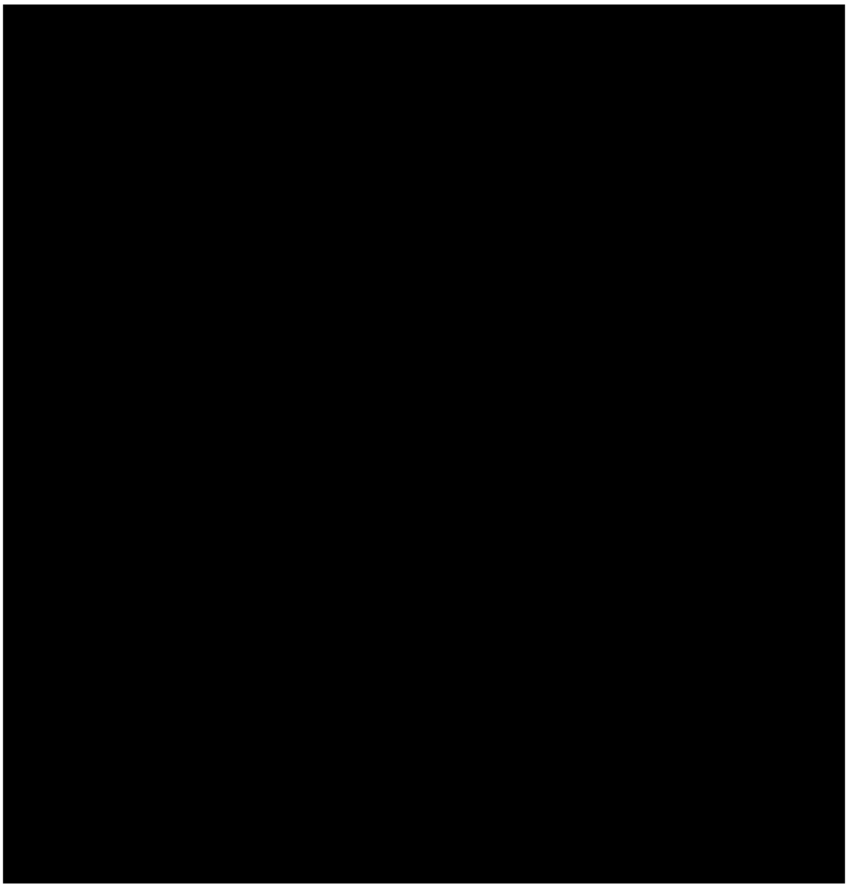
Response to Disturbance of Forest Species

Southern Region

A project undertaken as part of the NSW Comprehensive Regional Assessments

February 2000



NSW CRA / RFA Steering CommitteeSydney

RESPONSE TO DISTURBANCE OF FOREST SPECIES IN CRA REGIONS IN NSW – SOUTHERN REGION

PREPARED BY

ENVIRONMENT AUSTRALIA

A project undertaken for the Joint Commonwealth NSW Regional Forest Agreement Steering Committee as part of the NSW Comprehensive Regional Assessments.

Project number NA 17/EH

NSW CRA / RFA Steering CommitteeSydney

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The project has been overseen and the methodology has been developed through the Environment and Heritage Technical Committee which includes representatives from the New South Wales and Commonwealth Governments and stakeholder groups.

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EXECUTIVE SUMMARY

This report has been prepared for the joint Commonwealth/State Steering Committee, which oversees the Comprehensive Regional Assessments of forests in New South Wales.

The Comprehensive Regional Assessments (CRAs) provide the scientific basis on which the State and Commonwealth governments will sign Regional Forest Agreements (RFAs) for the major forests of New South Wales. These agreements will determine the future of the State's forests, providing a balance between conservation and ecologically sustainable use of forest resources.

Project Objectives

This project was undertaken to identify the conservation needs of flora and fauna species in the Southern Region of NSW. It was managed jointly by the NSW National Parks and Wildlife Service, State Forests of NSW and Environment Australia (Commonwealth), with Environment Australia as the lead agency.

Flora and fauna were treated in separate assessments. Initially NSW National Parks and Wildlife Service compiled lists of forest dependent fauna and flora in the region. In a series of workshops, expert ecologists were asked to provide information on the habitat and critical resource requirements, ecological attributes and disturbances affecting the listed species. Experts ranked the listed species in order of need to be included in a formal reserve system, and provided information on life history characteristics and density of each species to be used to estimate the area of land (target area) needed for their conservation.

Experts also provided information to help apply these target areas in an ecologically meaningful way. This included recommendations on location of barriers which separated populations, and how the target needed to be applied within each distinct population.

The main chapters of this report cover the methods and results of the project. Appendices provide lists of species and detailed tables of results.

The outcomes of this project will be used, firstly, to guide the design of reserves in the Southern region so that the habitats of the most threatened species are protected. Secondly the results are also intended to help in the management of forested land over the region.

1. INTRODUCTION

The National Forest Policy Statement (NFPS) signed in 1992, included, amongst other things, an undertaking to manage Australia's forests to conserve biological diversity (Commonwealth of Australia 1992). In order to achieve this objective it was agreed that a comprehensive, adequate and representative (CAR) reserve system be created in accordance with a nationally agreed set of criteria, known as the JANIS criteria (Commonwealth of Australia 1997). This reserve system would form an integral component of any Regional Forest Agreement (RFA) signed by the State and Commonwealth governments which would outline the long term management and use of forests in each of a number of RFA regions. The information needed to draw up these agreements are collected during the Comprehensive Regional Assessments (CRA), which consist of a number of different projects aimed at identify the full range of environmental, heritage, economic and social values within the forests.

For NSW CRAs, the Response to Disturbance (RTD) Project was undertaken to identify and synthesise forest species conservation requirements. This information will assist in ensuring the reserve system meets the JANIS criteria pertaining to the conservation of forest species. The most relevant of these being:

- The reserve system should seek to maximise the area of high quality habitat for all known elements of biodiversity…(criterion 5)., and
- Reserves should be large enough to sustain the viability, quality and integrity of populations (criterion 6) (Commonwealth of Australia 1997).

The RTD Project provides key information about forest dependent species that is needed to create an efficient reserve system (targets, reservation priorities) and where possible outlines other information to guide management that will fulfil these JANIS criteria. It has been divided into two sections, one examining the requirements of fauna species and the other, the requirements of flora species.

Throughout the world wildlife managers recognise that it is immensely difficult and expensive to collect sufficient data to confidently describe the conservation requirements of any species. In most cases managers have to rely on the opinions or best guesses of the researchers who know most about the species. With this in mind, Environment Australia has sought to advance the development of methods that would improve the transparency and objectivity of this kind of expert advice. Some of the foremost thinkers on these methods, including Professor Hugh Possingham of University of Adelaide, and Dr Mark Burgman of Melbourne University, have been closely involved. The Response to Disturbance project, and its equivalents in other States, has provided an opportunity to test and refine these new approaches to the conservation of species.

2. METHODS

2.1 INTRODUCTION

The Response to Disturbance project sought to provide information that would: (1) aid the design of reserves for the protection of priority species, and (2) assist in the review of and further development of management prescriptions for species. The methods used were different for flora and fauna and are, therefore, presented seperately. The aim of the assessments was to determine how best to protect species given their habitat requirements and threatening processes. This project interacted with the projects responsible for modelling the habitat of flora and fauna species to produce information that can be used to guide the allocation of reserves in the region. It also provided information to the Ecologically Sustainable Forest Management (ESFM) group to review and revise the Conservation Protocols used in NSW State Forests.

2.2 FAUNA

The data needed by the project was collected during two workshops held between June and October 1999. In Workshop 1, information was collected on habitat requirements, disturbances, reproductive lifespans, trophic level and reservation priority for each species. Workshop 2 was conducted in two parts, the first addressing the Coastal subregion, and the second addressing the Tablelands subregion. In Workshop 2 the size of target areas and how they should be applied were estimated. This will be explained in greater detail later in this report. These workshops were attended by species experts nominated by the Environment and Heritage Technical Committee (EHTC) and the state agencies. An independent specialist was nominated for each species group workshop, and one independent generalist was nominated to attend them all to ensure continuity between groups. The experts who attended the workshops are listed in Table 2a.

Table 2a: Experts who attended the fauna workshops for the Southern Region Response to Disturbance Project. IND = Independent nominated by EHTC, SF = expert nominated by State Forests of NSW, NPWS = expert nominated by NSW National Parks and Wildlife Servce, S = specialist expert, G = generalist expert, – = not present.

Species Group	Workshop 1	Workshop 2 – Coast	Workshop 2 – Tablelands
Ground Mammals	Peter Catling (IND-G) Chris Belcher (IND-S) Jim Shields (SF) Linda Broome (NPWS)	Peter Catling (IND-G) Chris Belcher (IND-S) Jim Shields (SF) Linda Broome (NPWS)	– (IND-G) Chris Belcher (IND-S) Jim Shields (SF) Andrew Claridge (NPWS)
Arboreal Mammals	Peter Catling (IND-G) Phil Gibbons (IND-S) Jim Shields (SF) Dave Milledge (NPWS)	Peter Catling (IND-G) Phil Gibbons (IND-S) Rod Kavanagh (SF) James Dawson (NPWS)	– (IND-G) Ross Goldingay (IND-S) Rod Kavanagh (SF) Rod Pietsch (NPWS)
Nocturnal Birds	Peter Catling (IND-G) Penny Olsen (IND-S) Rod Kavanagh (SF) Dave Milledge (NPWS)	Peter Catling (IND-G) Penny Olsen (IND-S) Rod Kavanagh (SF) James Dawson (NPWS)	– (IND-G) Penny Olsen (IND-S) Rod Kavanagh (SF) Rod Pietsch (NPWS)

Species Group	Workshop 1	Workshop 2 – Coast	Workshop 2 – Tablelands
Diurnal Birds	Peter Catling (IND-G) Harry Recher (IND-S) Mike Crowley (SF) Anthony Overs (NPWS)	– (IND-G) Rick Webster (IND-S) Mike Crowley (SF) Anthony Overs (NPWS)	– (IND-G) Penny Olsen (IND-S) Mike Crowley (SF) Anthony Overs (NPWS)
Bats	Peter Catling (IND-G) Doug Mills (IND-S) Brad Law (SF) Andy Spate (NPWS)	– (IND-G) Doug Mills (IND-S) Brad Law (SF) Andy Spate (NPWS)	– (IND-G) Doug Mills (IND-S) Brad Law (SF) Andy Spate (NPWS)
Reptiles	Peter Catling (IND-G) Ross Sadlier (IND-S) Frank Lemckert (SF) Warwick Smith (NPWS)	– (IND-G) Ross Sadlier (IND-S) Frank Lemckert (SF) Warwick Smith (NPWS)	– (IND-G) Ross Sadlier (IND-S) Frank Lemckert (SF) Michael Pennay (NPWS)
Frogs	Peter Catling (IND-G) Will Osborne (IND-S) Frank Lemckert (SF) Warwick Smith (NPWS)	– (IND-G) Will Osborne (IND-S) Frank Lemckert (SF) Warwick Smith (NPWS)	– (IND-G) Will Osborne (IND-S) Frank Lemckert (SF) Michael Pennay (NPWS)
Aquatic Fauna	Peter Catling (IND-G) Alan Lugg (IND-S) Mike Crowley (SF) Mark Lintermans (NPWS)	Not conducted for Aquatics	Not conducted for Aquatics

2.2.1 Species List

The objective of this task was to select the species to be assessed during the project. A comprehensive list of forest dependent species for the Southern CRA region was compiled by NSW NPWS staff.

A forest dependent species is defined as a species that is dependent on forested ecosystems for any component of its life cycle.

Within the context of the RFAs the definition of forested ecosystems includes associated environments such as stream systems and their biota which are dependent on maintaining ecological processes in the forests themselves, and woodlands as defined by JANIS.

The list was reduced by the removal of the common and secure species. The list was further refined by experts at the first workshop to give priority to those species that are likely to go extinct, decline further or start to decline in the absence of management action. The final list included species listed on schedules to the *Threatened Species Conservation Act 1995* (NSW) and the *Endangered Species Protection Act 1992* (Commonwealth), as well as species considered by experts to be of concern in the region.

2.2.2 Habitat Requirements

During the first workshop, experts described the habitat requirements of the priority species. This involved identifying the critical resources needed by species to survive which may include such things as tree hollows, rocky outcrops, snags or a particular forest structure. If a species was dependent upon a certain disturbance regime, such as undisturbed inner forest, particular stream flow regime or high fire frequency, this information was also included.

Habitat requirements were identified for different life history stages. These were broken down into habitats and resources needed for breeding, juveniles, dispersal, shelter and feeding. Experts also specified other resources that may be critical for species but did not fall into the above categories, such as basking sites for reptiles or pool-riffle sequences for aquatic fauna.

The description of habitat requirements and critical resources needed by priority species was completed prior to the assessment of disturbances as this information then assisted targeting the types of disturbances that may have adverse impacts on the species, and the likely consequences of these disturbances. Information provided by this assessment will also help direct management decisions by indicating the types of habitat or resources that need to be created or maintained through management actions. This is relevant to both on and off reserve management and to the development and application of prescriptions for species to ameliorate threatening processes.

2.2.3 Disturbances

Information describing the disturbances that affect the priority species was collected during the first workshop. This involved experts listing all the disturbances affecting a species and then ranking them in terms of their relative importance or threat to the persistence of the species. In many cases, experts included a brief description of how the disturbance affected the species (eg loss of nesting sites/shelter, fragmentation of habitat for dispersal, reduction in food resources, increased predation, sight feeding and gill function impaired by suspended silt etc).

Disturbances were ranked across all tenures, with a rank of one indicating those disturbances having the greatest impact on the regional population. Where experts disagreed on disturbance rankings, this was recorded.

The information collected on disturbances will be used in several ways:

1. Aid a review of the current Conservation protocols to ensure they address the processes thought to be threatening the priority species;
2. Guide reserve design by identifying habitat that may be unsuitable for inclusion in a reserve for species or alternatively areas reserves should not be placed near;
3. Refine the description of high quality habitat by indicating possibly unsuitable areas;
4. Assist in the derivation of reservation priority ranks since these require an understanding of the threats affecting species and the potential for management prescriptions to deal with them; and
5. Provide the first step in a diagnosis of why a population is declining.

2.2.4 Reservation Priority Ranking

At the end of the first workshop experts were asked to assign each species a reservation priority rank. This rank reflects the relative priority of a species to be included in a formal reserve system. The ranks were between 1 and 5 with species ranked 1 being the greatest priority to be placed in a formal reserve. This information is used in C-Plan, the reserve selection tool, to weight each species according to its ‘need’ to be in a formal reserve.

When assigning the ranks experts considered the following criteria:

- The vulnerability of species to off-reserve disturbances. Those species that are more vulnerable were ranked higher
- The ability of the Conservation Protocols or management prescriptions to ameliorate the disturbances
- The intrinsic risk of extinction of species. Those species which are rare or uncommon tended to be ranked higher than more common or widespread species.

The ranks ranged from 1 to 5. Species ranked 1 are the highest priority for inclusion into a reserve system. The process by which the ranks were derived is as follows:

1. Each expert involved in the workshops provided a rank for each species. Where all four experts provided the same rank for a species this was the rank assigned for that species.
2. Where there were different ranks provided for the same species, experts provided reasoning for their rankings, and discussed these until an agreement was reached.

2.2.5 Setting Species Equity Target Areas (SETAs)

Species Equity Target Formula

The aim of this assessment was to estimate the area of habitat needed to maintain a species metapopulation. The preferred approach to estimating such an area is a formal Population Viability Analysis for each species (Possingham *et al*. 1993, Lindenmayer and Possingham 1994). A great deal of information on the biology of a species is needed to run this type of analysis. Since many of the species living in forests are poorly understood, this approach is not possible.

As an alternative, Professor Hugh Possingham developed a simple formula, using a minimum set of life history parameters that influence the area a species needs. The formula shown below will provide a target area that will give all species assessed an equitable chance of survival.

$$Area = 1000\frac{T}{D\sqrt{L}}$$

Where:

T = a score for trophic level to indicate population variability. Species that have more 'reliable' food sources are thought to suffer less variation and therefore can persist at lower numbers. Trophic levels range from 1 for a vertebrate predator to 8 for a granivore.

D = the typical density of the species in the area where the target area is to be applied, and

L = The mean number of reproductive years for a female that reaches maturity. This parameter ensures that species with short reproductive lifespans will have relatively larger target areas (and therefore populations). This is to accommodate species that will suffer serious declines following a bad breeding season.

Trophic level is an index of population variability. Species at higher trophic levels (predators) experience less variation than herbivores or granivores. A species with lower population variation has a lower risk of extinction and therefore can persist with fewer individuals. T was set at one for a predator of vertebrates, two for insectivores, sap-feeders and other categories, three for a herbivore or frugivore, and eight for a granivore. Experts were encouraged to adjust this value where they felt the variability of the species population was not truly reflected using this method. In doing so, experts could select a value between one and eight.

Reproductive Lifespan is included because longer-lived animals are better able to persist at lower population sizes than short-lived animals.

The density parameter gives a spatial dimension to the result, with populations at lower densities requiring more area than a high-density population. Density was estimated for the areas predicted to be habitat by the species-modelling project. Where more than one habitat quality class was modelled, density was estimated separately for each of these classes.

The intent of this formula is to rank species according to their need for space and to provide 'ball park' figures to aim for when creating reserves. In evaluating a reserve system for a species Possingham suggests that areas of suitable habitat should be counted only if they are contiguous and represent at least 10% of the species target area.

Experts provided estimates of T and L in Workshop 1, and D in Workshop 2. Where possible empirical data was used in the formula but, in many cases, estimates were used since data was not available.

Defining Distinct Populations

To adequately reserve a species across its natural range, all distinct populations of the species needed to be identified within the region. A Species Equity Target Area (SETA) was then applied to each of these distinct populations. Populations were identified as distinct if recolonisation following local extinction was considered unlikely to occur within about 100-200 years. Species with a greater dispersal ability would generally have fewer boundaries identified and, therefore, fewer SETAs or distinct populations.

Workshop 2 was conducted in two parts, with Coast and Tablelands addressed separately. Experts identified ‘distinct’ populations in each subregion for each of the species assessed. Where species population boundaries approximately aligned with the political division between Coastal and Tablelands, experts agreed in the Coastal workshop to assign separate targets to Coastal and Tablelands. A number of species populations encompassed the entire Southern Region. Experts estimated the proportion of the target to be assigned to each subregion in the Coastal workshop.

Density Estimation

Populations are not evenly distributed across the landscape and not all suitable habitat is continuously occupied. The Species Equity formula seeks to identify enough habitat to support a targeted population size and so must account for unoccupied areas. Adult density estimates, which were used in the Species Equity Formula, were tied to the species habitat models. The models outline up to 3 habitat quality classes, and densities were estimated for each habitat quality class with the highest densities predicted in the highest quality habitat. This means that the areal target for a species will vary according to the habitat quality class it is applied to. If the target is met in the highest quality habitat it will be smaller than if it were met in lower quality habitat.

Density estimates are influenced by model quality. Where a model over-predicts the amount of habitat that a species occupies, the density estimates relating to these models will be relatively lower, since unoccupied habitat has to be factored in. This results in very large target areas.

Experts based estimates on knowledge of the modelled area and how it compared to areas for which density estimates were available. Estimates were preferentially based on findings from studies within the Southern Region, but if none was available studies from nearby areas were used. Where no study results were available, experts based estimates on familiarity with the species and the modelled area.

2.3 FLORA

2.3.1 Introduction

The RTD component of the assessments for Southern CRA region brought together information from a number of CRA databases, the CRA Threatened Plants Project and the CRA Species Modelling Project, into two expert driven workshops. The main aims of the workshops were to use the best available data, and the expert knowledge of experienced field botanists, to:

- review the flora species list for the region and identify a shortlist of priority taxa for further assessment;
- data validation of point records;
- review species habitat models;
- set conservation targets (amount needed to reserve) for identified priority taxa;
- set reservation priority ranks for identified priority taxa, and;
- where possible provide management recommendations.

The species list, proposed method for shortlisting, and areal target setting protocol were circulated to agencies and experts prior to the workshops commencing. Final agreement on methods for setting areal targets, population (locality based) targets and the reservation priority ranks were reached by stakeholders, agency representatives and experts at the beginning of the first workshop (12-16 July 1999). The methods were essentially the same as that used for northern NSW CRA’s.

During the first workshop, experts reviewed the species list, validated point records, and set population targets and reservation priority ranks for approximately 50% of the identified priority taxa. During the second workshop, experts applied the principles of the areal target setting protocol to taxa whose occupied habitat could be digitised, and validated point records and set population targets and reservation priority ranks for any remaining priority taxa.

This document provides information on the main outputs from the threatened flora workshops conducted for Southern CRA region, for the primary purpose of the review of outcomes by the Environment and Heritage Technical Committee (EHTC) which oversees all CRA projects.

2.3.2 Workshop Experts

Associate Professor Mark Burgman from Melbourne University, a leading academic on the conservation and management of plant species, was contracted to provide advice and assistance in relation to PVA analysis and the setting of conservation targets of threatened plant species. The main output of this advice was the ongoing development of the target setting protocol outlined in Appendix 1, as well as being available for inter-agency meetings, and at the beginning of the first workshop to help facilitate reaching agreement on the methodologies to be used.

During the workshops themselves a panel of experienced field botanists and ecologists made all estimates, judgements and decisions relating to the application of the agreed methodologies. The panel included a total of four experts, two independent experts, as well as an agency expert from each of NSW NPWS and State Forests of NSW (Table 2b). State agencies chose and provided their own experts, while the members of the EHTC selected the independent experts.

Table 2b: List of experts involved in the threatened flora workshops

Expert	Independent or Agency Expert
Phil Gilmour	Independent Expert
Michael Doherty	Independent Expert
Douglas Binns	SFNSW Expert
John Briggs	NPWS Expert

2.3.3 Species Lists

Full Species List

A comprehensive regional species list for Southern CRA regions was compiled by NSW NPWS using a number of different data sources. Native species on this list (totalling 2763) were assessed using the following criteria**:**

- Species were assessed as to whether they were forest or forest catchment \ envelope dependent (A forest catchment \ envelope dependent species may not be directly dependent on the forest but removal of the surrounding forest changes the local hydrology, solar exposure etc in such a way that the species' long term survival is seriously threatened.)
- Species assessed as part of the Eden CRA were identified,
- Species assessed as part of the IAP (a precursor to the CRA) were identified,
- Whether the species has been recently described,
- Which Southern CRA area the species occurs in
  - South coast (east of the Hume and Monaro highways and south of the Illawarra highway)
  - Northern tablelands (west and north of the Hume highway)
  - Southern tablelands (west of the Monaro and south of the Hume highways, ie west to Holbrook and Albury)

JANIS Species List

All species on this list were further assessed to identify those species that satisfy the following JANIS criteria:

Species at risk of extinction

- Listed under TSC or ESP legislation; and
- Listed under ROTAP; and
- Declining.

Biogeographic criteria

- Regional endemic,
- Disjunct population; and
- Edge of range; and
- Phylogenetically distinct.

1232 species were identified as satisfying these JANIS criteria. However, due to limited resources, data and time it was necessary to be able to effectively differentiate between these species and identify a list of highest priority species for detailed consideration within the CRA process.

Priority Species List

In order to identify a manageable list of the highest priority species, the following criteria were applied to each of the 1232 species identified as satisfying JANIS criteria:

- each species was placed into one of four priorities for conservation (Table 2c), and:
- all forest or forest catchment/envelope dependent species were graded as high (H) or low (L) priority for more detailed assessments.

Species identified with a CRA Conservation Rank of C1, C2 or C3 and also graded as high priority (H), form the priority species list.

Table 2c: Conservation Priority Rank

C1	**Critically Threatened**. Identified as a highest priority taxon; Presumed Extinct, Endangered or Vulnerable (as listed on the NSW Threatened Species Conservation Act and the Commonwealth Endangered Species Protection Act); taxa considered by experts to warrant formal listing on National or State legislation as a Critically Threatened taxon.
C2	**Threatened**. Identified as a high priority taxon; taxa considered Threatened, Rare, Uncommon or Poorly Known (ROTAP taxa or as noted in the Flora of NSW); taxa considered by the Flora Expert Panel to warrant listing as Threatened but not as Critically Threatened on National or State legislation or ROTAP.
C3	**Regionally Significant**. Identified as a priority taxon of regional conservation significance; taxa considered regionally endemic *; taxa considered by the experts to have regional conservation significance and may warranting listing as a Threatened or Critically Threatened taxon or should be considered as part of this process. *A species is defined as endemic if 75% of its' known range is within the Southern CRA region.
C4	**Scientifically Important.** Identified as a priority taxon; includes taxa that have disjunct populations, reach their distributional limits or are phylogenetically distinct, within the region; includes taxa considered by experts to have scientific importance but not National, State or Regional conservation significance.

