mammal Club of the Field Naturalists Society of South Australia's records were an important source of data overall.
Published references: The relatively few published references were also consulted.
Personal Communications: Information was also obtained from private individuals with emphasis on less common or poorly known species.
"Frogwatch Records". Frogwatch is annual community based event for recording frogs.
Reserves Database (administered by the South Australian Department for Environment and Heritage (DEH) and **The Atlas of Australian Birds** (Blakers *et al*. 1984).

BIRD SPECIES PATTERNS
PATN exploratory analysis (Belbin 1989) was conducted on presence/absence data of 75 bird species recorded from the 157 survey quadrats. Migratory species, raptors, waterbirds, and nocturnal species were not included in the analysis. The PATN analysis clustered the quadrat bird species presence/absence data into groups based on similarity. Refer to Vegetation methods above for further details of PATN.

INVERTEBRATES
Insects were collected from 74 quadrats within Biological Survey number 117, "Southern Mt Lofty" (refer Appendix II for a full list). Ants were collected from these 74 quadrats (plus an additional 21 of the vertebrate survey quadrats – refer Invertebrate chapter for quadrat details.)

Insects were collected from macro and micro pitfalls (as per Biological Survey of SA method (Owens 2000). Some hand collecting was also carried out.

AQUATIC MACROINVERTEBRATES
A large number of reference sites were selected and sampled from S.A. over the course of the Monitoring River Health Initiative (MRHI) and Australian River Assessment (AUSRIVAS) programs for the production of a database, which could be used to construct predictive bio-assessment computer models. Reference sites were identified on the basis of being 'least-disturbed' and unimpaired by significant human activities. Few pristine sites exist in this State, particularly in the MLR, as most catchments have been altered through land use changes and associated vegetation clearance associated with the concentration of people near Adelaide and along the coastline. Criteria used for reference site selection included the presence of the following: national benchmark hydrological monitoring stations; nationally significant riverine wetlands; National Parks and Conservation Parks; significant stream fauna; significantly unique water gauge stations, and representation of the gradients present in the morphology of the State's rivers.

Test sites were those sites identified to be of importance in assessing the condition of a river that were known or suspected to be experiencing a water quality problem or impact from some sort of habitat disturbance (Anon. 1994). A small number of test sites were sampled in 1994-95 to ensure that the models developed from the reference sites were sensitive enough to distinguish highly impacted sites. Later sampling in 1997-1999 focused on sampling as many sites in the State as possible, which are potentially impacted from some sort of disturbance.

Sampling, sample processing and identification
Sampling was carried out in South Australia twice yearly, during April-June (mostly autumn) and October-December (spring-early summer), to provide an indication of the types of animals and range of conditions present in streams over time. The main focus of this work was to ensure that sampling the different habitats present at a site captured the broadest range of macroinvertebrates. This was because different animals live in different parts of a stream, with some preferring turbulent flowing water (riffles), whereas others may occur in standing water (edges), or areas with rocks or macrophytes. Some animals occupy streams at different times of the year, making it important to sample the stream on more than one occasion in any one year.

Macroinvertebrate samples were taken using a pond net to capture those animals present in a total area of 10 linear metres in each habitat. Samples were then taken back to the laboratory where the macroinvertebrates were sorted, identified and counted.

Numerous water chemistry and physical habitat characteristics were also measured at each site to assist in the assessment process. These included such things as stream width and depth, composition of the sediments, current speed, conductivity, pH, nutrient and ion concentrations, temperature, colour and turbidity.

Classification and selection of predictor variables
- Reference sites were classified into groups with similar macroinvertebrate communities using multivariate classification methods.
- Another multivariate method called Stepwise Multiple Discriminant Function Analysis was then used to determine which sub-set of environmental variables best described the groups of sites. This sub-set of variables accounted for most of the variation between groups of sites and consisted of variables which were known to be largely unaffected by human activities. In most cases they were strongly related to location (e.g. latitude, longitude, altitude, distance from the source, etc.).

Using the predictive model(s)
- The predictive environmental variables were used to match the test sites with groups of reference

sites, and a calculation of the probability of each site belonging to each group was made.
- Once group membership of a test site was determined the taxa that should occur at an individual site were predicted.

The taxa that were actually collected were then compared with those that were predicted. The severity of any impact was assessed by the difference between how the predicted collection varied from what was observed.

Sampling sites

A total of 262 sites were sampled from the Mt Lofty Ranges study area (MLR) between 1994 and 1999 (Refer Figure 115 and Appendix XXVII for site details). Of the 983 samples collected, 391 were from riffles (shallow, fast-flowing water over a rocky substrate) and the rest were from pool/edge (non-flowing) or macrophyte (aquatic plant) habitats.