Phil Gilmour was contracted to develop the full species list and to conduct the initial shortlisting. Subsequent to this, a cross agency review group consisting of NSW NPWS and SFNSW experts reviewed the preliminary shortlist, including a review of the conservation ranks, forest dependency and priority for further CRA assessment (High or Low). The reviewed list went out to all experts involved in the Threatened Flora workshops prior to the workshops, and was subsequently finalised by all experts during the workshops.

2.3.4 Conservation Targets

Conservation targets were set for all priority taxa using two different methods:

1. Area based Targets. For taxa whose occupied habitat had been mapped, areal targets were set using some of the principles of the protocol of Burgman *et al* (1999) – refer to APPENDIX 1. The protocol provides targets for the amount of area required by each species, so that each has an equitable chance of persistence according to their life history characteristics and the types of threatening processes affecting them. It was initially anticipated that areal targets would be derived based on modelled potential habitat, as described in the protocol. However, as outlined later in the section on the habitat models, none of the models were accepted by experts as being useful in the context of the current process. Consequently, areal targets were set using mapped occupied areas, but incorporating some of the principles outlined in the Burgman protocol.
2. Population Targets. For those taxa for which mapped occupied areas were not available, a locality based population target was set. These targets are expressed as either a percentage of a taxon's reliably known localities, or where population sizes were reasonably known, a buffer was applied that represents the relative size of the population at each locality for each taxon (see section on Application of targets).

1. Area based targets

In developing a CAR reserve system, JANIS provides directions for assigning quantitative areal targets for forest ecosystems, old growth and wilderness values. For example, a vulnerable forest ecosystem has a target of 60% of its current areal extent. However, for species there are no specific quantitative guidelines within JANIS for setting targets. Rather, JANIS includes more generalised criteria such as:

"The reserve system should seek to maximise the area of high quality habitat for…rare, vulnerable or endangered species"; and

"Reserves should be large enough to sustain the viability, quality and integrity of populations".

In order to set areal targets for species, methodologies were required that would adequately address these criteria. Burgman *et al* (1999) outline the enormity of the task of trying to set conservation targets for plant species. In the context of the RFA, the challenge faced was to prescribe adequate and equitable conservation strategies for a large number of threatened plant taxa within a very short timeframe. However, as Burgman *et al* (1999) point out, there are also the problems of a lack of detailed demographic work on many of these taxa, and in general a lack of a broad range of Population Viability Analysis methods for plants. The protocol developed by Burgman *et al* (1999) was designed in such a way as to overcome these problems as best as possible or practicable. It incorporates basic principles of PVA that it was envisaged could be applied rapidly to a large number of taxa, based on life-history attributes and disturbance responses that are likely to be available, or guessable, for most taxa. It should be emphasised that the intent of the protocol is as a decision support tool, not a black box. The protocol provides a framework to assist experts in setting conservation targets that give each priority plant species an equal chance of survival over the coming decades.

The F parameter, defined as "...the initial (reproductively mature) population size sufficient to withstand the influences of demographic and environmental uncertainty, assuming an environment free of disturbances characteristic of land use practices since 1750", explicitly excludes the impact of post-1750 threats which are dealt with in other parts of the protocol. The determination of F takes into account factors such as: seed bank dynamics, disturbance response mechanisms, life history, demographics, outbreeding/selfing characteristics, and genetic homogeneity (Burgman *et al* 1999). To ensure a consistent approach to setting F values within the workshop, a reference table was created (Table 2d) based on longevity (a critical determinant of F) and resilience (determined by any of the other aforementioned factors). This table is based on the modelled values provided in the protocol (see APPENDIX 1). The table was used as an initial reference point from which experts could assign a higher or lower value depending on the particular characteristics of the taxon in question.

Table 2d: Reference F values

Longevity (years)	Naturally Very Resilient (F / 2)	Naturally Resilient (F / 1.5)	F Reference (x1)	Naturally Vulnerable (F x 1.5)	Naturally Very Vulnerable (F x 2)
1	34430	45906	68860	103289	137719
2	19674	26232	39348	59022	78697
3	14006	18674	28011	42017	56022
4	10929	14572	21858	32787	43716
5	8992	11989	17984	26976	35968
6	7659	10212	15318	22978	30637
7	6688	8917	13376	20064	26752
8	5946	7929	11893	17839	23786
9	5362	7149	10724	16086	21448
10	4890	6519	9779	14669	19558
11	4500	6000	9000	13500	17999
12	4171	5561	8342	12512	16683
13	3892	5190	7784	11677	15569
14	3650	4867	7301	10951	14601
15	3439	4586	6879	10318	13757
16	3254	4339	6508	9762	13016
17	3090	4121	6181	9271	12362
18	2944	3925	5888	8832	11776
19	2812	3749	5623	8435	11247
20	2693	3590	5385	8078	10771
25	2233	2977	4466	6699	8932
30	1920	2560	3840	5761	7681
40	1519	2025	3038	4557	6076
50	1271	1694	2541	3812	5082
60	1101	1468	2201	3302	4403
70	976	1302	1953	2929	3906
80	881	1175	1762	2643	3524
90	805	1073	1610	2414	3219
100	743	991	1487	2230	2973
200	444	592	888	1332	1777
500	231	308	462	692	923
1000	142	190	285	427	570
2000	88	118	177	265	353

2. Population Targets

For taxa that did not have mapped areas of occupied habitat, it is meaningless to set an areal target. For these taxa, either locality based population targets were set which are expressed as a percentage of a taxon's validated localities, or where population sizes were reasonably known, a buffer was applied to each locality that represents the relative size of the population at each locality for each taxon (see also section on application of targets). The method incorporated (largely arbitrary) baseline targets based on the conservation priority rank and reservation priority index of each taxon (Table 2e). Experts then adjusted these baseline targets up or down by considering a range of factors including: critical ecological and life history characteristics of taxa, F, notions of risk spreading, sampling bias on different tenures and the threats occurring within reserves.

Table 2e: Baseline Reference Targets

Reservation Priority Rank	Conservation Priority Rank		
	C1	C2	C3
1	100%	100%	80%
2	100%	80%	60%

3	80%	60%	40%
4	60%	20%	10%
5	20%	10%	10%

2.3.5 Review of Habitat Models

The detailed description of the habitat models developed by NPWS as part of the CRA Species modelling project will be outlined in the Species Modelling report. Some of the models had had prior input and review by relevant experts, and during the Threatened Flora workshops the models were subject to a final critical review by the workshop experts. The models were considered in terms of identifying areas of potential habitat (which includes both occupied and unoccupied areas). There was not enough time to distinguish between different qualities of habitat within the potential habitat, and to do so would add another dimension to the areal target setting protocol.

2.3.6 Reservation Priority Ranks

Because it was unlikely that all species targets could be met within formal conservation reserves, a method of ranking species priority for reservation was developed and agreed to by stakeholders, agencies and experts. The method was tenure free and based on expert panel judgement of both the intrinsic risk associated with each taxon (e.g. low numbers, small number of populations, etc.), and their relative vulnerability to off-reserve threatening processes (such as clearing or forestry operations). While consensus was obtained among the expert panel for the majority of taxa assessed, wherever consensus could not be reached, the majority view was recorded along with the view of any dissenters. The method involved assigning a value of one (most vulnerable, highest priority for reservation) to five (least vulnerable, lowest priority for reservation) to each taxon. It should be emphasised that the ranking's are relative, and that taxa assigned a lower priority are still likely to require some level of formal protection.

2.3.7 Application of Targets

Once the targets were generated for each priority taxon, rules were required to ensure the correct application of the targets within the C-Plan GIS software. These rules relate to each of the following factors:

- Buffering around known localities, in proportion to the number of individuals.
- Identification of metapopulations.

3. RESULTS

3.1 FAUNA

3.1.1 Species List

APPENDIX 2 contains a list of the 69 species assessed during Workshop 1. Five of these species were aquatic fauna, and 64 were terrestrial fauna. Initially 63 terrestrial species were assessed in Workshop 1. However the Painted Honeyeater (*Grantiella picta*) was included after Workshop 1 upon recommendation of experts. Information relating to this species was compiled by correspondence among experts prior to Workshop 2: Tablelands. For some species experts agreed not to set a target as they had no way of assessing what an appropriate target would be. Targets were set for 49 species in Workshop 2: Coast and 42 species in Workshop 2: Tablelands. Species for which targets were set are also listed in APPENDIX 2.

Lampray was initially listed as two species (*Mordacia praecox* and *Mordacia mordax*). Given a lack of data to the species level (only two records were available to species level), experts decided to assess Lampray at the genus level.

3.1.2 Habitat Requirements

APPENDIX 3 contains descriptions of the critical resource requirements of each of the species assessed.

3.1.3 Disturbances

Terrestrial Fauna

A range of disturbances was identified for each species. APPENDIX 4 provides information on the disturbances that affect each species and ranking indicating their relative impact on the species. Habitat clearing affected every species group and almost all of the species within these groups, and was generally given a ranking of 1 (Figures 3a and 3b). Other disturbances that had a ranking of 1 and that affected more than two species groups include habitat fragmentation, fire (timing and frequency), logging and competition or predation by vertebrate pests (Figure 3b).

Aquatic Fauna

APPENDIX 4 provides information on the disturbances that affect each species and the priority ranking of these. Disturbances affecting Lampray could not be identified as there is insufficient knowledge of threats to the species, however experts listed several possibilities. Siltation was identified as affecting all of the other species considered, ranking a 1 for two of the four species. A number of causes of siltation were listed, but were not individually ranked in terms of magnitude. These were clearing for agriculture, other clearing of vegetation, fire, logging and roading. Other disturbances with a ranking of 1 included fish passage barriers, water impoundments, loss of riparian vegetation, de-snagging, recreational fishing, disease and predation/ competition with exotic fish. Disturbances that were not related to forestry activities were commonly listed as of most concern for the species under consideration, and generally relate to management of large rivers. However experts commented that there are species not being considered in this process for which forestry-related disturbances are significant.

Barriers to passage of fish were listed as a disturbance for several species, particularly where migration is involved. However experts pointed out that in some situations blockages may actually aid survival of species by preventing invasion of exotic fish, in particular salmonids. These issues need to be considered case-by-case for activities involving construction or removal of fish passage barriers.

Experts commented that a listing as threatened or endangered might not have been the most appropriate criterion for inclusion of species in this process. It may have been more relevant to choose species most likely to be affected by forestry, even if not listed as threatened. Some examples mentioned were blackfish, galaxids and crayfish species not yet listed as threatened or endangered. Experts thought it was likely that listing as endangered or threatened was imminent for some of these species. Forestry was not considered a major issue in the management of the five species under assessment in comparison with other disturbances such as irrigation, dams, weirs, predation and competition with exotic species. Little is known about the species under consideration, so the nature and implications of disturbance were hard to assess. More common species may have been more appropriate for consideration as threats to them are better understood.

The Murray River Crayfish (*Euasticus armatus*) was the only invertebrate considered. Experts pointed out that although this is the only *Euasticus* species currently listed as under threat, a number of species of *Euasticus* occur in the zone which were not considered. The entire species group was flagged as in need of attention. The Murray River Crayfish is the only lowland river spiny crayfish, and is now extinct below Mildura. The cause of declines is not understood. It occurs in the Upper Murrumbidgee (no forested areas remaining), Goodradigbee and Tumut Rivers, and probably also in the Lachlan River drainage.

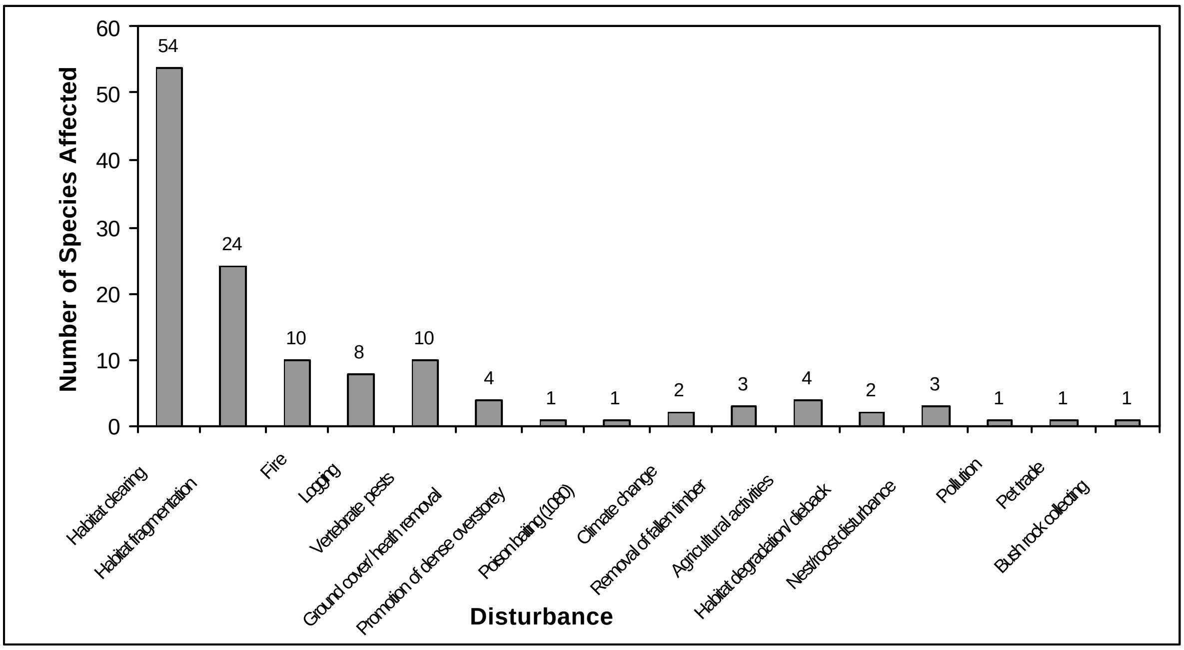

Figure 3a: The number of terrestrial species assessed for which the listed disturbance was ranked number one. A total of 64 terrestrial species were assessed.

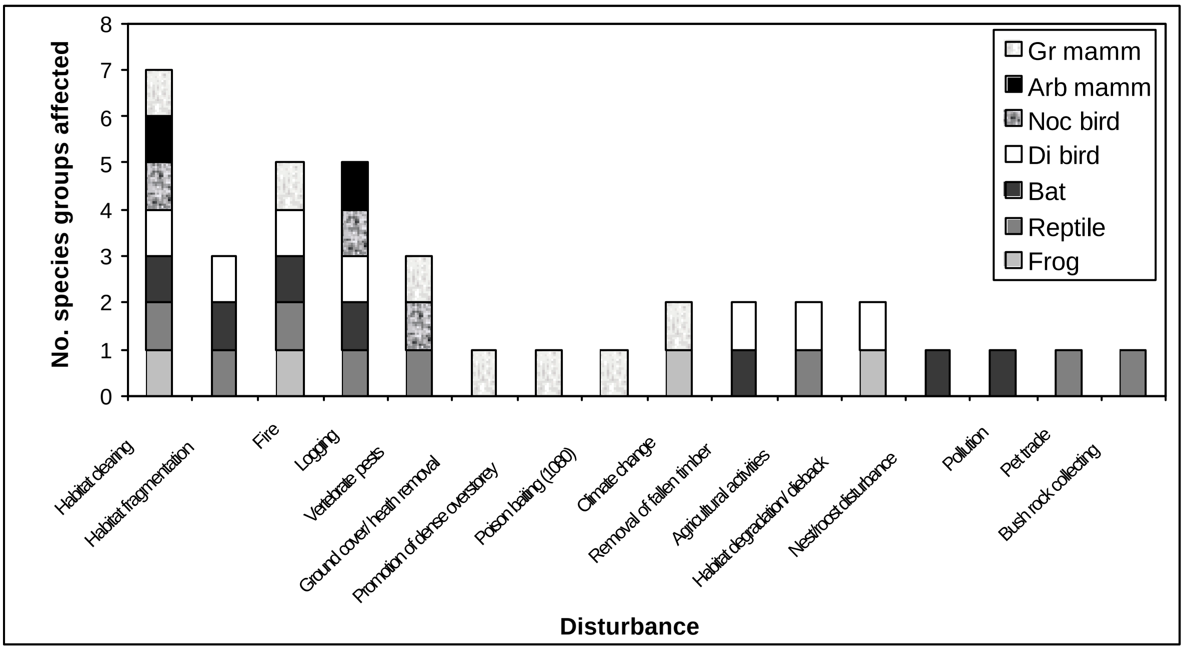

Figure 3b: The number of terrestrial species groups for which the listed disturbance was ranked number one for any species within the group. Species groups were arboreal mammals, ground mammals, nocturnal birds, diurnal birds, bats, reptiles and frogs.

3.1.4 Reservation Priority Ranks

APPENDIX 5 contains the reservation priority ranks assigned to each species. Figure 3c shows the percentage of species in each reservation priority rank, and the proportion of each priority rank made up of each species group.

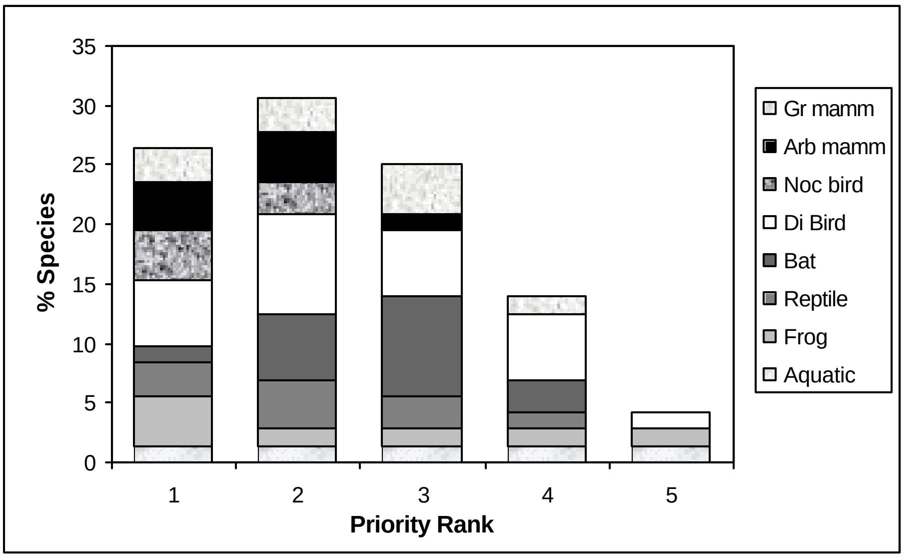

Figure 3c: Percentage of species in each reservation priority rank, and the proportion of each priority rank made up of each species group.

3.1.5 Setting Species Equity Target Areas (SETAs)

Reproductive Longevity and Trophic Level

In Workshop 1 trophic level and reproductive lifespan of females were estimated for all species. Estimation of trophic level was relatively straightforward for most species. There are a number of species where reproductive lifespan of females is unknown. For these species, the estimates were educated guesses by the experts. This was particularly the case for the relatively unknown frogs and bats. Reproductive lifespan and trophic level had previously been estimated in the UNE/LNE Response to Disurbance Workshop for some species that occur in the Southern Region. These figures were provided to experts, and were adjusted if there was a difference of opinion or recent research provided more accurate information. APPENDIX 6 contains the estimates of trophic level and reproductive longevity for each of the species assessed.

Defining Distinct Populations

Distinct populations of all species for which targets were set were identified in Workshop 2. Where extensive barriers of unsuitable habitat occurred and the species was relatively immobile, distinct populations were defined. The political boundary between the Coastal and Tablelands subregions approximately aligned with a natural discontinuity in habitat for many species, and was used to define separate SETAs for Coast and Tablelands for these species. Another common discontinuity was within the Tablelands subregion, separating the northern and southern parts. Separate SETAs were also assigned to species for which evidence existed that populations were genetically distinct, or possibly even separate species. The number of SETAs assigned to each species is listed in APPENDIX 9. For a number of species, particularly among the bird and bat groups, the entire Southern Region was regarded as a single population. For these species, the percentage of the target to be applied to each subregion was estimated. These proportions are listed in APPENDIX 9.

Density Estimates

The densities estimated in each habitat quality class for each distinct population of the assessed species are outlined in APPENDIX 7. Density estimates were tied to the habitat qualities predicted by the habitat modelling project. Experts found it difficult to estimate densities where the models over predicted the extent of habitat since they needed to take into account habitat that was never likely to be occupied by the species. For these species the densities estimated were lower than really occur.

Because the Tablelands subregion was addressed separately to Coastal, different models were used for species that occurred in both subregions. As density estimates are tied to the model for the species, where the model quality was different this often resulted in a different density estimate for each subregion. For some species there is also a real difference in density between Coast and Tablelands.

Where a single target was split across both subregions and different densities were used for each subregion, the total target area was calculated using both density estimates, and the appropriate proportion taken for each subregion. For example, the target for the Powerful Owl was assigned 80% Coast, 20% Tablelands. The coastal density was estimated to be 0.002 individuals/ha, giving a target of 188,982ha. 80% of this is 151,186ha. On the Tablelands, density was estimated to be 0.0015, giving a target of 251,976ha, 20% of which is 50,395ha. So the target area is Coastal target plus Tablelands target, totalling 201,581ha.

Amendment of Target Formula Multiplier

In some instances experts felt that the target formula multiplier (1000) was too large for the species in question, so the multiplier was reduced to a figure they considered more appropriate. This avoided inordinately large targets being calculated. This was the case for two bird species (Square-tailed Kite – revised to 10, and Pink Robin – revised to 500) where experts considered the species was freely mobile and the Southern Region supported only a portion of a larger population.

For two reptile species (*Nannoscincus maccoyi* and *Pseudemoia spenceri*) the multiplier was revised upwards to 5000 as experts considered the species was relatively immobile and occurred locally at relatively high densities. It was feared the target would be reached in one small patch, which did not provide sufficient patches to allow for recolonisation in the event of disturbance causing local extinction. The multiplier was increased to 2000 for the southern SETA of the Booroolong Frog (*Litoria booroolongensis*) and to 3000 for the northern SETA of the Giant Burrowing frog (*Heleioporus australiacus*). For both these species the modelled habitat area was very large relative to the target size, and the potential existed for reserved habitat to be too dispersed for recolonisation to be possible. Although *H. australiacus* is relatively immobile, experts felt there was no justification for separate SETAs in the northern part of the Southern Region as the species currently stands. For the Large Bentwing Bat (*Miniopterus schreibersii*) the multiplier was raised to 1500 to reflect its need for large numbers of bats in maternal roosts to maintain temperature.

Targets for Bats

<u>Cave Roosting Bats</u>: *Miniopterus schreibersii*, *Rhinolophus megaphyllus*, *Chalinolobus dwyeri* and *Myotis macropus*

Cave-roosting bats were considered to have two separate issues facing them: reservation of roosting habitat and reservation of foraging habitat. Experts decided to retain use of the Species Equity Formula, but to focus attention around roosts. Roosts received differing levels of reservation according to their importance.

<u>*Miniopterus schreibersii*</u>

Initially, separate reservation priorities were assigned for roosting and foraging habitat, but experts decided during Workshop 2 – Coastal to set a target only for roosting habitat, and drop foraging habitat from the process. This approach was continued in Workshop 2 – Tablelands.

Three grades of non-maternal roost were defined:

- Roost 1: sites with long term persistence of relatively large numbers of bats
- Roost 2: sites known to host large numbers of bats or be important as staging sites for females en route to maternity sites
- Roost 3: sites used episodically by a few bats, or now perhaps abandoned.

Targets were assigned as outlined below. Core, intermediate and marginal habitat grades were assigned as concentric rings based on distance from the roost, and densities of bats estimated for each. The radius presented is the distance of the ring from the roost.

- Maternal roosts: 1km radius core, 10km intermediate, 30km marginal.
- Roost 1: 750m radius core, 5km intermediate, 30km marginal
- Roost 2: 100m radius core, 3km intermediate, 15km marginal
- Roost 3: 50m radius core.

A single target area was set, split 50% Coast, 50% Tablelands.

<u>*Rhinolophus megaphyllus*</u>

Foraging and roosting habitats were not distinguished for Rhinolophus megaphyllus, but it received a relatively high reservation priority to reflect the need for protection of roosts. Only a few roost sites are known for this species, but, as it does not forage far from roosts, there must be a roost not yet identified near all known records. Experts feared that important sites would be lost from the process if all attention was focused around known roosts. Likewise, if all known records were buffered, important areas could be missed where it hadn't been surveyed for. The model developed for this species focused on occurrence of foraging habitat. It was not possible, with current resolution of geological data, to develop predictive models of roost occurrence. Experts agreed to develop buffers around known roosts and rely on the model to select additional sites where roosts had not yet been located.

Separate targets were assigned for Coastal and Tablelands, as the species is relatively immobile. Coastal R. megaphyllus are heavier and darker than those from inland, which suggests the populations may be distinct. Tablelands densities were considered to be lower than Coastal.

Chalinolobus dwyeri

Experts emphasised that much uncertainly exists as to how best reserve for this species, given lack of data. They agreed, in the absence of further information, to create buffers around the known roost sites, and around known records not at a roost. Habitat grades were assigned and the Species Equity formula used to generate a target. A single target area was set, split 50% Coast, 50% Tablelands. Experts highlighted that achieving this target does not equate to adequate reservation of the species, but is the best they could do with available data.

- Roosts: 1km radius core habitat, next 2km radius intermediate.
- Other records: 2km buffer of intermediate habitat.

Myotis macropus

Only one roost site, at Lake Burrenjuck, is known for this species. This roost is thought to be maternal. Experts agreed to define a buffer of radius 1km around the roost as core habitat, and define all habitat over or within 100m of the lake within the next 3km radius as intermediate grade habitat. The target set for this species is the total area of core and intermediate habitat. Other records for this species were left to protection by prescriptions.

Fruit Bats: *Pteropus poliocephalus* and *P. scapulatus*

Fruit bats are colonial and nomadic. Camp locations are traditional, but are only used when sporadic flowering resources are available. It is not clear what features repeatedly draw bats to traditional sites, so it is difficult to know how best to manage them. In addition, foraging habitat is difficult to predict due to seasonal and annual changes in flowering patterns. As areas of suitable habitat shift throughout and between years, the area of modelled habitat is large, resulting in low density estimates and large targets for both species. Being relatively marginal on the Tablelands, fruit bats occur less regularly than on the Coast. On the Coast, experts elected to focus attention around camps by defining habitat within 500m as core. Other modelled habitat was graded intermediate or marginal. The Species Equity formula was then applied to modelled habitat. Precise locations of camp sites on the Tablelands are not known, so it was not possible to buffer these as was done on the Coast. Instead, habitat grades were based on suitable vegetation types and the Species Equity formula used to generate a target area.

Other species for which Target Formula inappropriate

Highlands Tree-frog – *Litoria littlejohni*

L. littlejohni is a rare species, with very little known of its habitat requirements. It possibly has migratory habits, and therefore may require large areas of habitat. Experts considered a 250m radius buffer around known records should encompass all habitat needs. Given the rarity of the species (only 4 records in the Southern Region), this comes to a total of only 77ha.

Death Adder – *Acanthophis antarcticus*

No model was available so experts agreed on a 2km radius buffer to be reserved around all known records. This amounts to a total target of 4987ha, based on 6 records in the Coastal part of the Southern Region.

Brush-tailed Rock Wallaby

Insufficient data was available to develop a predictive model for this species, so experts generated a model based on buffers around the single extant record and historical records which occurred within 2km of areas of high ruggedness. The target area was the summed area of these buffers. Experts acknowledged this might result in suitable habitat being missed during reserve selection, but were unable to generate a more satisfactory model in the absence of additional data and suitable GIS layers.

Smoky Mouse

As with the Brush-tailed Rock Wallaby, an adequate predictive model could not be generated based on available data and GIS layers. Experts elected to set buffers around known records, the target area being the total area of these buffers. Concern was raised that key habitat could be missed by this approach, but agreed to proceed given a lack of alternatives. Experts highlighted a need for research into suitable management practices for the species, and for targeted surveys to refine knowledge of habitat requirements.

Final Target Areas

Once any modifications to the Species Equity formula were taken into account, target areas were calculated using data collected in the two workshops, or determined to be the area of set buffers. Target areas allocated to each species are listed in APPENDIX 8. The number of targets allocated to each species and the basis for these are listed in APPENDIX 9.

Experts then outlined on maps how they wanted the target area allocated to the modelled habitat (eg north-south spread of target so not all clumped into one area, areas of lesser importance excluded from the model etc). These maps were retained by NSW National Parks and Wildlife Service, to be used in loading C-Plan.

3.1.6 Species for which targets were not set in one or both subregions

Terrestrial Fauna

For all of these species, insufficient data and/or GIS layers were available to generate an adequate model.

Eastern Pygmy Possum

Targets were not set for either subregion. Despite extensive survey effort, few records were available and there was not a clear enough pattern in their distribution to generate a predictive model. Concern was raised over effectiveness of survey techniques. While generally a coastal species, some records occurred in the Tablelands subregion. The species was given a preliminary listing as Vulnerable under NSW legislation in October 1999, and experts agreed to management of existing records by prescription once drafted.

Brush-tailed Phascogale

Targets were not set for either subregion. On the Coast only three data points were available, and experts were very uncertain about making recommendations on such scant data. It was not possible to model or otherwise select suitable habitat with any degree of certainty with the available data. Experts commented that, on the Tablelands, habitat for the Brush-tailed Phascogale was closely associated with Squirrel Glider habitat, but did not have sufficient confidence in the Squirrel Glider model to rely upon it for this species too.

Experts were reluctant to buffer existing records in either subregion, as they were not confident they adequately reflected the distribution of the species, and opted instead for management by standard prescriptions.

Barking Owl

Targets were not set for either subregion. On the Tablelands, experts acknowledged that lack of data was due in part to lack of sampling effort, but considered Barking Owl conservation to be largely a private land issue. Experts considered development of a prescription around known records was a preferable option for management of this species. SF and NPWS need to liaise with experts to develop an appropriate prescription. Such a prescription should focus primarily on riparian zones.

Masked Owl

A Coastal target was set, but no target was set for the Tablelands subregion. The Masked Owl is largely a coastal species, although there are some records in the Tablelands subregion. Experts thought available records on the Tablelands were probably not representative of the distribution of the species. Moreover records were probably not roost sites, so buffering was not likely to benefit the species greatly.

Bush Stone-curlew

Targets were not set for either subregion. Experts regarded the Tablelands subregion as probably more significant than the Coast for this species. Experts thought rather than a general prescription for this species, that individual prescriptions be developed through liaison with NPWS on a record-by-record basis.

Myotis macropus

A Tablelands target buffering the single known roost site was set, but no target could be set for the Coastal subregion or to protect other known records of the species. Little location data is available for this species, but its feeding behaviour is understood to be above water. Systematic, targeted surveys are needed to provide accurate distribution data. Much better stream attributes data are needed to model the habitat of this species. Experts agreed to leave the species to protection by prescriptions.

Saccolaimus flaviventris

Targets were not set for either subregion. Experts considered this species to use a wide variety of habitats. It forages over a large range, so buffering around known records was less appropriate than for less mobile species. It has a preference for areas with large trees and hollows, but it is likely that whatever is reserved for other species will benefit this species to some degree. Experts noted the requirements of this species are poorly understood, and that it is in need of further research.

Scoteanax rueppellii

A Coastal target was set, but no target was set for the Tablelands subregion. Records of this species in the Tablelands subregion were unreliable and scarce. However there are apparently real absences of the species from inland. Experts elected to exclude this species from the Tablelands target setting process primarily due to uncertainty around accuracy of records.

Pseudophryne australis

No target was set for the Coastal subregion. The species does not occur in the Tablelands subregion. Only one record was available, already within National Park. The model was inadequate for highlighting habitat for this species, and needed additional data to be of use. The species was considered to be well reserved to the north of the Southern Region.

Aquatic Species

Experts felt generating a target land area was not appropriate for aquatic species, and that a linear length of reserved stream would be more relevant. There was also a general agreement that, while some of these species are under extreme risk of extinction (in particular Trout Cod and Macquarie Perch), the issues facing these species are not likely to be addressed by reservation of forested habitat or by forestry protocols. More important issues are other river-use practices such as flood mitigation, de-snagging and timing of release of water from impoundments.

3.2 FLORA

3.2.1 Species Lists

The reviewed list went out to all experts involved in the Threatened Flora workshops prior to the workshops, and was subsequently finalised and agreed to by all experts during the workshops.

After the final expert review, 135 taxa (or metapopulations) were identified as high priority for further CRA assessment (H), high Conservation Rank (C1-C3), and forest or forest catchment/envelope dependent (APPENDIX 10). Of these 71 were identified as Presumed Extinct, Endangered or Vulnerable (as listed on the NSW Threatened Species Conservation Act or the Commonwealth Endangered Species Protection Act, and as identified during the RTD workshop assessments), 59 taxa were identified as Potentially Threatened, Threatened, Rare, Uncommon or Poorly Known (ROTAP taxa, as noted in the Flora of NSW, or as identified during the RTD workshop assessments) or Declining Regionally, and 5 taxa were considered Regionally significant. As a consequence of the review of the conservation ranks, 9 taxa were identified that may warrant listing on the TSC Schedules, while two taxa were identified that may warrant downgrading from E to V.

3.2.2 Conservation Targets

A total of 8 taxa had their occupied habitat identified. These taxa are shown in APPENDIX 10 and have a target type called “mapped area”. The areal targets to be applied to the mapped areas incorporate some of the principles of the Burgman protocol, such as F and the types of threats, and are given as a percentage of the mapped area. In all cases the percentage target was 100% of mapped area. For three of the taxa a weighting that reflects differences in the habitat quality (referred to as “carrying capacity” in APPENDIX 11) of different polygons of mapped area was utilised.

A total of 127 taxa were given locality based population targets for the Southern CRA region. Of these, 10 taxa had each location buffered according to its population size (APPENDIX 10 and 11). These included 62 taxa with a 100% target, 31 taxa with a 80% target, 20 taxa with a 60% target, 1 taxon with a 40% target , 9 taxa with a 20% target and 4 taxa with a 10% target.

3.2.3 Habitat Models

Initially around 30 species were considered by experts as reasonable candidates for modelling. Due to delays in the arrival of critical data layers, only a few preliminary models were available for review at the time of the first workshop. After reviewing some of these preliminary models, experts had concerns about the quality and usefulness of many of the models, and subsequently nine species were identified for which further attempts at modelling may be useful. NPWS carried out further modelling and expert review between the two workshops, but at the conclusion of the final workshop no models were accepted by experts. In some cases this was due to continuing concerns about the quality of the models (which could have been improved given more time and expert input). In order for the models to be usefully applied within C-Plan, the models need to be of a high enough quality so that there is a reasonable level of comfort that when meeting target within modelled areas that you would be actually selecting potential habitat. However, even for the better quality models there were concerns about the usefulness of the concept of potential habitat in the context of the current RFA process (absolute priority should be on known localities). Finally, since many of the calculated areal targets could be met in existing known occupied patches, which due to much greater densities (than potential habitat) would also contain many more individuals, and because of the much higher priority of including known localities, it was decided by experts to be preferable to use mapped occupied habitat rather than modelled potential habitat.

3.2.4 Reservation Priority Ranks

The final rankings are given in Appendix 10. The number of taxa classified into each of the five classes is given in Figure 3d. It should be emphasised that the rankings are relative, and that taxa assigned a lower priority are still likely to require some level of formal protection.

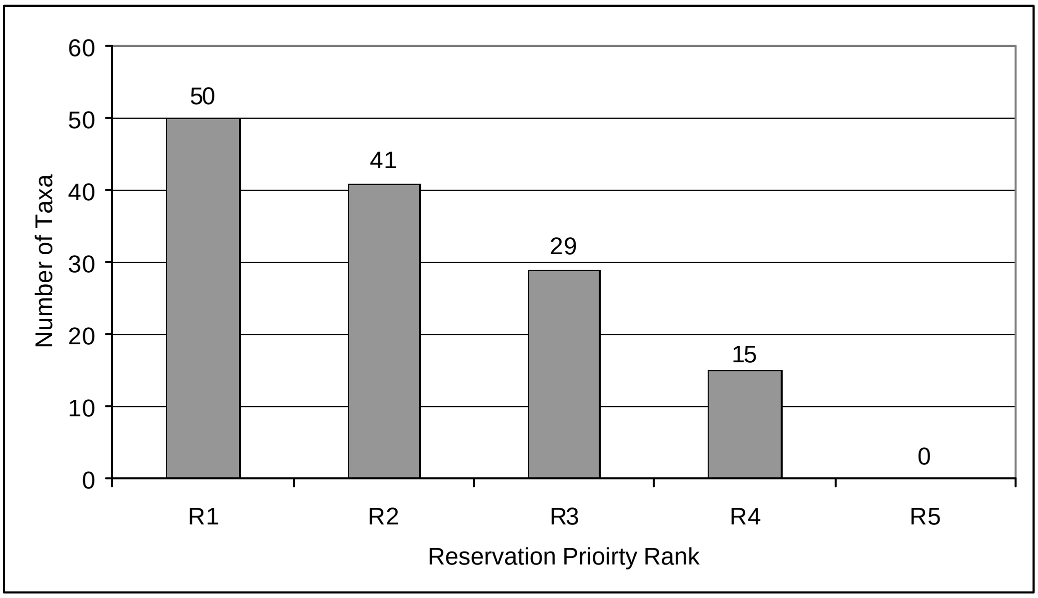

Figure 3d: Distribution of Reservation Priority Ranks for Priority Flora in Southern CRA region

3.2.5 Application of Targets

Buffering of points

It was decided that, where possible, point localities should be weighted according to the relative number of individuals at each locality. This was to ensure that, as C-Plan seeks the targets, localities with large populations are more likely to be included in any reserve scenario because they contribute a greater proportion of the overall target. The best way to achieve this weighting was to use buffers of varying sizes (and hence varying area) which indicates the relative size of the population relative to other populations, the target is then expressed as a percentage of the overall “area” of all populations for any particular taxon. Only taxa with reasonably well known population numbers could be buffered in this way. Those taxa that have been dealt with in this way are described as “Buffered point” in the target type field in APPENDIX 10.

Subregionalisation

Targets were rarely set on the basis of subregions. Where they were recognised they were considered by experts to most probably represent genetically isolated if not genetically distinct meta-populations.

4. DISCUSSION

4.1 FAUNA

4.1.1 Species List

The fauna species, assessed as part of the Response to Disturbance project, included all vertebrates considered to be forest dependent that were scheduled under either the *ESP Act* 1992 or the *TSC Act* 1995, as well as other species that agency staff and experts felt were of concern. Although aquatic species were included for assessment, ultimately targets were not set for this group. Experts in the aquatic species workshop commented that a listing of threatened or endangered might not have been the most appropriate criterion for inclusion of aquatic species, and would have preferred a list of more forest dependent species for assessment. It was also commented that very little is known about the aquatic species listed, and it may have been more appropriate to consider more common species, as threats to them are better understood. The only invertebrate listed for assessment was the Murray River Crayfish. Ideally additional invertebrates would be considered, however time and resource limitations meant this was not possible.

4.1.2 Habitat Requirements

The habitat requirements of species were identified for 2 reasons:

(1) to help focus the workshop participants on the disturbances likely to affect species; and

(2) to provide the ESFM committee information that will help develop management prescriptions for species.

Information collected in Response to Disturbance assessments for Eden and the Upper and Lower North-east Regions was provided to experts during this assessment. This information was then modified and updated to apply to the Southern Region. Experts found this approach to be effective and much more efficient than identifying habitat requirements from scratch, as was done in the Eden and Upper and Lower North East assessments.

4.1.3 Disturbances

Disturbances were generally less well understood than habitat requirements of species. However the process of identifying habitat requirements helped experts assess likely disturbances and their relative seriousness.

Land clearing was identified as by far the most serious threat to the species assessed. Not only was it the most commonly nominated disturbance, it was also the disturbance ranked highest for most species. Because most clearing occurs on private land, experts consistently emphasised a need to address vegetation managment on this tenure.

Other frequently nominated disturbances included habitat fragmentation, logging and predation. In many cases habitat fragmentation is a by-product of habitat clearing, so also difficult to address under the RFA process. However recognition of need for continuity of habitat can focus attention to reservation of remaining forested linkages, as well as highlight areas where replanting could restore connectivity. Unlike land clearing, logging does not have a permanent impact in all cases. This means that some species may persist in a logged landscape, albeit at lower densities. The impacts of logging may be managed effectively for some species. However, species that have habitat requirements typically found in old growth forests, such as hollows or deep leaf litter, are the most susceptible to commercial forestry (Scott 1991) and would therefore be the most difficult to manage. Vertebrate pests are also possible to manage effectively, however most techniques are costly (Olsen 1998).

Some species require attention on private land to adequately meet their needs. These could not be addressed by this process, but experts requested these species be mentioned in the report so the information was available to be addressed by some future process.

4.1.4 Reservation Priority Ranks

The estimation of the reservation priority ranks was difficult due to the subjective nature of the task. However by first identifying disturbances then ranking species in order of reservation priority, experts were better prepared to make decisions regarding the need for reservation of each species. While initially there were some discrepancies in ranks allocated by different experts, these readily were resolved in ensuing discussions. While ranking appeared fairly consistent within each species group, rankings for some groups tended to be overall rather higher than for other groups. The presence of the same generalist expert throughout all species group workshops aimed to keep some consistency in scoring, and some of these higher rankings can be explained by these species groups being under relatively greater threats.

The ranks were meant to reflect the relative priority of each species to be included in a formal reserve based on the disturbances affecting them. This means that some seriously endangered species were ranked as in less need of reservation than some less threatened species as their threats are not likely to be addressed by formal reservation alone. Such threats include disease and predation, which occur on all land tenures. High reservation priorities were not exclusively allocated to species vulnerable to forestry activities. Species affected by processes occurring largely on private land were also allocated high reservation priorities if it was considered they would benefit from formal reservation. Such threats include land clearing, which was overall regarded as the most serious threat to species.

A concern was raised about reservation of habitat for the Spotted-tailed Quoll. This species is sensitive to 1080 poison baiting, routinely used to control pest species such as foxes, wild dogs and rabbits. Poisoning can occur both through consumption of poisoned baits targeting pest carnivores, and also as secondary poisoning through consumption of poisoned rabbits. Aerial bait delivery is of particular concern, a method used by NSW National Parks and Wildlife Service in some National Parks. Unless this practice is ceased, reservation of habitat for quolls could actually be detrimental to the species, and experts were uneasy about assigning a high reservation priority if this was to be the case.

4.1.5 Application of Species Equity Target Areas

The size of target areas provided by the Species Equity Formula was influenced by estimates of the three parameters, Reproductive Longevity, Trophic Level and Density. Experts were fairly confident in their estimates of Trophic Level but found estimating Reproductive Longevity more difficult, particularly for species that were not well known. This was the case for many frog and bat species and some reptile species.

Density was the most difficult parameter to estimate and had the greatest influence on the size of the target area. Density estimates were influenced by model quality, which was in turn influenced by available GIS data layers and information on distribution and habitat requirements of the species. Where density estimates were low due to broadness of the model on which they were based, very large target areas were generated. There was a fear such targets may not be met during negotiations, and experts wanted it made clear the size of these targets was due to a lack of better data with which to develop a tighter model, not that species necessarily required such a large target area.

Nomadic species that required flowering vegetation received very large targets, of which only a small bit, if any, may be occupied at any one time. This is because seasonal and annual changes in flowering patterns make prediction difficult and all of the predicted habitat may be necessary at some point in time. This issue was particularly compounded for fruit bats, which are colonial as well as nomadic, resulting in sporadic occurrences of these species at locally very high densities. Density is the number of individuals over the entire modelled area, so was very low for these species, resulting in very large targets. It was commented that off-reserve management is essential for these species.

The densities estimated reflect current disturbance regimes. If some or all of these disturbances were to be ameliorated, densities would be higher, which would result in smaller target areas. The placement of habitat into a reserve system could increase the densities of species threatened by processes that occur off reserve. This means the area needed to conserve this species could be lower than predicted using the current method.

While the workshop participants recognised that the method used for developing targets was better than some alternative approaches because it attempted to base target areas on the ecological needs of the species, there were some issues raised where they felt the process was not appropriate. The Species Equity formula is necessarily simplistic to encompass the diverse needs of as many species as possible. Moreover, data are not available to develop a more refined approach for each species. However experts wished to highlight that there are some species whose particular needs could not be adequately addressed by the generalised CRA process, and more individual attention is needed.

Experts expressed a concern that the process favours species for which more information is available. These are generally relatively less threatened species. Lack of data meant targets could not be set for some threatened species, or very broad targets were set which may not be entirely appropriate to the species, but were the best estimate possible given current knowledge. For some other species, experts elected to set buffers as targets rather than using predictive models. Lack of data gave little option other than to simply protect the areas that have been identified to date, but there is considerable risk with the buffer approach that important habitat has not yet been identified, and hence may miss out on reservation. Experts raised a further example of some relatively mobile bat and bird species, where presence records do not necessarily reflect a requirement for that habitat as the individual may simply be passing through. On the other hand, potentially the area could be vitally important. Protection of roosts for species like these is probably of greater importance, but information often does not exist as to locations of roosts.

There was a concern that successfully meeting a target conveyed the impression that species had been adequately reserved, when the target may have been quite a poor estimate of the species needs. Experts emphasised the urgent need for further data on many of the species addressed by the process, to ensure their needs are in fact being met.

Experts in the Frog species group workshop commented that reservation of habitat for the Stuttering Barred Frog, *Mixophyes balbus*, will only partially address threats to the species, and that other issues such as disease will not be aided by reservation. It is likely that a similar situation exists for some other species in the process, where reservation will benefit the species to some degree, but does not address other processes that threaten the species.

4.1.6 Conclusion

After some discussion within the workshops, consensus was reached on a suitable target for each species addressed by Workshop 2. Experts also agreed when it was not possible or appropriate to set a target for a species. The methods used by the RTD project sought to capture as much information, as possible, on the priority fauna species. Due to a paucity of data on many of these species the project largely relied on the experts who work on the species involved. These experts provided data from a range of sources including published and unpublished studies, work in progress as well as personal observations and opinions. Some of the assessments were relatively subjective adding to the difficulties facing experts to provide consistent information. It is truly a credit to the experts involved, and adds confidence in the findings of this project, that at the end of the workshops there was agreement on the vast majority of information used and outcomes generated by the assessments.

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4.2.1 Conclusion

The RTD workshops were conducted in a spirit of consensus and were successful to the extent that virtually all of the outputs from the workshops were ultimately agreed to unanimously. On the odd occasion where the panel could not reach unanimous agreement, the dissents from the majority decision were documented. The information collected during the workshops was based on the best available data, current knowledge in the form of published and unpublished literature, and the detailed knowledge of a number of experienced field ecologists/botanists. Emphasis was placed on ensuring equitability between species in assigning targets as much as practicable, and to use the decision support tools as they were intended. That is, as frameworks to guide experts in developing the conservation requirements of threatened species. The inputs and final outputs were thoroughly reviewed throughout the workshops and ultimately, the critical outcomes (areal and population targets, reservation priority ranks) were expert derived and based on the best available data but where necessary incorporate their best judgement.

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APPENDIX 1

APPENDIX 1.1 AREAL TARGET SETTING PROTOCOL

Decision Support for Setting the Size of Plant Conservation Target Areas.

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Abstract: *Realistic time frames in which management decisions are made often preclude the completion of detailed analyses necessary for conservation planning. In these circumstances, efficient alternatives may assist in approximating the results of more thorough studies achievable given extensive resources and time. This study outlines a set of concepts and formulas that may be* *used in lieu of detailed population viability analyses and habitat modeling exercises to estimate the protected areas required to provide desirable conservation outcomes for a suite of threatened plant species. The method rests on the assessment of a population size that will result in a specified quasiextinction risk, based on very simple dynamic models. The area required to support a population of this size is adjusted to take into account deterministic and stochastic human influences. Targets may then be set for different disturbance regimes and geographic regions. Example applications are provided for some Australian plant species.*

Keywords: threatened plants, extinction, protected areas, decision support

Introduction

Governments throughout the world are formally committed to comprehensive, representative and adequate reserve systems. While the issues of comprehensiveness and representation may be addressed using reserve-design algorithms and gap analysis (Margules *et al.* 1988, Pressey 1994, 1995, Pressey *et al.* 1996, 1997), the issue of adequacy is best explored with population viability analysis (Boyce 1992, Burgman *et al.* 1993, Possingham *et al.* 1993). The Australian government has committed itself to adequate reserve systems, which conserve “viable” populations of all species throughout their natural range (e.g. JANIS 1997). A species may be considered viable if it faces a ‘small’ risk of decline or extinction or a negligible contraction in range within the next few decades. The notion of a viable population often is not clearly defined yet is essential if the issue of an adequate reserve system is to be addressed.

Vascular plants frequently are the focus of conservation efforts because their taxonomy is relatively complete, knowledge of species distributions is relatively good, and vegetation maps are used as surrogates for other elements of biodiversity in conservation planning (Elith 1999). For vascular plants in many Australian environments, processes that affect viability include both stochastic disturbance and deterministic pressures. Planning for individual species requires some kind of formal assessment of the risks posed by different impacts, and population viability analysis provides one avenue for synthesizing available knowledge.

There are many computer-based simulation tools for estimating viable population sizes and minimum viable habitat areas (see, for example, the review by Lindenmayer *et al.* 1995). Population modeling has been used to develop conservation strategies for a large number of animals and for many plant species. The number of published plant models allows some generalization about model structures, levels of variability and related issues (see Klemow and Raynal 1983, Mack & Pyke 1983, Burgman & Gerard 1988, Groenendael & Slim 1988, Moloney 1988, Venable & Brown 1988, Roerdink 1989, Menges 1990, Burgman & Lamont 1992, Ouborg 1993, Bradstock *et al.* 1996, Eriksson 1996, Nantel *et al.* 1996, Oostermeijer *et al.* 1996, Quintana-Ascencio & Menges 1996, Silvertown *et al.* 1996, Dreschler *et al.* 1999). However, in many decision-making processes, there is insufficient time to develop models for more than a handful of species. In most cases, expert judgement will determine the outcomes.

Here we present a protocol for setting a reservation target for any plant species, particularly useful when there are insufficient data or time to conduct population viability analyses. The approach is not intended to be an alternative to other ways of setting priorities and we acknowledge at the outset that the method has many limitations (see Appendix 1). It is intended to provide a decision-support framework within which the status of the knowledge concerning each species may be considered, facilitating discussion about how best to set conservation targets to protect a suite of species in a context that is relatively transparent. The method is designed to be efficient, so that in a short period of time (a few weeks), a group of experts might be able to set area conservation targets for many of the threatened taxa (100 or more) in a region. To emphasize the uncertainty inherent in the protocols, this study includes calculations of bounds on estimates of target areas for adequate conservation.

The need for an efficient decision support tool that uses available information is driven by the very short time frames, and the social and political imperatives of land use decisions. In Australia, the state, territory and federal governments have agreed that an extensive and permanent native forest estate would be maintained and managed in an ecologically sustainable manner with parallel development of internationally competitive and ecologically sustainable forest-based industries (CoA 1992). A vital element of the National Forest Policy Statement was that joint Commonwealth - State Comprehensive Regional Assessments (CRAs) of the environmental, heritage, social and economic values of the forests would be undertaken to develop a reserve system. One of the challenges for the planning process is to prescribe adequate conservation strategies for a large number of threatened plant taxa (more than 5,000 throughout Australia; Briggs & Leigh 1996). While community level reservation may accommodate common and widespread species, rare and threatened species tend to occur in localized or specialized habitats and their conservation needs must be specifically addressed (Keith 1990, Lynch 1994).

Method Overview

It is important that any method for setting conservation goals should take into account processes that lead to deterministic decline, as well as those that result in extinction from stochastic events (Caughley 1994). This study describes several mechanisms by which the consequences of both kinds of processes may be evaluated. The development of the protocol depends on the following general principles about extinction:

- All populations face some risk of decline and extinction, simply because they are exposed to the vagaries of natural temporal and spatial variation, even in habitat that is unaffected by human impacts. These background risks may be approximated by simple population models that include environmental and demographic variation. General guidelines outlined below are based on both simple models and the results of detailed population models for plants.
- To minimize the number of plant extinctions in the medium term, priorities for conservation should reflect the risks faced by different taxa. The allocation of protection measures should be guided by an understanding of the kinds of threats that may be mitigated by reservation or active management.
- Disturbance regimes may be modeled as processes resulting in an expected proportion of habitat remaining available throughout the period over which risks are evaluated.
- Catastrophes may be implicated in the local extinction of many plant taxa and conservation strategies are developed to minimize the risk of global loss.

The target-setting protocol is divided into a series of steps. Each step accounts for an assessment of habitat, or for one kind of deterministic or stochastic process that affects the area necessary to achieve a conservation goal (Fig. 1). The data required for implementation of the method are relatively modest, compared to those required for a detailed PVA (Table 1).

In many cases, direct, reliable estimates of these parameters will not be available. However, quantitative information based on subjective (expert) judgement may be adequate (Seiler & Alvarez 1996). The nature of conservation planning is such that decisions are made without full scientific knowledge. The protocols outlined below provide a transparent means of incorporating expert knowledge into a process for setting conservation priorities.

Incorporating uncertainty

Uncertainties should be propagated through the calculations and reported. The first step is to provide a best estimate and plausible upper and lower bounds for each of the parameters in Table 1. In most instances, confidence intervals or other formal statistics of dispersion will be unavailable, in which case, bounds may be estimated subjectively (Seiler & Alvarez 1996). Uncertainties in the parameters may be incorporated in the methods outlined below by applying the rules of interval arithmetic (Alefeld & Herzberger 1983) to the intervals formed by the upper and lower bounds of each of the parameters.

Detailed steps

Step 1. *Estimate the population size likely to persist under the influences of demographic and environmental uncertainty, assuming an environment free of disturbances characteristic of recent human landuse practices (F).*

We use a risk of quasiextinction, a 0.1% probability of falling below 50 adults at least once in 50 years, to provide a background risk against which to measure the utility of conservation actions. The benchmark of 50 years reflects the fact that concerns are with risks on a scale over which current management prescriptions may be effective. Risks measured over relatively short time-frames may suggest management actions at odds with those measured over longer periods (Menges 1998). We envisage that the reserve decisions made at this point will have most importance over the next 50 years. Over longer periods, other priorities and conservation strategies are likely to take precedence (but see the caveats in Appendix 1).

The benchmark of 50 adults acts as a common reference point for different taxa and represents the lower bound for the size of the population that we find unacceptably small for any species. The protocol could have used extinction as the benchmark, but populations of fewer than 50 adults are sufficiently small that processes other than those found in most population models (such as Allee effects and genetic processes) play a role. We have elected to concentrate on adult plants, defined as reproductively mature individuals, to provide a means of dealing with species with different life forms and life histories, and to remain consistent with IUCN (1994) conventions. For example, many plants have soil stored seeds that provide a buffer against adverse environmental events, while others persist using underground perenniating organs. These factors are accounted for in the estimation of the parameters for the equations used to calculate sufficient population sizes experiencing background disturbance regimes. Overall, the criteria represent a very modest target for the conservation of species, within a realistic management time frame. As the caveats in Appendix 1 suggest, values for F or the benchmarks of 50 adults and 50 years may be varied to suit species such as long-lived species or ephemerals with long-lived seed banks.

The quasiextinction risk criterion is expressed in terms of current population size by estimating an initial population size for each taxon such that there is a less than 0.1% chance of the population declining to 50 individuals at least once over the next 50 years. This implies that an outcome that involves about 25 of 25,000 Australian vascular plants becoming critically endangered within the next 50 years is acceptable. We assume that biologists can estimate this population size for each taxon, but we outline some guidelines.

The estimate of the parameter F is based on the background risk of extinction of the taxon, a benchmark likely to approximate the risks faced by many natural populations free of additional (recent) disturbances imposed on the landscape (in Australia, this implies disturbance imposed since 1750). It provides a standard against which to compare the relative risks faced by different taxa.

Ideally, the values for *F* should be based on the best available population model, taking into account factors such as seed bank dynamics, disturbance response mechanisms, life history, demographics, outbreeding/selfing characteristics, and genetic homogeneity. In the absence of a species-specific model, *F* may be calculated based on a simple birth and death model. We have constructed such a model for a single population, with a growth rate approximately equal to its death rate (Table 2) and have calculated values of *F* for several taxa, based on detailed population viability analyses for individual species and on more generic models reflecting broad life-history traits. These species represent several of the functional groups identified by Noble and Slatyer (1981) including obligate seeders and resprouters, species with short and long-lived seed banks, and species in which adults are susceptible to disturbance. Table 2 is intended only as a guide.

The values for survival and variation and hence for *F* may be adjusted to reflect the biology and life history of a taxon that are likely to affect the background risks of decline. For example, persistent soil-stored seed will reduce the probability of extinction of a local population, and will reduce the value of *F*. Species with poor dispersal abilities may require larger *F* values (Table 3). Any such modifications could be guided by a simple model that accounts for demographic variation and moderate levels of environmental variation in an unstructured or stage-structured single population model without density dependence (examples are provided in Table 2). The number *F* may be smaller than the current population size, especially for abundant species. If *F* is less than the number that currently exists, then it implies that if there are no additional detrimental processes or catastrophes, then we may experience the loss of some individuals and still expect the species to have an acceptably low risk of quasiextinction.

Step 2. *Identify populations or groups of populations that currently experience similar disturbance regimes (termed disturbance regions). Perform all subsequent analyses on each disturbance region.*

Disturbance regions represent areas of the landscape that are subject to similar sources and intensities of disturbance. It will be necessary to characterize differences between regions in terms of their frequency and extent, and to estimate the time to recovery of the species following disturbance within each region. In this context, a disturbance is any process resulting from recent (post-1750) human activities that affects the abundance and distribution of plant taxa. Because only human disturbances are counted here, in many cases, land tenure may be a reasonable guide for defining disturbance regimes.

Step 3. *Identify and map the area of potential habitat.*

It is assumed that a map of the potential habitat for each species is available for each disturbance region, representing the part of the landscape in which a species may grow and reproduce. Potential habitat may be defined by any of several methods. For example, it may include all areas considered by an expert to be capable of supporting viable populations of the species in question. Alternatively, it may be defined by a set of spatial climate and/or environmental data layers and a bioclimatic model, or by a multiple regression model of existing locations together with data layers for each of the explanatory variables (Austin *et al.* 1990, Wiser *et al.* 1998, Elith 1999).

Other measures of the area inhabited by a species include the area of occupancy and the extent of occurrence (Fig. 2). Neither of these is ideal for the purposes of the protocol. The area of occupancy is the smallest area at any life-history stage essential to the survival of existing populations of a taxon (IUCN 1994). It represents currently occupied habitat. Extent of occurrence was defined by the IUCN (1994) as the area contained within the shortest continuous imaginary boundary, which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon, excluding cases of vagrancy. Extent of occurrence can often be measured by a minimum convex polygon (the smallest polygon in which no internal angle exceeds 180 degrees and which contains all the sites of occurrence). The measure reflects the fact that a taxon will not usually occur throughout the area of its extent of occurrence, which may, for example, contain unsuitable habitat and unoccupied suitable habitat. In the vast majority of circumstances, potential habitat will be larger than the area of occupancy and smaller than the extent of occurrence because it includes unoccupied suitable habitat and excludes unoccupied unsuitable habitat. Caution must be exercised in estimating the area of potential habitat to account for competition, predation and disturbance, which might exclude a species from otherwise suitable locations.

Step 4. *Outline the area of potential habitat surveyed.*

In some circumstances, all potential habitat will have been surveyed systematically, and occurrences of the species mapped reliably. Parts of a species' potential range may have been surveyed in some repeatable fashion, using standard sampling techniques. Surveys may have been intended to record presence/absence of the species, or to estimate abundance. Most often, maps of potential habitat are based on opportunistic records and expert judgement. Distribution information based on herbarium records (opportunistic presence-only information) may be supplemented by expert judgement of absences. Irrespective of how the information is acquired, the portion of the potential habitat that has been searched should be outlined. The area of potential habitat searched within disturbance region i is termed H_i (Table 1).

Step 5. *Estimate population size and calculate average population density.*

Estimate the size of the adult population within the surveyed potential habitat (N_i). The estimate may be derived from quantitative survey information if it is available, or from expert knowledge. Use this estimate, together with the surveyed area, to calculate the number of adult plants per hectare (D),

$$D = N_i / H_i.$$

The average population density, D, estimated here should represent the average density of reproductively mature plants within potential habitat, accounting for the fact that the plants persist under the perturbations of a natural disturbance regime. It should not include any additional (anthropogenic) sources of disturbance considered explicitly in later steps.

Plant density may be calculated or estimated per disturbance region, although it may be very difficult and time-consuming to have the experts arrive at density figures for each disturbance region and to quantify 'areas searched' without considerable uncertainty. It may be preferable to use the density figure based upon a single habitat model for all calculations but retain some scope for experts to adjust the figures to reflect the long-term average density expected within potential habitat. In most cases, the long-term average density will be best reflected in the disturbance region that has least subjected to anthropogenic disturbance. For any particular species, it may be preferable to use the density figure for a disturbance region that represents the most undisturbed habitat.

Step 6. *Estimate a target area for protection based on background disturbance processes.*

The raw target area for reservation or protection, A_0, is the area of potential habitat required to support a taxon, given particular life-history characteristics, such that it has a less than 0.1% chance of falling below 50 individuals, once in the next 50 years, assuming pre-1750 conditions;

$$A_0 = F / D.$$

Step 7. *Modify the target area to account for additional (anthropogenic) disturbances.*

Step 7a. *Identify relatively small-scale disturbance impacts affecting the species' potential habitat from which the species recovers within the management time frame of 50 years. Use estimates of the* *characteristics of these disturbances to calculate the proportion of potential habitat that will be available to the species at any time.*

Identify the different kinds of stochastic impacts that may lead to an area being unsuitable. This could be a single event such as a prescribed fire at a particular time of year, or a logging effect. More typically it will be a combination of events such as two or more fires in a short time interval. These are termed adverse regimes 1, 2, 3 etc. The average annual area of these impacts should generally be less than the total potential habitat. We assume that these events are randomly and independently distributed across the landscape with respect to the distribution of the taxon. This is a plausible model for a surprisingly broad class of disturbance processes (Gardner *et al.* 1987, Johnson & Gutsell 1994, Pacala *et al.* 1996, McCarthy & Gill 1997).

Habitat requires n years before it is again suitable for the taxon (termed the recovery time, representing the time between disturbance and the appearance of reproductively mature adults). This parameter is required to calculate the average proportion, S, of potential habitat available to a species each year. If a disturbance has a characteristic annual probability independently distributed across the landscape, the expected proportion of areas that are n years old is equal to the proportion of the area disturbed n years ago (=p) multiplied by the probability that these areas were not disturbed subsequently, $(1-p)^{n-1}$ (McCarthy & Burgman 1995).

The parameter n_d is the time between disturbance and the point at which a plant has developed sufficiently to reproduce. It includes the time to reach reproductive maturity for plants that are eliminated by recurrent disturbance, such as obligate seeders. We may also define n_u, the time between disturbance and the point at which the habitat has developed so that it is unsuitable for the species. This will be relevant for species that inhabit early successional stages within a landscape and which rely on periodic disturbances of particular kinds for germination or regeneration. For these species, the absence of a disturbance may result in unfavorable habitat beyond n_u years.

Given p_x, the proportion of the potential habitat disturbed on average each year by process x within the disturbance region in question, then the proportion of the landscape, q_u, that is undisturbed each year by a total of z disturbance processes is

$$q_u = (1- p_1)(1- p_2) \ldots (1- p_z)$$

where p_1, p_2 are the probabilities of disturbance from processes 1, 2, and so on for z independent processes. Relatively small-scale disturbances are modeled as processes that have similar consequences, making the areas ‘young’ with respect to the ecology of the species in question.

The parameters p may be estimated if any of the following characteristics are known (or can be guessed at);

- the proportion of the landscape (or the population) that is, on average, more than n years old,
- the proportion of the landscape (or the population) that is, on average, less than n years old,
- the average size of disturbance events (annual total area disturbed within the potential habitat), or
- the return time between events (the average time between disturbances at a point in the landscape).

This information may be based on expert knowledge of disturbance processes, or on recorded information such as fire perimeter records, and spatial and temporal analysis of disturbance regimes. It may be that the disturbance regimes are too complex to allow a reliable estimate of the parameters p and n. In such circumstances, it may be easier directly to estimate S, the proportion of the potential habitat that is suitable for occupation by the species.

Given n_d, the recovery time for the species following a disturbance, and n_u, the number of years after the disturbance until the habitat is no longer suitable for the species, then the average proportion, S, of the potential habitat that will be suitable for the species at any time within the management time horizon of 50 years, accounting for disturbances that are either too frequent or too infrequent, is

$$S = q_u^{n_d} - q_u^{n_u}$$

The parameters n_d and n_u encapsulate the window of opportunity for the species. Before n_d, the area is too young for a seed-producing individual to have developed, and after n_u, the area is too old to support the species. We have assumed that the recovery time following disturbance is the same, irrespective of the kind of disturbance.

For example, assume a taxon is adversely affected by unseasonal fire, and this disturbance regime is imposed on the background of a natural fire regime. The taxon recovers naturally after fire because its soil-stored seed bank is stimulated to regenerate by fire. However, suppose there is a 10 year time lag between the fire event and the development of adults that will replenish the seed bank ($n_d = 10$). If the additional fire events burn about 1/80 of the potential habitat annually, then the probability of disturbance for a site, p, is 1/80. We assume there is no upper bound, n_u, in this example. The proportion of the potential habitat that will be suitable for the taxon, given this additional source of disturbance, is

$$S = (1 - \frac{1}{80})^{10} = 88\%$$

That is, about 12% of the potential habitat, on average, will support populations that are too young to withstand other disturbances such as unplanned wildfires because they will have not produced seed to replenish the seed bank that was depleted following the most recent disturbance. Fire management activities effectively reduce available habitat by 12%.

The last element of this step is to adjust the target area to take into account habitat that is temporarily unsuitable due to small-scale stochastic disturbances. The target area should be adjusted such that we may expect an area equivalent to A_0 will be available for a taxon in any one year;

$$A_1 = A_0/S.$$

Step 7b. *Adjust the target area to account for deterministic trends that irreversibly affect the species' potential habitat.*

Such adverse trends cause permanent loss of habitat (at least within the management time frame) and the consequent permanent loss of the species at a site. Examples may include land clearance for agriculture, roads and urban development, or salinization processes. The parameter L is the rate of loss of potential habitat (the proportion of remaining habitat lost to this process) per year due to irreversible attrition. The proportion of the target area, A_1, remaining at the end of 50 years is $A_1(1 - L)^{50}$ and the area of potential habitat required at present such that A_0 could be expected to be available 50 years hence, given i such processes, is

$$A_2 = \frac{A_1}{c_1(1-L_1)^{50} + c_2(1-L_2)^{50} + \ldots + (1 - \sum c_i)}$$

where c_1, c_2 represent the proportion of the potential habitat threatened by processes 1 and 2 during the next 50 years. For example, L_1=0.25 means that 1/4 of the remaining habitat (starting with c_1 in year 1) is lost per year, so in 2 years $9c_1/16$ remains. The values of c_i should sum to be less than or equal to 1. The formula assumes that a proportion, c_1, of the habitat is threatened by process 1. A proportion c_2 is threatened by process 2, and so on. If processes 1 and 2 are coincident in space (such as land clearance and salinization) then they should be treated as a single process. This equation can be used to distinguish between reserved and non-reserved components of the target area if there is a differential susceptibility to irreversible impacts according to tenure. For example, land clearance may be a threat to a taxon on one tenure but not on another.

Step 7c. *Adjust the target area to account for processes that permanently reduce the density of populations within their area of occupancy.*

Some human impacts result in more or less permanent reductions in local population density, without an ongoing decline in abundance or range. Such processes may not necessarily eliminate the taxon from any location, but may reduce the viability of a taxon at a site. Examples may include grazing of livestock or increased disease rates, which result in reduced local population density. Estimate values for r_i, the proportional reduction in local density due to each of the i impacts. The area of potential habitat required to ensure the level of persistence specified at the outset is

$$A_3 = A_2/(\Pi r_i).$$

where Π represents the product of *i* numbers. For example, if grazing reduces the average density of a population within its extent of occurrence by 10% and a disease reduces population density by 20%, then *r* for grazing is 0.9 and *r* for disease impacts is 0.8. The area A_3 will equal $A_2/(0.9*0.8)$.

This is the final step in estimating the total area required for a particular taxon within each disturbance region, such that it has a less than 0.1% chance of falling below 50 individuals once in the next 50 years. Subsequent steps may be used to guide the allocation of this area among different potential locations.

Step 8. *Identify catastrophes likely to affect the species' potential habitat, the number of more or less discrete populations, and the dispersal capabilities of the species.*

Here, we define catastrophes as events that eliminate a population (100% loss). This use of the term is not standard but it serves to discriminate extreme events from other random disturbances. Catastrophes include larger scale, infrequent disturbances such as floods, intense wildfires or disease outbreaks. The definition of catastrophes implies that the average annual area affected by these impacts is much greater than the total potential habitat area of each population of the species. For these purposes, a population may be thought of as any group of individuals that is affected by a common catastrophe.

Determine the annual probability of each catastrophe. In virtually all cases this will involve a certain amount of intelligent guesswork. In case of events such as extreme fires, the data may be the product of an explicit model. The number of populations a species needs to persist depends on the frequency of these catastrophes and whether the catastrophe results in local extirpation. The greater the frequency of catastrophes and the more intense their effects, the greater the number of populations.

Strategies for spreading risk among several populations assume that populations may be selected far enough apart to ensure that catastrophes occur more or less independently, requiring a minimum level of separation that exceeds the maximum area affected by each catastrophe. They also assume that the dispersal mechanisms of the species are sufficient that propagules or dispersing individuals may recolonize populations eliminated by a catastrophe.

Consideration of the appropriate number of populations must also take into account the magnitude of autocorrelation between environmental fluctuations (of a non-catastrophic kind) in different patches, and the ability of the species to disperse among patches. If dispersal ability is poor and environmental correlations are strong, then fewer patches will result in lower overall risks of extinction. If dispersal abilities are good and environmental correlations are relatively weak, then a more patches will result in lower overall risks of extinction.

Step 9. *Combine targets across disturbance regions*

Add regional targets together to achieve a species target. Select areas such that the total area protected is sufficient to meet the condition that the taxon is less than 0.1% likely to fall below 50 mature individuals within the next 50 years.

An area A_3 has been calculated for each disturbance region. This is the area that would be required if the target area for the taxon were to be selected from that region alone. The areas A_3 differ because potential habitat subjected to different disturbances has different conservation value. Different types of 'reserves' afford different levels of protection. Not all will be equally effective at offsetting extinction risks. The different values of A_3 reflect the different disturbance regimes. Land is selected under Step 9 according to the ability of land from each disturbance region to maintain viable populations. Thus, the value of A_3 from a large National Park may be half that of A_3 calculated for a zone subjected to a different disturbance regime. Targets for conservation may be met in a number of ways and the formula in step 9 ensures that the target is met, irrespective of the way in which land is allocated for a species among different disturbance regions.

The calculations between steps 1 and 8 result in a value of A_3 for each of k disturbance regions which may be denoted A_3^k. Select areas from the k disturbance regions such that

$$\frac{X^1}{A_3^1} + \frac{X^2}{A_3^2} + \frac{X^3}{A_3^3} + \ldots + \frac{X^k}{A_3^k} \geq 1$$

where X^k areas are selected from n disturbance regions and the values for A^k are the required areas, A_3, calculated for each of the n disturbance regions. That is, the X's are the areas (in ha) reserved in each disturbance region.

Strict application of this criterion would allow k-1 sites to become extinct if one site is larger than the target area. This does not mean that such a strategy is recommended. Rather, the conservation of a species throughout its range and in representative parts of its habitat may be equally important considerations.

Step 10. *Evaluate habitat maps and evaluate the adequacy of strategies; set objectives accounting for spatial and species-specific constraints.*

Any combination of patches may be selected to achieve the target area. A strategy that conserves many small, isolated patches, none of which is likely to survive for long, might appear to satisfy the criteria described here. Taken to its extreme, a target may be satisfied by circumscribing small areas around individual plants. However, the method is intended to support other decision making tools; it is not intended to supplant common sense. For example, any decision process should be underpinned by an objective to conserve patches that have some minimum probability of persistence, before they are counted towards species-wide management objectives. For example, it may be possible to specify that the minimum patch size should be one that supports at least 10% of the total target. The calculations outlined here assume plants can disperse easily between patches, and the existence of anything that inhibits dispersal (either by the species itself or its dispersal agents) should influence decisions about the best spatial strategy for conservation of the species.

In making decisions about plant conservation, not all targets will be met. In some cases, the required habitat will not be available. In other cases, the habitat may not be able to be protected or managed, even when it is available. The statistic A_3 calculated for each taxon may be used to provide information in addition to a simple area statement. The ratio

$$I_M = \frac{X^1}{A_3^1} + \frac{X^2}{A_3^2} + \frac{X^3}{A_3^3} + \ldots + \frac{X^n}{A_3^n}$$

gives an indication of how well the target has been met. When it equals 1, the target has been met. When it is greater than 1, the target has been exceeded, and when it is less than 1, the target has not been achieved. The ratio may also be used to provide guidance and support for the ranking of priorities for negotiations regarding land use and tenure. Satisfying this equation may create incentives to select as much area as possible from regions under the least threat tempered by the requirement to conserve a minimum number of locations, and the relative costs of reserving land in the different regions.

Similarly, A_3 may be compared with H. One may calculate the ratio

$$I_H = \frac{H^1}{A_3^1} + \frac{H^2}{A_3^2} + \frac{H^3}{A_3^3} + ... + \frac{H^n}{A_3^n}$$

If available habitat *H*, is substantially less than the area required, I_M will be small and it implies that even the protection of all existing potential habitat is unlikely to sustain the species. The larger the discrepancy, the greater the threat to the species' continued existence. The smaller the number, the greater the imperative to do more than just conserve land (passively).

Examples

The following three examples illustrate the utility of the protocol and describe the operation of the various functions. All three are threatened species. The first species, *Banksia cuneata*, was included because there exists a detailed population viability model for the species (Burgman & Lamont 1992), and it is used to illustrate the relationship between the equations described here and a more detailed viability analysis. The first set of calculations includes interval estimates for some of the most uncertain parameters. These intervals are carried through the calculations, and are used to compare the results of the equations with the results of the detailed model.

Banksia cuneata

Banksia cuneata is an endangered tall shrub that grows to 5m tall in six localized stands in undulating sand plains of the south-west of Western Australia. Interactions between soil preferences, drought stress and interspecific competition probably limit its geographic distribution (Lamont *et al.* 1991). Burgman & Lamont (1992) wrote a population viability model that used 13 stages (five juvenile, seven subadult and one adult stage). We assumed the parameters for the model were those specified by Burgman & Lamont (1992) (including coefficients of variation in demographic parameters of 10%, uncorrelated variation between fecundity and survivorship, perfect correlation between survivorship terms, demographic uncertainty, and exponential population growth). In particular, adults are killed by fire and regeneration is stimulated by random fire events (in the model, fires occur naturally with a probability 0.1 per annum, and kill an average of half the mature plants in a stand).

- Step 1. Under these conditions, an initial population size of 6400 mature plants (plants more than five years old) has a probability close to 0.1% of falling below 50 individuals at least once in the next 50 years (F=6400 [5400, 7400] where the values in parentheses represent bounds for F).
- Step 2. All potential habitat is within a single disturbance region.
- Step 3. There are six remaining populations totalling fewer than 400 mature plants. The populations have a total range of less than 60 km.
- Steps 4 and 5. The total area of potential habitat has been surveyed. In places where they grow, stands of *B. cuneata* are quite dense, but stands occur only sporadically. Average density (D) within remaining habitat is about 10 [5, 15] plants per hectare. Uncertainty is created by uncertainty about what constitutes the limits of potential habitat.
- Step 6. Total target area needed to support 4100 mature plants $A_0 = F/D$ = 6400/10 = 640 [360, 1480] ha.
- Step 7. For the sake of illustration, it is assumed that fires originating in surrounding developed land increase the risk of fire in *B. cuneata* stands from 0.1 to 0.2 (an added risk of 0.1). There is a five year time lag between germination and reproductive maturity (n_d =5) and plants loose reproductive potential at about age 45 (n_u=45). Thus,

$$S = p_u^{n_d} - p_u^{n_u}$$

$$= (1 - 0.1)^5 - (1-0.1)^{45} = 0.58$$

The adjusted habitat area,

$$A_1 = 640/0.58 = 1103 \ [630, 2552] \text{ ha.}$$

There are no additional deterministic processes that reduce habitat area or local population density, so that $A_1 = A_2 = A_3$.

- Step 8. There are no potentially catastrophic processes. The possibility of loss by land clearance is not entirely discounted, but the populations are legally protected and clearance would lead to substantial penalties. We assume these measures will be effective.
- Steps 9 and 10. The population size required for ‘adequate’ protection, even in the absence of additional fire risk, is more than 10 times the existing population size. Using

$$I_H = \frac{H}{A_3} = 35/705 = 0.05\ [0.01, 0.06],$$

  it is clear that all available habitat should be protected and that active management strategies are warranted.

This example was compared to the population viability model by increasing the fire risk in the model from 0.1 to 0.2, and then adjusting the initial population size so that it again gave a risk of falling below 50 individuals of close to 0.1%. The initial population size needed to achieve the equivalent extinction risk was 13,100, implying a population reduction to about 0.49 of the undisturbed population (compared to 0.58 based on the equations above) and an area target of 1310 [873, 2620] ha. Applying the same levels of uncertainty in density estimates to both results, there is considerable overlap between the two interval estimates of the area required for adequate conservation. The equations above give a reasonable approximation of the more detailed population model, given the levels of uncertainty in the calculations.

Boronia keysii

This species is listed in Queensland and nationally as Vulnerable and it is endemic to Queensland. There is no detailed population viability model for this species, as is the case for the great majority of threatened plants. It is a sprawling shrub to about 2m, and it lives for 15 to 30 years. It is an obligate seeder, with a long-lived seed bank that is exhausted by frequent disturbance. A mildly explosive pod provides some short-distance dispersal. There are about 10,000 known adult plants in 15 populations occurring from mixed eucalypt and brushbox woodland to open forest which vary in height from 8 to 35 m. The juvenile period for the species is about 3 years. The period from reproductive maturity until senescence is about 15 years. If there were an absence of disturbance in a population for more than 50 years the seed bank would be exhausted. This species is included because it experiences deterministic declines in addition to stochastic pressures. Interval calculations are not shown for the sake of clarity.

- Step 1. Required population target in the absence of additional disturbance (F): 4000
- Step 2. Single disturbance regime.
- Steps 3 to 4. Area of potential habitat (H): 150 ha (same as occupied habitat)
- Step 5. Density (D): 67 plants/ha.
- Step 6. Target area (A_0): 4000/67 = 60 ha.
- Step 7a. Disturbances from which the species’ recovers: Two fires within four years, exhausting the seed bank: $p_1 = 0.3$.

$$S = p_u^{n_d} - p_u^{n_u}$$

$$= (1 - 0.3)^3 - (1-0.3)^{18} = 0.341$$

The proportion of suitable habitat = 0.341. The target area accounting for additional disturbance:

$A_1 = A_0/S$ = 60/0. 341= 176 ha.

- Step 7b. Trends that irreversibly affect the species' potential habitat include agricultural clearing and continual treatment (50% of habitat susceptible at 10% per year), changed hydrological conditions (20% of habitat susceptible at 5% per year), and weed invasion (6% of habitat susceptible at 5% per year)

$$A_2 = \frac{176}{0.5(1-0.1)^{50} + 0.2(1-0.05)^{50} + 0.06(1-0.05)^{50} + (1-0.76)} = 733 \text{ ha}$$

- Step 7c. The density of populations is not affected within their area of occupancy, so $A_3 = A_2$.
- Step 8. There are no obvious catastrophes that may affect the populations.
- Steps 9-10. The ratio of available habitat (H) to required habitat, (A_3), is 150/733 = 0.205.

Because the index is less than 1, it suggests that under current disturbance conditions, the area of habitat available is not sufficient to ensure that the species has a better than 99.9% chance of surviving for the next 50 years. However, if all of the threats to which the species is subject and from which there is no recovery could be eliminated (land clearance, changed hydrological conditions and weed invasion: step 7c) then the target could be achieved by protecting all remaining habitat. Another alternative may be to manage the fire regime to reduce the incidence of too frequent fires.

Parsonsia dorrigoensis

This species is a sparsely distributed vine of forests on the north coast of New South Wales. It recruits continuously but infrequently and is killed by fire. There is no persistent seed bank and age to maturity is about 4 years. Plants produce less than 1 pod per plant per year. About 1500 plants were found within a search of 375 ha of potential habitat. There is no detailed model for the species. It is included as an example because it persists within different disturbance regions. As in the previous example, interval calculations are omitted for clarity.

- Step 1. Required population target in the absence of additional disturbance (F): 4000
- Step 2. There are three disturbance regions.
- Step 3.
  Region 1. Ballinger River, New England, Ballinger River, Horseshoe Road (2000 ha)
  Region 2. Dorrigo Tops (500 ha)
  Region 3. Conglomerate - Orara (1000 ha)

For Region 1.

- Steps 4 and 5. Density (D): 4 plants/ha.
- Step 6. Target area (A_0): 4000/4 = 1000 ha.
- Step 7a. Probability of fire, p = 0.02. The proportion of suitable habitat, S= $(1\text{-}0.02)^4$ = 0.922. Target area accounting for additional disturbance: $A_1 = A_0/S$ = 1000/.922 = 1,084 ha.
- Step 7b. There are no trends that irreversibly affect the species' potential habitat, so $A_2 = A_1$
- Step 7c. The density of populations is not affected within their area of occupancy, so $A_3 = A_2$.

For Region 2.

- Steps 4 and 5. Density (D): 4 plants/ha.
- Step 6. Target area (A_0): 4000/4 = 1000 ha.
- Step 7a. Probability of fire, p = 0.04. The proportion of suitable habitat, S= $(1\text{-}0.04)^4$ = 0.781. Target area accounting for additional disturbance: $A_1 = A_0/S$ = 1000/.781 = 1,177 ha.

- Step 7b. There are no trends that irreversibly affect the species' potential habitat, so $A_2 = A_1$
- Step 7c. The density of populations is not affected within their area of occupancy, so $A_3 = A_2$.

For Region 3.

- Steps 4 and 5. Density (D): 4 plants/ha.
- Step 6. Target area (A_0): 4000/4 = 1000 ha.
- Step 7a. Probability of fire, p = 0.05. The proportion of suitable habitat, S= (1-0.05)^4 = 0.774. Target area accounting for additional disturbance: $A_1 = A_0/S$ = 1000/.774 = 1292 ha.
- Step 7b. There are no trends that irreversibly affect the species' potential habitat, so $A_2 = A_1$
- Step 7c. The density of populations is not affected within their area of occupancy, so $A_3 = A_2$.

Reservation strategy

- Step 8. There are no obvious catastrophes that may affect the populations.
- Steps 9 and 10. There are three disturbance regions, so there are numerous solutions that will satisfy the required target area. For example, option 1 may be to select all of the required land from disturbance region 1, giving

$$\frac{1084}{1084} + \frac{0}{1177} + \frac{0}{1292} = 1$$

Alternatively, the strategy may be to select equally valuable parcels of land from each of the three disturbance regions,

$$\frac{361}{1084} + \frac{392}{1177} + \frac{431}{1292} = 1$$

More land is required from disturbance region 3 because it experiences more frequent fires and a larger proportion of the habitat on average is unsuitable. In all cases, the amount of available habitat (H) exceeds the required habitat, (A_3), and both of the above solutions provide a solution in which I = 1. This set of calculations assumes that the species is able to recolonize a burnt area immediately following fire. It is unlikely that this assumption is correct. It may well be worth recalculating the above equations, assuming that there is a lag between a fire and reappearance of mature adults that includes both developmental time from seed and the average time taken to recolonize. If the delay is, say, 20 years, then this could be introduced by changing the power in step 7 from 4 to 24. The requirements for protection would increase to 1624, 2664 and 3425 ha respectively for each of the three regions in isolation, resulting in achievable targets given the amount of available habitat.

Discussion

These examples make it clear that application of a common set of rules does more than produce a number. The protocol serves to focus attention on the causes of threat that affect habitat area and population density, and may lead to recommendations that directly affect the most important processes. It only requires that each threatening process is typified in terms of its effect on the disturbance and recovery dynamics of the species in question. Thus, the method may be used to evaluate the impacts of land clearance, changed fire frequency, cattle grazing, competition from exotics, harvesting, or changed hydrology, if the consequences of these processes can be characterized appropriately.

In addition, the protocol serves to put the threats faced by different species in perspective, compared to the threats faced by others. There may be many species on a list of endangered taxa, but the prospects for *B. cuneata* are such that conservation resources should perhaps be directed towards it before the other two species evaluated here. A further advantage is that the assumptions made in reaching conclusions are explicit and the equations provide a means by which these assumptions may be relaxed. For example, we assumed immediate recolonization of disturbed sites by *Parsonsia dorrigoensis*. The assumption is in plain view and we may re-evaluate our priorities after relaxing this assumption and recalculating the quantities.

In general, it would be wise to calculate target areas and rank priorities for species using a range of values, from best guesses to lower bounds. If ranges are collected for all variables, then area targets may be estimated with appropriate minimum and maximum ranges. Apart from representing the reliability of target area estimates, this makes it clear that estimates from the equations are only approximations, and that they should be used to support decisions, rather than to be the sole basis for decisions. The results are only to be used as guides for reservation/management targets. In the end, all decisions should be tempered by expert judgement and constrained by information and priorities that are not part of these few simple equations.

Target areas may change as management practices change or as distributional and ecological knowledge improves. For example, the planning process may take into account the conservation status of species derived from independent rule sets, or the taxonomic uniqueness of a species. Resource constraints and political and public priorities contribute to conservation outcomes. The process of identifying land to satisfy individual species targets may also be constrained by the need for efficiency and comprehensiveness in achieving other conservation goals. The equations above are intended to provide a framework within which the relative susceptibility of plant taxa to explicitly defined disturbance regimes may be included in the conservation planning process.

In the absence of detailed population models, or at least some experience in building these models, estimating F may prove problematic. Absolute values are important because absolute land areas will be protected. However, so long as the values for F make sense relative to one another (that is, so long as the rank order of the values among different species is more of less correct), then the relative status of the different species may be correctly interpreted. If the range of species is sufficiently broad, then Table 2 will provide some guidance on setting absolute levels for the relative values of F.

To achieve adequate conservation, it is necessary to evaluate population viability. Shaffer (1981) suggested that a viable population is one that has a less than 1% chance of extinction in 1000 years - other authors set different target extinction probabilities over different time frames. In general, assessing viability without a detailed Population Viability Analysis is difficult and some authors suggest that all predictions of extinction probability should be treated with caution (Possingham *et al.* 1993, Taylor 1995, Beissinger and Westphal 1998, Ludwig 1999). The notion of adequacy is bound up with acceptable risk. If we assume that an adequate number of populations and an adequate area are those in which the chance of the total adult population falling below 50 individuals within 50 years is less than 0.1%, then we would accept that 0.1% of the biota could fall to population sizes below 50 adults. There are 25,000 species of vascular plants in Australia, meaning that we would find it acceptable for 25 species to become critically endangered at some time over the next 50 years. If this level of risk is too high, we might settle on, say, a 0.01% chance of the total adult population falling below 50 individuals within 50 years.

The methods here are an attempt to address the need identified by Schemske *et al.* (1994): 'The combination of escalating threats to species and severe fiscal and political constraints have created a need for conservation biologists and land managers to develop realistic and efficient guidelines for the management of rare and endangered species' (Schemske *et al.*, 1994; p. 595). Perhaps the most difficult part of developing tools to assist pragmatic decision making is to find the right balance between what is possible given time and knowledge constraints, and what is necessary given the values at risk if the process results in bad decisions. The tools presented here are not intended to replace existing protocols for setting conservation targets. They provide a relatively rapid, transparent and explicit means of assessing the conservation requirements of plants that may support decision-making processes in circumstances in which time and resource constraints preclude thorough habitat and population viability modeling.

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Appendix 1. Caveats on the use of the protocol

Because the protocol described here is intended to support better decisions, rather than to be a decision making tool, it is important to state its assumptions and limitations clearly and unambiguously. In applications of the protocol, we assume the following conditions:

- The potential habitat of each taxon can be mapped, or inferred from spatially distributed data.
- Some information on the density and distribution of populations is available.
- General notions of preferred habitat, basic life-history attributes of the taxon and some understanding of disturbance regimes governing the taxon in question are available (in the worst case, life-history attributes might be guessed from the attributes of similar taxa).
- Applications will deal explicitly with uncertainty in the data by evaluating the sensitivity of the result to the reliability of the data. One way of doing this is to specify upper and lower bounds for each parameter, and explore the consequences of any decisions based on equivocal information. One may, as a result, choose to apply the precautionary principal in interpreting uncertainty.
- The users are aware of the spatial and ecological context of a species, and issues such as the adjacency of habitat features, dependencies on other species and related ecological issues will be accommodated in any final judgement concerning the conservation status and reservation needs of a taxon.
- The formulae do not address the issue of ecological sustainability. Rather, they are intended to be used as a tool to guide the equitable distribution of limited conservation resources among taxa. The adequacy of any common benchmark for protection must be established independently of the application of these formulae, and should be treated explicitly.
- The application of these formulae must be carried out in dynamic association with plans for landuse and management activities. The expressions below require judgements to be made concerning expected disturbance regimes, both on and off reserves. Any change in the expected treatment of different tenures would require a re-evaluation of the conservation requirements of the species.
- The application of these formulae to a subset of a region’s taxa (with the consequent exclusion of other regional taxa including those not currently listed, those not currently recognized and described, and those belonging to groups other than vascular plants, including aquatic species, vertebrates, invertebrates and non-vascular plants) does not imply that those not considered are necessarily adequately protected.
- The users are aware that the estimation of parameters for the model reflecting background (pre-1750) conditions must account for the potentially biased and suboptimal conditions in which taxa currently persist. Elements such as the lifespan, reproductive mode, ecological dependencies and life history traits are embedded in the estimation of the initial population size required to achieve an equitable outcome, or are included in deliberations over the setting of conservation priorities, of which the protocol below is a part.
- In applying the formulae, it may be appropriate to develop targets for taxa other than recognized species. For example, refugia or other geographic areas may harbor genetically isolated and distinct populations that are considered to be worth protecting in the same way as one might protect a formally recognized species. Dispersal distances and the level of habitat fragmentation will play a role in determining targets for each taxon. We usually do not know for certain the degree of genetic exchange between supposed biological populations and typically species concepts are defined operationally by morphological criteria. In the interests of providing the best protection to the broadest spectrum of genetic variation, we might hope that taxonomy is sufficiently robust that species usually provide the most appropriate focus for conservation. If a decision was made to define targets for populations or sets of populations within a species, then the biological basis for the decision should be rationalized. Isolation by itself would not ordinarily be sufficient evidence of genetic uniqueness.
- The target area for a taxon may be split among regions that experience different disturbance regimes. The protocols here assume that the final choice of the spatial distribution of targets will be sensitive to the

landscape context of the taxon's habitat, dispersal distances, the adjacency of habitat attributes, the location of barriers to dispersal, the need to protect genetic variation throughout the range of the species, and the need to spread risk among geographically separate populations.

- A benchmark of 50 years is chosen to set an equitable risk of extinction among species because it is anticipated that the actions that result from these analyses are likely to have greatest impact within the next 50 years. Implicitly, it is assumed that an effective strategy to minimize the number of medium and long-term extinctions is to minimize their likelihood in the short-term. Otherwise, short-term outcomes will determine the state of the system before long-term expectations have a chance to be realized. However, the evaluation of the conservation requirements of different taxa should not be blind to ecological time horizons, particularly those relevant to longer-lived species. It would be appropriate to develop an expectation for conservation requirements, assuming a time horizon of (say) 10 generations as well as the requirements for 50 years, to ensure that the conservation effort does not become focused on short-lived species. Many species have life history strategies adapted to recruitment windows or rare disturbance events that span decades if not centuries in their occurrence. Data on the requirements for long-lived species could be used to inform judgements during the process of setting conservation targets. Similarly, strict interpretation of the objective to maintain 50 adults may be detrimental to the long-term persistence of a species, particularly in the case of ephemerals. The criterion could be varied, for example, to apply only in the year immediately following the cue stimulating transition from the propagule to the adult phase.
- One of the most important outputs of the process will be the provision of a sensitivity analysis, so that experts responsible for providing final judgements concerning conservation requirements may evaluate the consequences and the importance of their estimates.

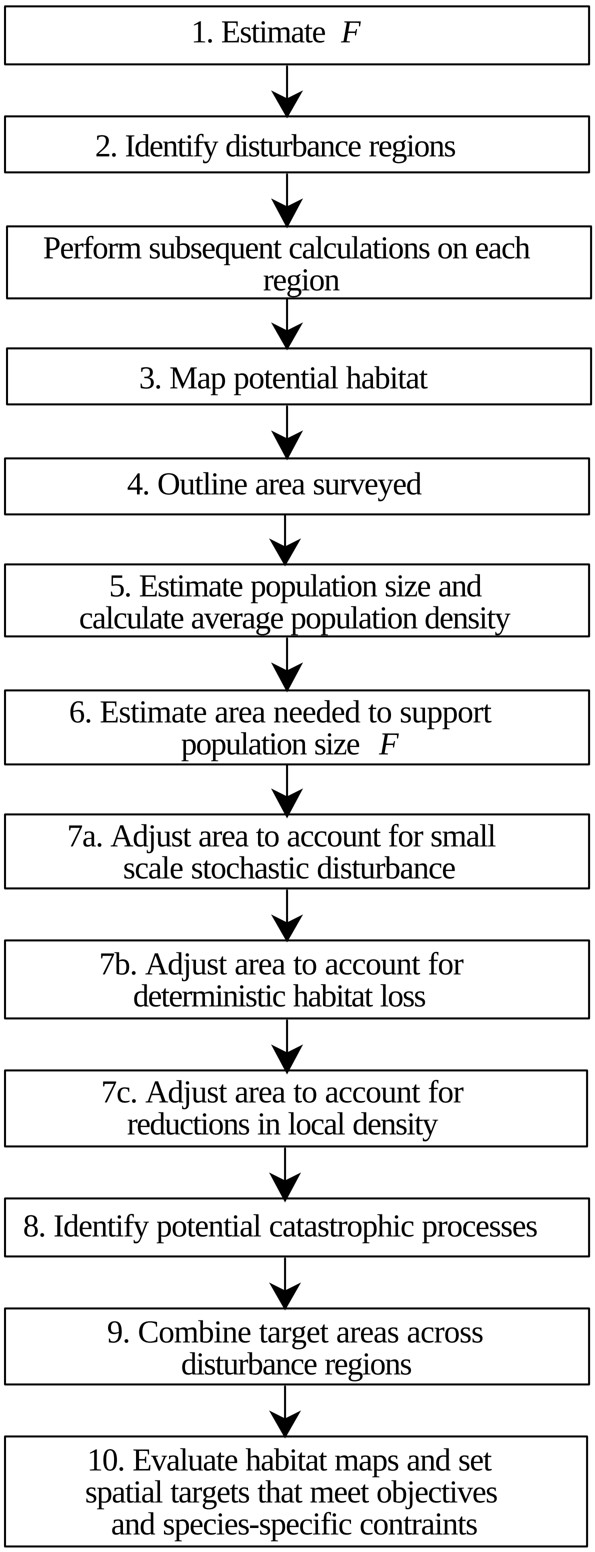

Figure 1. Flow chart for the target setting protocol.

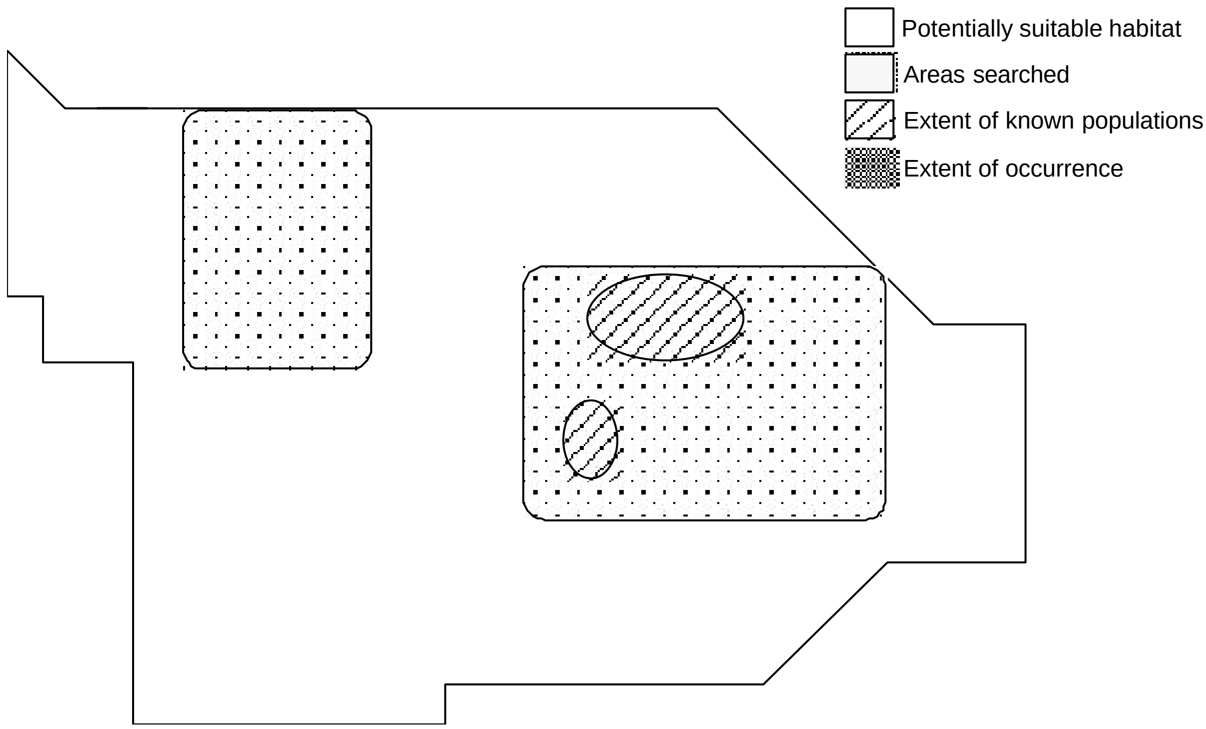

Figure 2. Representation of the area of potentially suitable habitat of a taxon, based on a spatially explicit habitat model. To calculate the density of the taxon (ha/plant), the total area searched is divided by the number of adult plants found within the area searched. The area of occupancy defined by the IUCN (1994) would include only the hatched areas representing the extent of the known populations. The extent of occurrence defined by the IUCN (1994) would include a minimum convex polygon drawn around the known populations, shown by the heavy line.

Table 1. Parameters for the target-setting protocol

Parameter	Definition
H_i	Area of potential habitat in disturbance region *i* that has been searched (surveyed) for the species (ha).
N	The number of adult plants within the surveyed potential habitat, *H.*
F	Population size that faces a 0.1% chance of falling below 50 adults, at least once in the next 50 years, assuming no human impacts (a benchmark for evaluating risks across different taxa).
p_i	annual probability of disturbance (or the proportion of habitat disturbed annually) by small scale disturbance *i.*
n_d	time taken for the species to recover from a disturbance.
n_u	number of years after a disturbance until the habitat is no longer suitable for the species (assuming no further disturbance).
L_i	proportion of remaining habitat lost to a deterministic process, *i.*
r_i	proportional reduction in local density due to impact *i.*

Table 2. Examples of values of the initial population size, *F*, necessary to achieve a probability of less than 0.1% of falling below 50 mature individuals at least once in the next 50 years. In all of the models below, the average birth and death rates in the population were such that, under deterministic conditions, the population would persist indefinitely without increasing (i.e., the growth rate λ~1).

			Initial population sizes giving p(quasiextinction) ≤ 0.1%					
Taxon	Longevity (survivorship or life expectancy)	Regeneration response[2]	CV[1] variable	CV=.05	*CV=.1*	*CV=.15*	*CV=.2*	*CV=.25*
Hypothetical taxon[1]	s=0	continuous		520	1000	7500	23000	60000
	s=0.2	continuous		480	800	2500	17000	50000
	s=0.5	continuous		390	650	1800	12500	44000
	s=0.9	continuous		280	550	1650	9800	40000
	s=0.98	continuous		180	500	1600	6000	38000
Banksia goodii[3]	300 years	continuous	300					
Banksia cuneata[4]	50 years	disturbance	6400					
Alnus incana[5]	20 years	continuous	750					
Arisaema triphyllum[6]		continuous	11100					
Pentaclethra macroloba[7]	100 years	continuous	2300					

1. The first five examples are based on a generic model that assumed a single, unstructured population in which survival and reproduction were sampled from a binomial distribution, and the vital rates were sampled independently from a lognormal distribution (see Burgman *et al.* 1993). The CV represents the level of environmental variation in λ from year to year, without autocorrelation or density dependence (see also Menges 1998).
2. A variety of life history strategies for plants may provide some guidance towards establishing the size of a population that is likely to persist for 50 years, given a habitat free of recent additional anthropogenic disturbances.
3. After Drechsler *et al.* (1998). The model uses pessimistic assumptions concerning survival following fire, based on limited field data. Different assumptions produce an *F* value of around 100.
4. After Burgman and Lamont (1992).
5. After Huenneke and Marks (1987).
6. After Bierzychudek (1982); the model used the pooled data for two populations, with transition probabilities reduced uniformly by 10% to reduce λ to 1.01, so that the model represents a population persisting at or close to its natural carrying capacity.
7. After Hartshorn (1975); the model is for a large canopy species dominating the tropical wet forests in the Atlantic lowlands of Costa Rica. There is limited seed dormancy and no asexual reproduction. The latter two models are based on implementations in Ferson (1991).

Table 3: Other Factors Affecting *F*.

Positive Circumstance (Resilience)	**Negative Circumstances (Vulnerability)**
Many large populations	Few small, isolated populations
Widespread distribution	Very restricted distribution
Habitat generalist	Habitat specialist
Not restricted to a temporal niche	Restricted to a temporal niche
Not subject to extreme habitat fluctuations	Subject to extreme habitat fluctuations
No particular genetic vulnerability	Genetic vulnerability
Vigorous post-disturbance regeneration	Weak post-disturbance regeneration
Rapid, vigorous growth	Slow, weak growth
Quickly achieves site dominance	A poor competitor
All life stages resilient	Particular life stages vulnerable
Short time to set first seed / produce propagules	Long time to set first seed / propagules
Long reproductive lifespan	Short reproductive lifespan
Robust breeding system	Dysfunctional breeding system
Readily pollinated	Not readily pollinated
Reliable seed production	Extremely variable seed production
High seed production and viability	Low seed production and viability
Long seed / propagule viability	Short seed / propagule viability
Seed / propagules not exhausted by disturbance	Seed / propagules exhausted by disturbance
Good dispersal	Poor dispersal
Generally survives fire and other damage	Generally killed by fire and other damage
Not adversely affected by pre-1750 disturbance	Adversely affected by pre-1750 disturbance
Adapted to existing grazing, drought, fire regime	Not adapted to grazing, drought, fire regime
Able to coppice or resprout	Not able to coppice or resprout
Not vulnerable to pathogens, disease, insects, etc.	Vulnerable to pathogens, disease, insects, etc.
Not dependent on vulnerable mutualist	Dependent on a vulnerable mutualist

APPENDIX 2

APPENDIX 2.1 FAUNA SPECIES ASSESSED IN WORKSHOP 1 OF THE RESPONSE TO DISTURBANCE PROJECT FOR THE SOUTHERN REGION, AND WHETHER TARGETS SET IN WORKSHOP 2 COAST AND TABLELANDS.

SPECIES			Sub-region	Target set Coast	Target set Tablelands
GROUP	**SCIENTIFIC NAME**	**COMMON NAME**			
Ground Mammal	*Dasyurus maculatus*	Spotted-tailed Quoll	B	YES	YES
Ground Mammal	*Isoodon obesulus*	Southern Brown Bandicoot	C	YES	N/A
Ground Mammal	*Mastacomys fuscus*	Broad-toothed Rat	T	N/A	YES
Ground Mammal	*Petrogale penicillata*	Brush-tailed Rock Wallaby	B	YES	YES
Ground Mammal	*Perameles nasuta*	Long-nosed Bandicoot	B	YES	YES
Ground Mammal	*Potorous tridactylus*	Long-nosed Potoroo	C	YES	N/A
Ground Mammal	*Pseudomys fumeus*	Smoky Mouse	B	YES	YES
Ground Mammal	*Sminthopsis leucopus*	White-footed Dunnart	C	YES	N/A
Arboreal Mammal	*Cercartetus nanus*	Eastern Pygmy Possum	B	NO	NO
Arboreal Mammal	*Petauroides volans*	Greater Glider	B	YES	YES
Arboreal Mammal	*Petaurus australis*	Yellow-bellied Glider	B	YES	YES
Arboreal Mammal	*Petaurus norfolcensis*	Squirrel Glider	B	YES	YES
Arboreal Mammal	*Phascogale tapoatafa*	Brush-tailed Phascogale	B	NO	NO
Arboreal Mammal	*Phascolarctos cinereus*	Koala	B	YES	YES
Nocturnal Bird	*Burhinus grallarius*	Bush Stone-curlew	B	NO	NO
Nocturnal Bird	*Ninox connivens*	Barking Owl	B	NO	NO
Nocturnal Bird	*Ninox strenua*	Powerful Owl	B	YES	YES
Nocturnal Bird	*Tyto novaehollandiae*	Masked Owl	B	YES	NO
Nocturnal Bird	*Tyto tenebricosa*	Sooty Owl	B	YES	YES
Diurnal Bird	*Calyptorhynchus funereus*	Yellow-tailed Black Cockatoo	B	YES	YES
Diurnal Bird	*Calyptorhynchus lathami*	Glossy Black Cockatoo	C	YES	N/A
Diurnal Bird	*Cinclosoma punctatum*	Spotted Quail-thrush	B	YES	YES
Diurnal Bird	*Climacteris erythrops*	Red-browed Treecreeper	B	YES	YES
Diurnal Bird	*Climacteris picumnus*	Brown Treecreeper	B	YES	YES
Diurnal Bird	*Dasyornis brachypterus*	Eastern Bristlebird	C	YES	N/A
Diurnal Bird	*Eurystomus orientalis*	Dollarbird	B	YES	YES
Diurnal Bird	*Falcunculus frontatus*	Crested Shrike-tit	B	YES	YES
Diurnal Bird*	*Grantiella picta*	Painted Honeyeater	T	N/A	YES
Diurnal Bird	*Lathamus discolor*	Swift Parrot	B	YES	YES
Diurnal Bird	*Lophoictinia isura*	Square-tailed Kite	B	YES	YES
Diurnal Bird	*Melanodryas cucullata*	Hooded Robin	B	YES	YES
Diurnal Bird	*Melithreptus gularis*	Black-chinned Honeyeater	T	N/A	YES
Diurnal Bird	*Neophema pulchella*	Turquoise Parrot	B	YES	YES
Diurnal Bird	*Pachycephala olivacea*	Olive Whistler	B	YES	YES

SPECIES			Sub-region	Target set Coast	Target set Tablelands
GROUP	**SCIENTIFIC NAME**	**COMMON NAME**			
Diurnal Bird	*Petroica rodinogaster*	Pink Robin	B	YES	YES
Diurnal Bird	*Polytelis swainsonii*	Superb Parrot	T	N/A	YES
Diurnal Bird	*Sericornis citreogularis*	Yellow-throated scrub wren	C	YES	N/A
Diurnal Bird	*Xanthomyza phrygia*	Regent Honeyeater	B	YES	YES
Bat	*Chalinolobus dwyeri*	Large Pied Bat	B	YES	YES
Bat	*Falsistrellus tasmaniensis*	Eastern False Pipistrelle	B	YES	YES
Bat	*Kerivoula papuensis*	Golden-tipped Bat	C	YES	N/A
Bat	*Miniopterus schreibersii*	Large (Common) Bentwing Bat	B	YES	YES
Bat	*Mormopterus norfolkensis*	Eastern Little Mastiff Bat	B	YES	YES
Bat	*Mormopterus sp. 1*	Unnamed Mastiff Bat	C	YES	N/A
Bat	*Myotis macropus*	Large-footed Myotis	B	NO	YES
Bat	*Pteropus poliocephalus*	Grey headed Flying-fox	B	YES	YES
Bat	*Pteropus scapulatus*	Little Red Flying-fox	B	YES	YES
Bat	*Rhinolophus megaphyllus*	Eastern Horseshoe Bat	B	YES	YES
Bat	*Saccolaimus flaviventris*	Yellow-bellied Sheathtail Bat	B	NO	NO
Bat	*Scoteanax rueppellii*	Greater Broad-nosed Bat	B	YES	NO
Reptile	*Acanthophis antarcticus*	Common Death Adder	C	YES	N/A
Reptile	*Morelia spilota variegata*	Carpet Python	T	N/A	YES
Reptile	*Morelia spilota spilota*	Diamond Python	C	YES	N/A
Reptile	*Hoplocephalus bungaroides*	Broad-headed Snake	C	YES	N/A
Reptile	*Nannoscincus maccoyi*	Maccoy's Skink	B	YES	YES
Reptile	*Pseudemoia spenceri*	Spencer's Skink	B	YES	YES
Reptile	*Varanus rosenbergii*	Heath Monitor	B	YES	YES
Frog	*Heleioporus australiacus*	Giant Burrowing Frog	C	YES	N/A
Frog	*Litoria booroolongensis*	Booroolong Frog	T	N/A	YES
Frog	*Litoria littlejohni*	Highlands Tree Frog	C	YES	N/A
Frog	*Mixophyes balbus*	Stuttering Barred Frog	C	YES	N/A
Frog	*Pseudophryne australis*	Red-crowned Toadlet	C	NO	N/A
Frog	*Pseudophryne bibronii*	Brown Toadlet	T	N/A	YES
Frog	*Pseudophryne pengilleyi*	Northern Corroboree Frog	T	N/A	YES
Aquatic	*Prototroctes maraena*	Australian Grayling	C	NO	NO
Aquatic	*Macquaria australasica*	Macquarie Perch	B	NO	NO
Aquatic	*Maccullochella macquariensis*	Trout Cod	T	NO	NO
Aquatic	*Mordacia spp*	Lampray (Non-parasitic and Short-headed)	B	NO	NO
Aquatic	*Euasticus armatus*	Murray River Crayfish	T	NO	NO
Total	**69**		**69**	**49**	**42**

C = Coastal species, T = Tablelands species, B = Both subregions, N/A indicates does not occur in subregion.

* The Painted Honeyeater (*Grantiella picta*) was included after Workshop 1 upon recommendation of experts. Information relating to this species was compiled by correspondence among experts prior to Workshop 2: Tablelands.

APPENDIX 3

APPENDIX 3.1 CRITICAL HABITAT REQUIREMENTS OF THE GROUND MAMMALS

SPECIES	HABITAT DESCRIPTION
White-footed Dunnart	
Breeding	As for shelter
Feeding	Terrestrial invertebrates and skinks - leaf litter is important.
Juveniles	? as for shelter
Sheltering	Fallen logs, macrozamia, boulder fissures; Xanthorrehea
Dispersing	Open cover
Other ---------	Dry, damp and wet sclerophyll forest; coastal dunes; open heath; dry heath; open understorey, ridges, sparse ground cover. Nb: No targeted surveys have been done for this species.
Smoky Mouse	
Breeding	Dense cover required for nesting; otherwise as general habitat type; burrows (including rocks, tree roots, Xanthorrehea etc – opportunistic); communal nests of up to 5 females
Feeding	Open dry slopes (but also feeds in dense vegetation); seeds and hypogeal fungi (in winter).
Juveniles	? as for shelter
Sheltering	Dense heath with or without rocks; burrows (includes rocks, tree roots etc…).
Dispersing	Up to 1 km possibly more; doesn't appear to be specific habitat requirements.
Other ---------	Fabaceae/Mimosaceae (aka Papillionaceae), *Xanthorehea australis*, Leptospermum sp.; forest and woodland (including alpine and sub-alpine habitats) with heath understorey (tree species are not critical); heath is important (populations are found primarily where heath is found); ground cover can be open or dense, but dense cover is required for nesting
Southern-brown Bandicoot	
Breeding	Nest in all parts of the topographic sequence, provided there is dense understorey cover and/or large fallen trees.
Feeding	Forage on all parts of the topographic sequence, though mainly on slopes and ridges (Claridge *et al*. 1991). Primarily feed on soil-dwelling invertebrates; also fruit-bodies of hypogeous fungi, seeds and other plant materials.
Juveniles	? as for shelter
Sheltering	As for shelter
Dispersing	Dispersing animals require contiguous understorey cover to avoid predation.
Other ---------	Recorded from a range of habitat types, though more typically found in heathland environments on sandy friable soils. Also present in forests and woodlands, provided there is a heathy or shrubby understorey. Common plant genera include: *Acacia*, *Banksia*, *Daviesia*, *Epacris*, *Hakea*, *Leptospermum*, *Melaleuca* and *Platylobium*. Thought to require a range of habitats of different seral stages, but no clear pattern of occupation in relation to time since last disturbance.
Long-nosed bandicoot	
Breeding	As for shelter
Feeding	Primarily soil dwelling invertebrates, secondarily fungi; also tubers and seeds; not skeletal soils; will forage in open areas as long as dense ground cover near by.

SPECIES	HABITAT DESCRIPTION
Juveniles	? as for shelter
Sheltering	Dense ground cover
Dispersing	Dense ground cover
Other ---------	All vegetation types; dense ground cover/understorey on wetter aspects; all parts of topographical sequence but possibly more in riparian strips; higher occurrence at lower elevations with fertile soils; not dry forests of ACT and South West slopes.
Long-nosed potoroo	
Breeding	As for shelter
Feeding	Sandy soils with ground cover – generally damp soils; hypogeal fungi 50%, also invertebrates, tubers, fruits
Juveniles	As adults
Sheltering	Dense ground cover; fallen trees (logs) also important
Dispersing	Dense ground cover
Other ---------	Heathland, woodland, dry and wet sclerophyll forest and rainforest; dense ground cover on sandy and friable soils (eg wiregrass, ferns, heath), includes swampy areas, found on all parts of the topographic sequences; generally where rainfall exceeds 500mm/yr.
Spotted-tailed Quoll	
Breeding	Maternal den sites are especially important (6-8 weeks of year); logs with cryptic entrances (30cms width minimum) and cavity can be large; rock outcrops; windrows; burrows (eg disused wombat/rabbit) mostly in gullies and lower slopes
Feeding	Nutrient rich sites; adults – medium-sized mammals (eg possums, bandicoots) and birds; juveniles – small-sized mammals, reptiles, invertebrates; where greater gliders are abundant (at least 3 greater gliders/ha) they can form a large part of the diet
Juveniles	? as for adults
Sheltering	Minimum of 20 dens/animal; will use tree heads and butts post-logging; high habitat complexity is associated with a high abundance of Spotted-tailed Quolls
Dispersing	No specific habitat requirements
Other ---------	Den sites and prey abundance determine habitat use (don't use habitats in proportion to their availability – prefer drainage areas and riparian zones – probably related to the abundance of prey [CB studies indicate]; any forested habitat, logging history doesn't appear to be important as long as canopy cover is greater than 50%; trees, logs, stumps >80 dbh; predominantly use gullies and lower slopes (riparian zones and flats important); flats, escarpments and saddles; too frequent, or too hot, fires can remove limit den resource; post-logging burns also remove ground cover making habitat unsuitable in the short-term (5-10 yrs)
Broad-toothed Rat	
Breeding	As for shelter and feeding
Feeding	Thickets of grasses and sedges in wet heathland, woodland, sedgeland and wet sclerophyll forest at higher elevations; diet consists of grasses, sedges, bark and leaves
Juveniles	? as for shelter
Sheltering	Nests of shredded grass under logs or dense vegetation – use runways under dense ground vegetation; are especially prevalent in the drainage lines
Dispersing	? as for shelter and feeding
Other ---------	
Brush-tailed Rock Wallaby	
Breeding	North facing cliffs with caves and rock shelters with multiple entrances
Feeding	Grassland or grassy open forest adjacent to rocky escarpments; distance from shelter foraged related to predatory pressure from foxes and dogs
Juveniles	? as for breeding
Sheltering	As for breeding
Dispersing	?
Other ---------	

APPENDIX 3.2 CRITICAL HABITAT REQUIREMENTS OF THE ARBOREAL MAMMALS

SPECIES	HABITAT DESCRIPTION
Eastern Pygmy Possum	
Breeding	Recorded breeding in dead trees and stumps
Juveniles	Not known
Feeding	High diversity of flowering mid-understorey species required eg shrubs; banksia often a component
Sheltering	Does use tree hollows; home range 1.5 ha
Dispersing	Not known - vegetation cover in understorey likely to be important.
Other ---------	Found in a wide range of environments from west sclerophyll forest to heath.
Greater Glider	
Breeding	Large hollow trees (strong positive association with tree size)
Juveniles	Not known
Feeding	New growth (leaves) preferred (rather than leaves on young trees); found in forests with *E. viminalis, E. radiata, E. fastigata, E. obliqua, E cypellocarpa, E. muelleriana, E. dalrympleana*; spotted gum (*E. maculata*), blue gum, yellow stringbark, blackbutt, sydney blue gum, *E. robertsonii* and Mountain Gum forest in the western part of the region
Sheltering	Gliders generally use the larger trees present in a stand (not restricted to trees with 100-200cm dbh as in UNE/LNE)
Dispersing	? as for other/feeding
Other ---------	Widespread distribution throughout the forest but much more common above 875m (however, altitudinal limiting factor in the western part of the CRA above 1200m asl in alpine ash – populations sparse in these areas); tall wet forests on flat to undulating land at high elevations; major gully systems on productive sites with tall wet forests containing large trees on coastal sites; closely associated with old-growth forests with dense foliage in upper canopy
Yellow-bellied Glider	
Breeding	Large hollow trees
Juveniles	Not known
Feeding	Invertebrates, eucalypt sap, nectar, pollen, manna and insect exudates; *E. ovata ,E. cypellocarpa, E. elata, E. viminalis, E. fastigata* and *E. pilularis*, *E. maculata*, *E. punctata*, *E.saligna*, *E. piperita*, *E. scias*, *E. dalrympleana*, and swamp mahogany provide a wide range of foraging resources; possibly *E. nitans* at higher elevations where it occurs; other species which provide important habitat for sap feeding include *E. muelleriana*, *E. obliqua, E. angophoroides, and E. gummifera;* prefer large tree (>60cm DBH) but will use down to 20cm DBH
Sheltering	As for breeding
Dispersing	Can disperse through regrowth forest; requires trees within gliding distance (on flat ground in tall forest- >140m, in steep forest, glides may be much longer (up to 300m); trees may be quite scattered; will not cross open ground like the Squirrel Glider.
Other ---------	Mature tree element is needed; occupies a range of forest types; more common at ecotone between dry and wet sclerophyll; mosaic of tree species including some which flower in winter; more abundant below 750m (however, occurs in forests >800m in Mittagong area and >900m asl in the Tumbarumba area); more common in landscapes where less than 55% had been heavily logged and rainforest was a significant component (>16%)
Koala	
Breeding	? as for feeding/other
Juveniles	Not known
Feeding	Need food tree diversity; prefer younger eucalypt leaves; historical records suggest Forest Red Gum was the preferred food tree, but also *E punctata*, and *E viminalis* and *E tereticornis* especially on high quality sites; preferred species vary according to nutirent levels, fibre content, volatile and heavy oil content and moisture content
Sheltering	Requires woodland or forest
Dispersing	Any forested or open habitat (including pasture, grassland), as long as scattered trees are present

SPECIES	HABITAT DESCRIPTION
Other ---------	Generally drier sites; traditionally associated with tree species such as *E. manifera*, *E. tereticornis*, *E. bridgesiana*, *E. goniocalyx*, *E. melliodora* and red stringybark; uneven age stand forests are preferred; forests logged at least 15 years ago on south facing slopes may also contain greater densities; stems of 40-80cm DBH
Squirrel Glider	
Breeding	Tree hollows with small entrances
Juveniles	Not known
Feeding	Preferred habitat contains winter flowering eucalypts or banksias including Swamp Mahogany, Spotted Gum, Coast Banksia, Ironbarks, Casuarina nuts; probable association with larger trees with high nectar flows; prefers areas with late senescent trees.
Sheltering	Hollow bearing trees
Dispersing	Can disperse through a broad range of open and disturbed habitats (including paddocks, grassland).
Other ---------	Proportion of habitat characterised by old trees – can be scattered
Brush-tailed Phascogale	
Breeding	Tree hollows with very small entrance
Juveniles	Not known
Feeding	Dry sclerophyll forest and woodlands; trees >20cms dbh; diversity of tree species including those with decorticating bark; associated with flatter terrain where foxes are absent
Sheltering	Logs and stumps, hollow-bearing trees
Dispersing	Tree cover, observed crossing 300m open space
Other ---------	Unlikely to occur in region except perhaps in the west – box ironbark important

APPENDIX 3.3 CRITICAL HABITAT REQUIREMENTS OF THE NOCTURNAL BIRDS

SPECIES	HABITAT DESCRIPTION
Powerful Owl	
Breeding/roosting	Large, live, old trees; hollows (on the branch and trunk); high density of arboreal mammals (prey); nests tend to be in drainage lines (including minor drainage features), sometimes upslope; dense thickets to protect breeding roosts; 1st, 2nd & 3rd order streams
Feeding	Wide range of wet and dry forest types; arboreal mammals, large birds, flying foxes; prey species must be managed for, eg when ringtail possums are major dietary component, shrubby understorey is important, when greater gliders are major prey understorey vegetation is not important
Juveniles	Patches of tall, dense shrubs; usually dense understorey thickets are used for protection (eg from feral predators)
Sheltering/roosting	Mid-story thickets; *Allocasuarina littoralis* thickets; lily pily/rainforest vegetation along gully lines; tend to roost in eucalyptus vegetation on the tablelands; drainage lines important, especially at the heads
Dispersing	No critical resources identified
Other ---------	Relatively common on the tablelands.
Sooty Owl	
Breeding	Wet forest (rainforest & wet sclerophyll) with a well developed mesomorphic understorey; very large, live, old trees with hollows; in big gullies, where eucalypts occur on the edge of rainforest; more likely on 2nd & 3rd order streams; will also use caves
Feeding	Forage out of roosting habitat into drier areas; principally forage in wet gullies; very diverse diet including small & medium-sized terrestrial & arboreal mammals, very few birds
Juveniles	Utilise patches of forest characterised by tall, dense understorey
Sheltering	Patches of dense, tall understorey; hollows in live and dead trees; vine tangles; dense treefern heads; caves and rocky ledges; rainforest veg near waterfalls and rock ledges; gorges; dark spots in the landscape
Dispersing	Forest cover
Other ---------	

SPECIES	HABITAT DESCRIPTION
Masked Owl	
Breeding	Hollows in large, live trees that tend to be vertical and in the trunk
Feeding	Sclerophyll forest with sparse, open, understorey, particularly the ecotone between wet and dry forest, and non-forest habitat; medium & small terrestrial mammals; some arboreal mammals and birds
Juveniles	?
Sheltering	Primarily hollows, but also in densely foliaged understorey trees including exotics
Dispersing	No specific requirements
Other ---------	
Barking Owl	
Breeding	Large hollows in large, live trees; near or on floodplains; associated with redgum forest types and sparse groundcover; dry forest woodland with dense thickets of eucalypt, paperbark or viney scrub; cypress pine
Feeding	Diverse diet, eg rabbits, birds, insects' some ground mammals, arboreal mammals and bats, woodlands and ecotones are important
Juveniles	Thickets for roosting
Sheltering	Thickets, eg *A. floribunda*, tea tree, wattle
Dispersing	No specific requirements
Other ---------	
Bush Stone Curlew	
Breeding	Nest on ground, often under trees of open woodland with understorey of short, sparse or lush grass; often near dead fallen timber, or sometimes among brushwood; consistently in relatively open areas < 13m away from trees; occasionally in short grass in open (reference: HANZAB 1993)
Feeding	Forage on dry open ground, occasionally under woodland trees, among grass, pasture or crops; in summer, watercourses utilised; eat mainly insects, molluscs, centipedes, crustaceans, spiders, frogs, lizards and snakes but also some vegetation and seeds; soil friable.(reference: HANZAB 1993)
Juveniles	?
Sheltering	Roost on ground among leaf-litter, often among clumps or thickets of trees in, or adjacent to, more open habitat; within day-shelters, percentage cover of fallen tree debris is higher, there is more bare ground, lower grass and less disturbance (eg from farming practices) open (reference: HANZAB 1993)
Dispersing	As above
Other ---------	Lightly timbered open forest and woodland, including farmland with forest remnants; ground cover of short sparse grass and few or no shrubs; often fallen timber present; often associated with woodlands of *Casuarina* but also *Eucalyptus*, *Acacia* or *Epolycarpa*; avoid rainforest and heavy forest but may roost in edge of rainforest abutting open country and recorded in well-timbered remnant riverine red gum (reference: HANZAB 1993); only likely to be an issue in the western part of the region; don't occur in steep country

APPENDIX 3.4 CRITICAL HABITAT REQUIREMENTS OF THE DIURNAL BIRDS

SPECIES	HABITAT DESCRIPTION
Yellow tailed Black Cockatoo	
Breeding	Needs large hollows (>30cm) in eucalyptus (alive or dead); many nests occur in riparian zones
Juveniles	?
Feeding	Larvae of large moths found on acacia and eucalypts ; seeds from acacia, grevillea (after fire). Dependency on pine nuts in diet has a negative effect, resulting in egg shell thinning
Sheltering Roosting	Needs large limbs
Dispersing	Movements not restricted to forests
Other ---------	Eucalyptus. forest and woodlands at all altitudes
Glossy Black Cockatoo	
Breeding	Large trees with large hollows (dead and alive) near streams; will forage close to the nest

SPECIES	HABITAT DESCRIPTION
	but are capable of travelling up to 20km away; require water source (gutters on roads & dams)
Juveniles	?
Feeding	Dependent on adult *Allocasuarina littoralis* and *Casuarina verticillata*; individual trees are selected on basis of N content in seeds; will occasionally use alternative foods
Sheltering/ Roosting	Stands of tall trees in elevated locations like ridgelines within range of the feeding resource; there is an interaction between roost sites and surface water sites
Dispersing	Not dependent on forest cover
Other ---------	
Spotted Quail-thrush	
Breeding	Ground breeder; dry rocky ridges/ tussocks/ sunny side of dry ridges;
Juveniles	?
Feeding	Omnivore; insects; small lizards; invertebrates; seeds
Sheltering	as for breeding
Dispersing	Forest cover required
Other ---------	
Red-browed Treecreeper	
Breeding	Small hollows and crevices in general habitat; 5-20m off ground
Juveniles	?
Feeding	Ant feeders; forage on mature (> 20yrs) standing and fallen trees under clumps of decorticating bark on trunk and main branches
Sheltering	Crevices off the ground
Dispersing	Forest cover required
Other ---------	Maintains a permanent territory and therefore requires core habitat all year; rough barked
Brown Treecreeper	
Breeding	Small hollows/cracks in dead or live trees; also uses stumps/fence posts
Juveniles	?
Feeding	Fallen timber - ants primary dietary component
Sheltering	Cracks/fissures
Dispersing	Tree cover required, eg open woodlands and grasslands with standing trees
Other ---------	Fallen timber critical - related to food supply; primarily a woodland species
Eastern Bristlebird	
Breeding	Heath dependent
Juveniles	?
Feeding	Primarily insectivores; fruits of heath plants
Sheltering	Heath dependent
Dispersing	Heath dependent
Other ---------	Primarily heathland but does utilise forest edges; not considered to be forest dependent
Dollar Bird	
Breeding	Large hollows in live or dead trees; high site fidelity
Juveniles	?
Feeding	Large insects (eg cicadas); feed on the wing
Sheltering	Trees
Dispersing	Highly mobile; migrant species
Other ---------	Forest edges; open woodland; farmland with isolated paddock trees; widespread & highly mobile (migrant from SE Asia)
Crested Shrike-tit	
Breeding	Nests high in trees from 5-25m - upper canopy nester in Eucalypts
Juveniles	?
Feeding	Insects; spiders; larvae - living under peeling & decaying bark; leaf galls
Sheltering	As for breeding/feeding
Dispersing	Woodland/ forest dependent, includes riparian corridors, which is particularly important in the western region
Other ---------	Woodlands & open forests; river red gums on water courses; generally widespread in all habitats

SPECIES	HABITAT DESCRIPTION
Painted Honeyeater	
Breeding	Woodland or open woodland habitats are those dominated by White Box *Eucalyptus albens*, Yellow Box *E. melliodora*, Red Stringybark *E. macrorhyncha*, Mugga Ironbark *E. sideroxylon*, Boree *Acacia pendula* and River Oak *Casuarina cunninghamiana* communities. Woodlands which host Mistletoes *Amyema spp*. Are particularly important
Juveniles	Generally move north to open woodlands and scrubs
Feeding	As for breeding. Feeds almost exclusively on mistletoe berries; also takes insects and nectar
Sheltering	As for breeding
Dispersing	
Other ---------	
Swift Parrot	
Breeding	Not relevant - breeds in Tasmania
Juveniles	?
Feeding	Flowering eucalypt forest and woodland; dislikes dense forest; needs trees old enough to flower (>10yr); dependent on local seasonal phenology of forest/woodland; species include woollybutt, yellowbox, white box, grey box, iron barks and forest
Sheltering	As for feeding
Dispersing	No specific habitat requirements
Other ---------	
Square-tailed Kite	
Breeding	Tall, open sclerophyll forest and woodland with or adjacent to high densities of passerine birds (prey); typically tablelands and coastal plains; nests in tall trees with large branches
Juveniles	? as for breeding
Feeding	High density of passerine birds, particularly honeyeaters; will occasionally take lorikeets, quail, pippets, canopy foliage gleaners
Sheltering	As for breeding
Dispersing	No specific habitat requirements
Other ---------	Migrants - spring/summer visitors (breeding season); very large home range area of approx. 100km^2
Hooded Robin	
Breeding	Dry, open sclerophyll forest and structurally diverse woodland with patchy, grassy ground cover; associated with intermediate and higher nutrient; saplings 2-5 m high necessary for nesting
Juveniles	?
Feeding	Ground invertebrates and some aerial invertebrates
Sheltering	As for breeding
Dispersing	Continuous woodland cover required including farmland with patchy tree cover
Other ---------	Minimum patch size of 100ha (area required to contain 1-2 pairs birds)
Black-chinned Honeyeater	
Breeding	Open Eucalypt woodland often with no understorey; also occurs in spinnifex scrub; timber stands along water courses; ironbark forests in Western slopes; high cup nests suspended in foliage
Juveniles	?
Feeding	Almost exclusively insectivourous; flowering ironbark
Sheltering	As for breeding
Dispersing	No specific habitat requirements
Other ---------	Only one record in the region; see general habitat requirements
Turquoise Parrot	
Breeding	Edges of woodlands (including grassy clearings within forests) and dry sclerophyll forest with high proportion of native grasses and forbs; preference for high nutrient sites; nests in hollows (which includes posts & stumps), frequently in dead trees; nests often <2m above ground (HANZAAB 1999)
Juveniles	?
Feeding	Seeds of native grasses and forbs; takes some leafy native foliage; will take some exotic seeds; mainly native grassland species

SPECIES	HABITAT DESCRIPTION
Sheltering	Mosaic of foraging habitat and woody vegetation
Dispersing	?
Other ---------	
Olive Whistler	
Breeding	Sub-stage 0.5 - 5m in general habitat; breeds above 600m; nests low on branches
Juveniles	?
Feeding	Same as breeding and down to the ground - spends most of time on the ground; insects & arthropods
Sheltering	As for breeding
Dispersing	Moves to lower altitudes and a variety of habitats outside the breeding season
Other ---------	Southern populations/race secure compared with Northern populations; alpine to sub-alpine thicket; temperate rainforest; wet sclerophyll forest gullies; blanket bush & tree ferns
Pink Robin	
Breeding	Possibly doesn't breed in NSW; otherwise, sub-stage 0.5-5m in general habitat
Juveniles	?
Feeding	Same as breeding and down to the ground; insects and arthropods
Sheltering	As for breeding and 'other'
Dispersing	Moves to lower altitudes and a variety of habitats outside the breeding season, moves long distances
Other ---------	Temperate rainforest; very wet sclerophyll forests >500m
Superb Parrot	
Breeding	Nests in commons (ie communal nester) in groups of between 1-6 pairs; high nest-site fidelity; dead & live trees used; hollow dependent- need relatively high density of hollow bearing trees (minimum of 6) (therefore isolated trees in paddocks not enough); nest tress usually found less than 200m of water courses;
Juveniles	?
Feeding	Will feed in urban areas; native grasses, green wattle pods, fruits, berries, nectar, buds, flowers, occasionally insects, spilt grain
Sheltering	As for breeding
Dispersing	Migrate north at end of January for the winter
Other ---------	Forest; mixed boxed woodland, cypress pine
Yellow-throated scrub wren	
Breeding	Hanging nests suspended in foliage <5m over water
Juveniles	?
Feeding	Insects; seeds; small molluscs (snails); mostly on ground
Sheltering	Same as general
Dispersing	Continuous habitat
Other ---------	Rainforest; wet sclerophyll forests; dense vegetation near water; usually occurs between 400-1000m;
Regent Honeyeater	
Breeding	Core breeding areas usually the western slopes of the Great Divide – primarily in box-ironbark woodlands; occasional coastal breeders; Chilton one of three identifiedcore breeding areas
Juveniles	?
Feeding	Nectar, lerps and insects; mainly nectar from *E. sideroxylon, E. melliodora,* but also from *E. robusta* and the mistletoe *Amyema cambagei;* flowering eucalypts on richer soil types with different phenologies to provide reliable supply of nectar
Sheltering	As for breeding/other
Dispersing	Disperse widely after breeding; follow flowering patterns – movements not predictable
Other ---------	Dry sclerophyll forest and woodlands (containing forest red-gum) on western slopes of divide; gallery forests of she-oak; swamp mahogany trees and stands during cooler months; uses *E. longifolia, E. tricarpa* and *E. tereticorn*; yellow-box, white-box, Mugga ironbark, grey box.

APPENDIX 3.5 CRITICAL HABITAT REQUIREMENTS OF THE BATS

SPECIES	HABITAT DESCRIPTION
Chalinolobus dwyeri	
Breeding	Caves, possibly mines; generally sandstone areas
Juveniles	?
Feeding	Predominantly dry forest with some moist forest; probably specialist insectivore
Sheltering	As for breeding, plus used fairy martin nests
Dispersing	?
Other ---------	Little known of this species especially in in the Southern region. Association with sandstone including caves, overhangs and taphony (honeycomb formations in sandstone)
Falsistrellus tasmaniensis	
Breeding	Hollows – large for maternity roosts (therefore large, old trees); dry sclerophyll and moist eucalyptus forest; also alluvial redgum forest
Juveniles	?
Feeding	Dry sclerophyll, moist eucalyptus forest and rainforest; eats beetles, moths and possibly other bats, trend for productive forest
Sheltering	Hollows generally
Dispersing	
Other ---------	Generally found east of the escarpment (<600m asl); coastal, probably more an association with temperature approximately < 14C mean annual temperature
Kerivoula papuensis	
Breeding	Temperate rainforest, wet sclerophyll and riparian forest; tree hollows used and sometimes bird nests; strong association with riparian areas
Juveniles	?
Feeding	Insects and spiders; forage in native forest; generally associated with creek-lines and gullies
Sheltering	Same as breeding habitat; also utilise bird nests over creeklines
Dispersing	Continuous forest habitat (probably avoids cleared areas)
Other ---------	Generally associated with creek-lines and gullies
Miniopterus schreibersii	
Breeding	Usually occur in low densities; use select limestone cave systems; will congregate in maternity roosts in high numbers (up to 100 000); may be a threshold number of individuals to successfully breed
Juveniles	?
Feeding	Aerial insects particularly moths; range of habitats
Sheltering	Range of artificial structures including culverts, drains, mines etc, plus caves; complex social structure - range of roost sites for different functions eg maternity, wintering, acclimatisation
Dispersing	?
Other ---------	Very large foraging areas; location of roost site determines foraging environment/habitat; only two maternity sites in the region; edges perhaps preferred, ie ecotones between forest & cleared land
Mormopterus norfolkensis	
Breeding	Large mature tree hollows in all forest (native) types
Juveniles	?
Feeding	Probably more forest dependent species than *Mormopterus* sp 1
Sheltering	Large mature tree hollows and under bark
Dispersing	?
Other ---------	
***Mormopterus sp*. 1**	
Breeding	Large mature tree hollows in all forest (native) types
Juveniles	?
Feeding	Native forest, cleared areas and remnant vegetation
Sheltering	Large mature tree hollows and under bark
Dispersing	?

SPECIES	HABITAT DESCRIPTION
Other ---------	
Myotis macropus	
Breeding	Caves, tunnels, tree hollows and under bridges
Juveniles	?
Feeding	Water bodies such as rivers, creeks and pools, also farm dams and estuaries; feed upon aquatic insects, fish, insects over water
Sheltering	Caves, tunnels, tree hollows and under bridges
Dispersing	?
Other ---------	Permanent water required
Pteropus poliocephalus	
Breeding	As for shelter but more restricted
Juveniles	?
Feeding	Nectar and fruit feeders on :forest red gum (now very rare but strong association historically), red bloodwood, spotted gum, banksia, rainforest fruit
Sheltering	Coastal sclerophyll forest along creek lines
Dispersing	?
Other ---------	
Pteropus scapulatus	
Breeding	Probably do not breed in region.
Juveniles	?
Feeding	Nectar specialist: river red gum, yellow-box, melaleuca swamps
Sheltering	Will share the same camp sites as *Pteropus poliocephalus*
Dispersing	More nomadic than *Pteropus poliocephalus*
Other ---------	More a northerly, inland species, probably go to the coast during big flowering events (eg spotted gum); Southern region can be regarded as marginal habitat for the species.
Rhinolophus megaphyllus	
Breeding	Humid caves and mines; females congregate to breed; sandstone, limestone and volcanics; range of forest types
Juveniles	?
Feeding	Aerial insects in range of forest types - more common in moister types, forages in understorey
Sheltering	As for breeding plus culverts, drains, moist tree hollows, NB: no records for this in southern, but no reason why not
Dispersing	Dispersal limited (< 60km); avoid open areas
Other ---------	Appears to be more vulnerable in drier areas; fairly secure along the coast; type locality was drowned
Saccolaimus flaviventris	
Breeding	Hollows in forests
Juveniles	?
Feeding	Flying insects
Sheltering	Hollows; may also use caves; has also been recorded in a tree hollow in a paddock
Dispersing	?
Other ---------	Little known about this species
Scoteanax rueppellii	
Breeding	Hollows (large hollows for maternity roosts); eucalypt forest - mid-high altitude,
Juveniles	?
Feeding	Beetles and moths; trend for productive forest
Sheltering	Hollows generally
Dispersing	?
Other ---------	Common in alpine ash forests at higher elevations (700-1000m asl); variable elevations at the coast, probably associated with warmer temperatures (approximately 14C mean annual temperature)

APPENDIX 3.6 CRITICAL HABITAT REQUIREMENTS OF THE REPTILES

SPECIES	HABITAT DESCRIPTION
Common Death Adder	
Breeding	Woodlands, heath; thick leaf litter; open forest understorey cover is important.
Juveniles	?
Feeding	Sedentary
Sheltering	As for breeding
Dispersing	?
Other ---------	Woodlands, heath; thick leaf litter; open forest understorey cover is important
Broad-headed Snake	
Breeding	Rocky outcrops, rock flakes and slabs, crevices; open sclerophyll forest, woodland and heath, sandstone outcrops; low to high elevation
Juveniles	?
Feeding	Likely to feed on geckos, small mammals and lizards
Sheltering	Uses woodland above and below the escarpment during summer (stags and hollow trees in these areas); rocky outcrops, rock flakes and slabs, crevices, tree hollows, stags
Dispersing	Rock outcrops, hollow trees; fallen trees between winter and summer sheltering sites may be
Other ---------	
Diamond Python	
Breeding	?
Juveniles	?
Feeding	Summer feeding activity concentrated in areas of high small mammal abundance
Sheltering	Hollow trees, hollow logs, rocks
Dispersing	Different summer and winter sheltering sites based on work in Hawkesbury Sandstone; hollow trees, hollow logs, rocks
Other ---------	Forest, heathland and escarpment - general habitat requirements – ambush predator so ground cover/understorey important
Carpet Python	
Breeding	?
Juveniles	?
Feeding	Summer feeding activity concentrated in areas of high small mammal abundance
Sheltering	Hollow trees, hollow logs, rocks
Dispersing	Different summer and winter sheltering sites based on work in Hawkesbury Sandstone; hollow trees, hollow logs, rocks
Other ---------	Forest, heathland and escarpment - general habitat requirements – ambush predator so ground cover/understorey important
Heath Monitor – 2 distinct, disjunct populations were identified – northern and southern	
Breeding	Sydney sandstone woodland, heathland; terrestrial termitaria
Juveniles	?
Feeding	Vertebrates and invertebrates
Sheltering	**Northern populations** rocks, hollow logs, dense ground layer vegetation, burrows; sandstone particularly important **Southern population** - rocks, hollow logs; burrows
Dispersing	**Northern populations**: dispersal requires some rocks, hollow logs, dense ground layer vegetation, burrows etc **Southern population** – dense ground layer vegetation **not** important
Other ---------	Mosaic of open areas (required for basking sites) and ground cover
Maccoy's Skink	
Breeding	As for ‘other’
Juveniles	As for ‘other’
Feeding	As for ‘other’
Sheltering	As for ‘other’
Dispersing	As for ‘other’

SPECIES	HABITAT DESCRIPTION
Other ---------	Cool moist forests with refugia (eg fallen logs), especially during winter, and leaf litter; friable soils probably important as it is a burrowing species
Spencer's Skink	
Breeding	As for 'other'
Juveniles	As for 'other'
Feeding	As for 'other'
Sheltering	As for 'other'
Dispersing	As for 'other'
Other ---------	Forest dependent species that prefers open mature forest and can tolerate recently disturbed forest as it provides access to sun and basking opportunities; rocks; dense understorey not good; essentially arboreal, in large stags; access to sun/basking opportunities is a critical factor

APPENDIX 3.7 CRITICAL HABITAT REQUIREMENTS OF THE FROGS

SPECIES	HABITAT DESCRIPTION
Giant Burrowing Frog	
Breeding	Closely associated with Sydney sandstone basin; mostly associated with hanging sandstone shelves and the upper laterals (first order streams **important habitat for the northern populations, but not necessarily true for the southern population**) that run through heathland and woodland; natural and man-made drainage lines
Juveniles	?
Feeding	Forages widely; adults forage terrestrially up to several hundred metres away from breeding sites; forages in woodlands, wet heath, dry and wet sclerophyll forest; feeds on large invertebrates.
Sheltering	Soil must be soft and sandy so that burrows can be constructed
Dispersing	Capable of dispersing long distances through intact native vegetation.
Other ---------	Sandy friable soils are important for burrowing; only found in native veg types; two populations in Southern region - northern Sydney Sandstone and a southern non-sandstone population.
Booroolong Frog	
Breeding	Shallow connected pools or isolated rock pools in rocky sections of streams
Juveniles	?
Feeding	?
Sheltering	Under rocks
Dispersing	?
Other ---------	Has been found in non-native vegetation; rocky sections in streams appear to be important; associated with permanent streams in wet and dry forest, woodland and cleared grazing land (but requires riparian vegetation); generally western running streams 200-1300m asl; suspect a riverine frog
Highlands Tree Frog	
Breeding	Breeding sites are variable
Juveniles	?
Feeding	?
Sheltering	?
Dispersing	?
Other ---------	4 records in the Southern region; has been found in disturbed forest; appears to be restricted to sandstone areas in the region; however there are also records from Eden (1 record) and Victoria
Stuttering Barred Frog	
Breeding	1st and 2nd order streams; permanently flowing pools or non-permanent streams with permanent large pools ; non perennial and perennial; riffles for egg laying - native fish present
Juveniles	?
Feeding	Native vegetation

SPECIES	HABITAT DESCRIPTION
Sheltering	Shelters under thick moist leaf-litter; Will dig a shallow burrow in loose soil under litter
Dispersing	?
Other ---------	Very few records; probably no altitude threshold in Southern; wet sclerophyll and rainforest areas probably important; riparian vegetation, moderately intact; forest dependent
Red-crowned Toadlet	
Breeding	Ephemeral seepages and first order streams in sandstone country, generally just below ridge tops; have been known to breed in road-side gutters
Juveniles	?
Feeding	Requires forest or heath cover; may be linked with termites; feed adjacent to breeding areas; forages terrestrially
Sheltering	Rocks and sandstone fissures, other shelter sites likely to include leaf litter
Dispersing	Don't know - but likely that natural vegetation required.
Other ---------	Very few records (all within reserves) - species at the southern limit of its range
Brown Toadlet	
Breeding	Ephermerally flooded depressions (pools etc…); terrestrial egg layer
Juveniles	Juveniles < 1yr - same habitat as for breeding; 1yr olds move into forest adjacent to breeding habitat
Feeding	Termites (mounds and logs) and ant specialist, forming a significant part of the diet
Sheltering	Under logs (probably more important in winter), leaf litter; burrows of other animals (eg of arthropods) and cracks
Dispersing	Native vegetation; substantial cover required
Other ---------	Association with native vegetation outside the breeding season; forest/trees important (related to food supply and shelter)
Northern Corroboree Frog	
Breeding	Upland bogs and seepages; terrestrial egg-layer
Juveniles	Near bogs and seepages for 1yr; sub-adults move into adjacent woodland
Feeding	Presumed that species feeds in forest and woodland around breeding sites probably under logs
Sheltering	Bogs and logs and possibly leaf litter; over-winter inside logs
Dispersing	Presumed that species disperses in forest and woodland around breeding sites
Other ---------	

APPENDIX 3.8 CRITICAL HABITAT REQUIREMENTS OF THE AQUATIC FAUNA

SPECIES	HABITAT DESCRIPTION
Australian Grayling	
Breeding	Fresh water gravel bed stream. May/June spawning. 12^{o}C temp. Must have access to sea. Clear water, relatively undisturbed riparian vegetation
Feeding	Estuarine/ marine. Need access from sea.
Juveniles	Insects (aquatic and terrestrial), algae
Sheltering	Schooling, midwater species. No strong affinity to structures (snags etc).
Dispersing	As for juveniles
Other ---------	Pool riffle sequences. Third order and above streams
Macquarie Perch(2-3 species)	
Breeding	Fresh water gravel bed stream with riffles. Oct/Nov spawning. 16^{o}C temp. Clear water, undisturbed riparian vegetation. No long spawning migration.
Feeding	Need for lots of cover - rocks, boulders, weed, snags
Juveniles	Aquatic invertebrates
Sheltering	Very strong affinity to structures (snags and boulders).
Dispersing	Not too fast/shallow flowing water. Won't cross shallow fords, through culverts, waterfalls. Saltwater a barrier to movement
Other ---------	Mainly confined to upper reaches of catchments with intact veg (today). Pool - riffle sequences very important. Third order and above streams.

SPECIES	HABITAT DESCRIPTION
Trout Cod	
Breeding	Spawning sites hollow logs(?), boulders. Eggs glued to hard substrate. Rising water temperature 17-18^{o}C. Possible upstream spawning migration. Spawning Sept-Nov
Feeding	Lots of cover - rocks, boulders, weed, snags
Juveniles	Aquatic invertebrates, crustaceans, small fish. Sit and wait predator
Sheltering	Very strong affinity to large, woody debris. Rocks, boulders. Preference for more midstream shelter.
Dispersing	Salt water barrier. Major dispersal at 2-3 years old, pres. downstream (assumed)
Other ---------	Large waterbody species
Lampray (2 species)	
Breeding	Flowing freshwater with sand, gravel, pebble substrate. Breeds Aug-Nov. Need access from estuaries
Feeding	Soft substrates of streams and rivers.
Juveniles	Juveniles - algae, detritus, microorganisms. Adults - fish (short-headed)??. Detritus (non parasitic)
Sheltering	Soft substrates
Dispersing	Aug-Nov - downstream to the sea. Aug-Dec - returns to freshwater. Climbs wet, vertical surfaces
Other ---------	
Murray River Crayfish	
Breeding	Spawn Apr-May. Carry eggs/larvae till Oct/Nov. Breeding May-Aug
Feeding	Same as adults. Need cover to avoid cannibalism/ predation
Juveniles	Detritivores/ carrion feeders
Sheltering	Burrowing in lowlands. Rocks and boulders in highlands.
Dispersing	Sedentary.
Other ---------	Well oxygenated water. Tolerate turbid but prefer clear.

APPENDIX 4

APPENDIX 4.1 DISTURBANCES IDENTIFIED FOR GROUND MAMMALS AND THEIR IMPACTS RANKED RELATIVE TO EACH OTHER

Species	Disturbance	Rank	Comments
White-footed Dunnart	Habitat clearing	1	
	Predation – cats, dogs, foxes	2	Especially cats
	Any management practice that promotes thick regeneration - eg logging, hazard reduction burning	2	Thick regeneration disadvantages this species.
	Weeds	3	Eg. Bitou (*Chrysanthemoides monilifera*)
Smoky Mouse	Too frequent fire (eg hazard reduction burns)	1	Eg <15 year intervals
	Any activity that removes heath understorey	1	Heath takes 50-100 years to regenerate.
	Predation - dogs, foxes, cats	1	
	Any management practice that promotes dense overstorey regeneration.	1	Pole stage of dense regeneration is poor habitat.
	Habitat clearing - mining, roading, logging	1	
Southern-brown Bandicoot	Too frequent fire (eg hazard reduction burns)	1	Eg <15 year intervals
	Any activity that removes heath understorey	1	Heath takes 50-100 years to regenerate
	Predation - dogs ,foxes, cats	1	
	Habitat clearing	1	
	Any management practice that promotes dense overstorey regeneration.	2	The pole stage of dense regeneration is poorer habitat
	Poison baiting (eg. Foxoff)	2	Unknown but potentially significant impact
	Fire exclusion	3	
Long-nosed bandicoot	Too frequent fire	1	Eg <15 year intervals
	Any activity that removes dense ground or shrub cover	1	
	Predation - dogs, foxes, cats	1	Including pets near urban centres
	Habitat clearing - urbanisation, fragmentation	1	
	Poison baiting (eg. Foxoff)	2	Unknown but potentially significant impact
	Grazing in riparian strips (esp. in west)	4	
Long-nosed potoroo	Too frequent fire	1	Eg <10 year intervals

Species	Disturbance	Rank	Comments
	Any activity that removes dense ground or shrub cover	1	
	Predation - dogs, foxes, cats	1	including pets near urban centres
	Habitat clearing - including urbanisation, fragmentation	1	
	Thinning in dense pole stands in coastal locations	2	
	Poison baiting (eg. Foxoff)	2	Unknown but potentially significant impact
	Grazing	3	
Spotted-tailed Quoll	Poison baiting (eg. Foxoff)	1	Primary and secondary poisoning * very significant impact
	Any activity that impacts on prey	2	
	Any activity that impacts on den sites	2	eg. Logging intensity - canopy cover removal >45% (depends where in the landscape)
	Habitat clearing - urbanisation, fragmentation	2	
	Too frequent fire	3	<20 year intervals (can impact on den resource as well)
	Predation and competition by exotic predators (dogs, foxes, cats)	3	
Broad-toothed Rat	Climate change	1	
	Predation - exotics (dogs, foxes, cats)	1	
	Habitat clearing - urbanisation, fragmentation, ski resorts/runs	2	
	Roading (that impedes movement)	2	
	Grazing	3	
Brush-tailed rock Wallaby	Predation - dogs, foxes	1	
	Competition - rabbits, goats	1	
	Poison baiting for rabbits (carrots - 1080)	2	
	Inappropriate fire regimes	3	
	Human interference - rock climbers	4	

APPENDIX 4.2 DISTURBANCES IDENTIFIED FOR ARBOREAL MAMMALS AND THEIR IMPACTS RANKED RELATIVE TO EACH OTHER

Species	Disturbance	Rank	Comments
Eastern Pygmy Possum	Habitat clearing – agriculture/urban	1	
	High frequency burning	2	RK questioned whether burning in forests with a heath understorey on south coast was as significant as in the north coast - suggested dropping ranking on basis that not a significant threat at landscape level. Agreed rank of 2
	Predation – cats, foxes, dogs	2	especially cats and foxes
	Grazing	3	
Greater Glider	Logging	1	Decided to not delineate between intensive and selective and use definition of logging in UNE/LNE. Selective logging was defined as 50% canopy removal. RK – Effect of single SL not a problem, but multiple, poorly

Species	Disturbance	Rank	Comments
			controlled, operations will. RK, JS – Protocols are ameliorating effects. PG – Not convinced protocols are working, selective logging can still affect age class of trees
	Habitat clearing - agriculture	1	
	Habitat clearing - urban development	2	
	Habitat clearing - plantation establishment	3	
	Firewood collection	4	
Yellow-bellied Glider	Habitat clearing - urban development	1	
	Logging	2	1 - DM - concerned at progressive loss of old trees – susceptible to localised extinction, PG - species is resilient compared to Greater Glider, 3 - JS -agrees to 2 as a compromise. Protection of riparian strips critical.
	Habitat clearing - agriculture	2	
	Habitat clearing - plantation establishment	4	
	Firewood collection	4	
Koala	Habitat clearing - agriculture	1	
	Habitat clearing - urban development	1	
	Wildfire	2	
	Predation – cats, foxes, dogs	3	
	Logging	4	
	Disease	5	
	Road kills	6	
Squirrel Glider	Habitat clearing – agriculture/urban	1	
	Logging	2	
	Predation – cats, foxes, dogs	3	
	Wildfire	4	
Brush-tailed Phascogale	Habitat clearing - agriculture	1	If clearing occurs in habitat then #1, otherwise, predators are #1
	Predation – cats, foxes, dogs	2	
	Firewood collection	2	
	Wildfire	3	
	Logging	4	Based on assumption that the species occurs primarily on the western slopes of the region
	Grazing	5	

APPENDIX 4.3 DISTURBANCES IDENTIFIED FOR NOCTURNAL BIRDS AND THEIR IMPACTS RANKED RELATIVE TO EACH OTHER

Species	Disturbance	Rank	Comments
Powerful Owl	Logging – that results in a reduction in abundance/availability of prey	1	Especially greater gliders
	Habitat clearing	1	
	Fire which disturbs prey populations (eg inappropriate fire regimes)	2	
	Logging that disturbs/destroys roosting trees	3	
	Predation/competition – cats, foxes, dogs	4	Impact on young/competition for prey

Species	Disturbance	Rank	Comments
	Roadkills	4	
	Human interference (eg. tourism – using playback techniques may disturb animals)	5	
Sooty Owl	Logging – that results in a reduction in abundance/availability of prey	1	
	Habitat clearing	1	
	Fire which disturbs prey populations	2	
	Logging that disturbs/destroys roosting trees	3	
	Predation/competition – cats, foxes, dogs	4	Impact on young/competition for prey
	Human interference (eg. tourism – using playback techniques may disturb animals)	5	
Masked Owl	Logging that increases structural density of forests	1	Cover prevents access to prey
	Habitat clearing	1	
	Logging that disturbs/destroys nesting/roosting trees	2	
	Wildfire	3	Cover prevents access to prey
	Roadkills	3	
	Predation/competition – cats, foxes, dogs	4	Impact on young/competition for prey
	Human interference (eg. tourism – using playback techniques may disturb animals)	5	
	Bees - competition for nests	6	Particularly in areas with few nest site opportunities
Barking Owl	Habitat clearing	1	
	Grazing	2	Compromises sapling regrowth
	Firewood collecting	3	Loss of nests
	Predation/competition – cats, foxes, dogs	3	Impact on young/competition for prey
	Bees - competition for nests	3	Particularly in areas with few nest site opportunities
	Human interference (eg. tourism – using playback techniques may disturb animals)	4	
	Rabbit control	5	
Bush Stone Curlew	Predation – cats, foxes, dogs	1	
	Removal of fallen dead timber	2	
	Pasture improvement	2	
	Habitation modification	3	Especially tree removal
	Heavy grazing	4	Lowering of invertebrate abundance and diversity - loss of microhabitat diversity

APPENDIX 4.4 DISTURBANCES IDENTIFIED FOR DIURNAL BIRDS AND THEIR IMPACTS RANKED RELATIVE TO EACH OTHER

Species	Disturbance	Rank	Comments
Yellow-tailed Black Cockatoo	Habitat clearing – agricultural/urban	1	

Species	Disturbance	Rank	Comments
	Any activity that affects the number and recruitment of hollow-bearing trees eg logging	2	
	Any fire frequency which affects the recruitment of Acacias	2	Fire frequency < or = 5 yrs at low intensities
	Pine Plantations	3	Reliance on pine nuts results in egg thinning
	Pet trade	4	
Glossy-black Cockatoo	Habitat clearing – agricultural/urban	1	
	Any activity that affects number and recruitment of hollow-bearing trees eg logging	2	
	Any fire frequency which affects the age class & recruitment of Allocasuarina	2	Fire frequency less than or equal to 5 yrs at low intensities
	Firewood collection	3	Large old trees - historically the collection of Allocasuarina for firewood affected this species (MC)
	Pet trade	4	
Spotted Quail-thrush	Habitat clearing – agricultural/urban	1	
	Frequent fire – eg hazard reduction burning	2	Fire frequency < or = 5 yrs at low intensities; removes leaf litter
	Habitat fragmentation	2	
	Predation – foxes, cats	2	Predation unknown, but likely to be a threat
	Firewood collection	3	Fallen timber
Red-browed Treecreeper	Habitat clearing	1	Unknown, but likely to be a threat
	Fragmentation	1	
	Any activity that affects the number and recruitment of trees with large, hollow branches, eg logging	2	
	Any activity that results in the loss and reduced number of large trees that decorticate bark (ie gums), eg logging	2	
	Predation – foxes, cats, dogs	4	
Brown Treecreeper	Habitat clearing – agricultural/urban	1	
	Habitat fragmentation	1	
	Removal of dead fallen timber	1	Eg farmers for grazing
	Grazing	2	
	Pasture improvement	2	Modification of the ground layer; pasture improvement - insect fauna affected - exotic pasture detrimental
	Predation – dogs, cats, foxes	3	Impact unknown, but likely to be a threat
	Dieback	3	
	Fire	4	
Eastern Bristlebird	Habitat clearing – agricultural/urban	1	
	Habitat fragmentation	1	
	Fire - too frequent burning	1	Fire < 8 yr intervals
	Predation – dogs, cats, foxes	3	Impact unknown, but likely to be a threat
	Grazing	3	
Dollar Bird	Habitat clearing – agricultural/urban	1	horticultural
	Fire/grazing which prevents the recruitment of trees	1	

Species	Disturbance	Rank	Comments
	Loss of hollow-bearing trees, eg firewood collection	1	Especially in open woodlands & farmland
	Dieback	3	
Crested Shrike-tit	Habitat clearing – agricultural/urban	1	
	Habitat fragmentation	2	
	Any activity that results in the loss and reduced number of large trees that decorticate bark (ie gums), eg logging	2	
	Dieback	3	
Painted Honeyeater	Clearing of habitats particularly for agriculture	1	
	Fragmentation of habitats	1	
	Priority given to trees containing mistletoe in logging operations	1	
	Anything that affects recruitment of trees in agric/ woodlands eg logging and grazing	2	
	Logging – removal of mature and large trees; reduction of age class	2	
	Degradation of woodlands incl. Dieback, lack regeneration, grazing, fire; firewood collection	2	
Swift Parrot	Habitat clearing – agricultural/urban	1	Especially on western slopes
	Habitat fragmentation	1	
	Dieback	2	
	Logging that reduces age class of trees	2	Trees need to be > or = 10 yrs for flowering (older trees more prolific flowering); prefer bigger trees
	Firewood collection	2	Especially on the western slopes - cutting of live trees is an issue
	Fire/grazing which prevents the recruitment of trees, eg logging & grazing	2	Especially in agriculture/ open woodlands & farmland
	Bees	5	Generally unknown; competition for nectar
Square-tailed Kite	Habitat clearing – agricultural/urban	1	
	Habitat fragmentation	1	
	Anything that affects prey availability & density, eg logging, grazing, fire	1	
	Fire/grazing which prevents the recruitment of trees, eg logging & grazing	2	especially in agriculture/ open woodlands & farmland
	Shooting	4	
	Egg collecting	4	
Hooded Robin	Habitat clearing – agricultural/urban	1	
	Habitat fragmentation	1	
	Firewood collection	1	
	Dieback	2	
	Anything that affects recruitment of trees in agricultural and woodlands eg logging & grazing	2	
	Pasture improvement	2	Affects insect availability & abundance
	Predation – dogs, cats, foxes	4	
Black-chinned Honeyeater	Habitat clearing – agricultural/urban	1	

Species	Disturbance	Rank	Comments
	Dieback	2	
	Anything that affects recruitment of trees in agric/ woodlands eg logging & grazing	2	
Turquoise Parrot	Habitat clearing – agricultural/urban	1	Anything that modifies ground cover is a threat
	Pasture improvement & cropping	1	
	Dieback	2	
	Anything that affects recruitment of trees in agric/ woodlands eg logging & grazing	2	
	Predation – dogs, cats, foxes	2	
	Firewood collection	3	
	Pet trade/ trapping/ egg collection	4	
	Road-kills	4	In association with spilled grain & native roadside vegetation corridors
Olive Whistler	Habitat clearing – agricultural/urban	1	Not likely to be a problem because occurs in habitat that won't be cleared – eg gullies and riparian habitat, but major problem throughout the species distribution
	Habitat fragmentation	1	
	Predation – dogs, cats, foxes	3	Population believed to be secure in Southern Region
	Frequent fire, eg hazard reduction burns	4	
Pink Robin	Habitat clearing – agricultural/urban	1?	May not be a problem because occurs in habitat (eg riparian) that won't be cleared
	Habitat fragmentation	1	
	Frequent fire	4	
	Predation – dogs, cats, foxes	5	Population believed to be secure in Southern Region
Superb Parrot	Anything that removes hollow bearing trees & their requirement (firewood collection, logging, senescence of trees,	1	
	Habitat fragmentation	1	
	Fire/grazing/pasture improvement	1	Affects food source and degrades ground cover
	Habitat clearing – agricultural/urban	1	
	Pet trade/trapping/egg collection	2	
	Road kills	2	in association with spilled grain & native roadside veg corridors
	Predation – dogs, cats, foxes	3	
	Introduced bees	3	Competition for nests sites
	Frequent fire, eg hazard reduction burns	4	
Yellow-throated scrub wren	Habitat clearing – agricultural/urban	1?	May not be a problem in Southern because occurs in habitat that won't be cleared – eg gullies and riparian habitat, but major problem throughout the species distribution
	Habitat fragmentation	1	
	Predation – dogs, cats, foxes	3	Population believed to be secure in Southern Region

Species	Disturbance	Rank	Comments
	Frequent fire, eg hazard reduction burns	4	
Regent Honeyeater	Habitat clearing – agricultural/urban	1	Especially western slopes
	Degradation of woodlands, eg dieback, grazing, fire; firewood collection	1	Lack of regeneration
	Habitat fragmentation	1	Especially woodland habitat
	Logging	2	removal of mature & large trees; reduction of age class
	Introduced bees	5	Generally unknown; competition for nectar

APPENDIX 4.5 DISTURBANCES IDENTIFIED FOR BATS AND THEIR IMPACTS RANKED RELATIVE TO EACH OTHER

Key: * difficult to assess the impact of disturbance on these species because so little is known

Species	Disturbance	Rank	Comments
Chalinolobus dwyeri*	Habitat clearing/fragmentation	1	
	Disturbance to roosting/nesting sites including recreational activities	2	Known threat
	Anything that results in loss of foraging habitat, eg frequent burning, logging, grazing	2	Anything that disturbs the understorey is likely to have an impact, particularly during the winter preparation period, which is a critical time. This species is only associated with sandstone areas where logging doesn’t occur, so logging is not likely to be an impact – based on the current information on this species distribution. BL prefer rank of 3 because disturbance to roosting sites is likely to be more important than disturbance to foraging habitat
	Wildfire	3	Has potential for short term significant impact but acknowledgment that in the long-term wildfire is part of Australian forest ecosystem processes
	Predation – dogs, cats, foxes	5	
Falsistrellus tasmaniensis	Habitat clearing/fragmentation	1	
	Logging, loss of hollow bearing trees	2	Has specific requirement compared to other bats
	Anything that results in loss of foraging habitat, eg frequent burning, logging, grazing	3	Anything that disturbs the understorey is likely to have an impact, particularly during the winter preparation period, which is a critical time.

Species	Disturbance	Rank	Comments
	Anything that causes dense regrowth of trees	3	Results in loss of structural complexity and changes to micro-climate (eg high water uptake of regrowth forest can result in drying); short term impact
	Climate change	4	
Kerivoula papuensis	Habitat clearing/fragmentation	1	
	Loss of hollows/roosting sites, eg logging	2	Current prescriptions don't log riparian areas so lower threat; also more flexible nest/roosting sites
	Anything that results in loss of understorey, eg frequent burning	2	
Miniopterus schreibersii	Disturbance to wintering sites eg recreational cavers	1	
	Disturbance to maternity sites including recreational cavers, vandals	1	
	Habitat clearing	2	
	Pesticides	3	
	Predation – dogs, cats, foxes	4	Especially cats
	Pine plantations - habitat replacement	4	Food supply affected
	Severe habitat fragmentation	4	
	Altered hydrology/micro climate eg: changes to vegetation/blackberries	5	Especially to maternity sites - warm moist environments important
Mormopterus norfolkensis	Habitat clearing	1	Including riparian habitat
	Loss of hollow bearing trees, eg logging	2	
	Habitat fragmentation	3	Not regarded as a primary threat as this species has been recorded in remnant vegetation
	Pesticides	3	Forage in farmland areas
	Anything that causes dense regrowth of trees and therefore loss of structural complexity	3	Short-term impact
	Anything that results in loss of foraging habitat (ie understorey), eg timing and frequency of burning, logging	4	Anything that disturbs the understorey is likely to have an impact, particularly during the winter preparation period, which is a critical time.
Mormopterus sp. 1	Habitat clearing	1	Including riparian habitat
	Loss of hollow bearing trees, eg logging	2	
	Habitat fragmentation	3	Not regarded as a primary threat as this species has been recorded in remnant vegetation
	Pesticides	3	Forage in farmland areas
	Anything that causes dense regrowth of trees and therefore loss of structural complexity	3	Short-term impact
	Anything that results in loss of foraging habitat (ie understorey), eg timing and frequency of burning, logging	4	Anything that disturbs the understorey is likely to have an impact, particularly during the winter preparation period, which is a critical time.
Myotis macropus	Habitat clearing	1	

Species	Disturbance	Rank	Comments
	Anything impacting on water bodies, eg swamp drainage, siltation (roading, frequent burning), pollution	1	
	Disturbance to roost sites, eg human interference, bridge replacement	1	
	Habitat fragmentation - severe	2	
	Loss of riparian areas	2	
	Loss of hollows/roosting sites, eg logging	3	Current prescriptions don't log riparian areas and thus logging is not a primary threat. This species also has a wide range of roosting sites, eg bridges etc…
	Replacement of log bridges with concrete bridges	4	
Pteropus poliocephalus	Habitat clearing	1	
	Disease	?	Unknown but could be significant
	Logging that could affect flowering patterns by changing age structure	3	
	Shooting	4	
	Inappropriate fire regimes that could affect flowering patterns	4	
	Bees	4	Competition for food
	Disturbance to roosting sites (eg shooting)	5	
	Powerlines/barbwire fences	5	Takes a disproportionate number of lactating/pregnant females
	Pollution, eg lead levels in urban areas	5	
Pteropus scapulatus	Habitat clearing	1	
	Shooting	4	
	Bees	4	
	Disturbance to roosting sites, eg shooting	5	
	Powerlines/barbwire fences	5	Takes a disproportionate number of lactating/pregnant females
	Disease	5	Unknown but could be significant
	Pollution, eg lead levels in urban areas	5	
	Inappropriate fire regimes that could affect flowering patterns	5	Possible impact, but extent this happens for this species' habitat is unknown
Rhinolophus megaphyllus	Disturbance to maternity sites, eg recreational cavers, vandals	1	
	Disturbance to over-wintering sites, eg recreational cavers	1	
	Habitat clearing	2	
	Habitat fragmentation	2	
	Anything that results in loss of the understorey, eg inappropriate fire regimes	3	Food supply affected
	Altered hydrology/micro-climate eg changes to vegetation or blackberries	3	Especially maternity sites - quite specific requirements - warm moist environments important
	Predation – dogs, cats, foxes	4	Especially cats
Saccolaimus flaviventris	Anything that results in the loss of hollows/roosting sites, eg logging, dieback on private property	1	

Species	Disturbance	Rank	Comments
	Habitat clearing	2	
	Pesticides	2	This species forages on private land
	Lyssa virus	?	Unknown level of impact/significance, but is know to occur in this species
Scoteanax rueppellii	Habitat clearing	1	Including riparian vegetation
	Anything that causes the loss of hollow-bearing trees, eg logging	2	
	Habitat fragmentation	3	Known to feed in remnants, thus lower importance
	Anything that results in loss of foraging habitat (ie understorey), eg timing and frequency of burning, logging	3	Anything that disturbs the understorey is likely to have an impact, particularly during the winter preparation period, which is a critical time.
	Anything that results in loss of foraging habitat (ie understorey), eg timing and frequency of burning, logging	3	Anything that disturbs the understorey is likely to have an impact, particularly during the winter preparation period, which is a critical time.

APPENDIX 4.6 DISTURBANCES IDENTIFIED FOR REPTILES AND THEIR IMPACTS RANKED RELATIVE TO EACH OTHER

Species	Disturbance	Rank	Comments
Death Adder	Habitat clearing/fragmentation	1	
	Regular burning in association with grazing, hazard reduction and post-logging burns	2	Loss of understorey and immediate loss of leaf-litter appears to be key problem
	Bush-rock collecting	2	Significant for populations in the Sydney sandstone area because of loss of habitat for prey species – not significant outside this area
	Wildfire	3	Major short term impact
	Logging	3	
	Human interference (killing, road kills)	4	
	Predation – dogs, cats, foxes	5	Young animals affected
Broad-headed Snake	Habitat clearing/fragmentation	1	
	Wildfire	1	Major short term impact
	Pet-trade collecting	1	Patchy effect dependent on access (eg in vicinity of roads); high impact where it occurs
	Bush-rock collecting	1	Loss of habitat for prey species in Sydney Sandstone areas
	Time of logging	2 5	Depends on time of year – potentially greater impact in summer (direct impact on individuals) Low score if logging occurs in winter
	Logging that removes large habitat trees or affects recruitment of such trees	2	Impact depends on management guidelines
	Regular burning in association with grazing, hazard reduction and post-logging burns	3	Loss of understorey and immediate loss of leaf-litter appears to be key problem
	Feral goats	4	

Species	Disturbance	Rank	Comments
	Predation – dogs, cats, foxes	5	
Diamond Python	Habitat clearing/fragmentation	1	Urban and agricultural
	Predation – dogs, cats, foxes	1	Major impact on nesting females, eggs, juveniles
	Regular burning in association with grazing, hazard reduction and post-logging burns	3	Loss of understorey and hollow logs on ground, reduction on prey items
	Bush-rock collecting	3	Impacts on juveniles in the escarpment/Sydney sandstone area – loss of prey
	Wildfire	4	Short-term high impact
	Logging that removes large habitat trees or affects recruitment of such trees	4	Impact on juveniles
Carpet Python	Habitat clearing/fragmentation	1	Urban and agricultural
	Predation – dogs, cats, foxes	1	Major impact on nesting females, eggs, juveniles
	Regular burning in association with grazing, hazard reduction and post-logging burns	2	Loss of understorey and hollow logs on ground, reduction on prey items
	Firewood collecting	2	
	Logging that removes large habitat trees or affects recruitment of such trees	4	Impact on juveniles
	Wildfire	5	
Heath Monitor – northern population	Habitat clearing/fragmentation	1	Especially urban
	Frequent burning	2	
	Predation – dogs, cats, foxes	3	Mainly cats
	Wildfire	3	
	Bush-rock collecting	3	
	Feral predator control	4	Unknown level of threat/impact
	Roadkills	4	
Heath Monitor – southern population	Habitat clearing/fragmentation	1	Especially urban
	Grazing and associated burning	1	Long term loss of understorey, tree regeneration and termitaria
	Firewood collecting	3	
	Frequent burning	3	
	Predation – dogs, cats, foxes	3	Mainly cats
	Wildfire	3	
	Roadkills	4	
	Feral predator control	4	Unknown level of threat/impact
Maccoy's Skink	Habitat clearing/fragmentation	1	
	Wildfire	1	Open canopy and reduced cover reduce humidity levels – this species is very susceptible to desiccation
	Logging	1	
	Frequent burning	2	Loss of leaf-litter and sheltering sites. However, unlikely to occur in skinks habitat, but major impact if it did
	Pigs	2	Soil disturbance – significant local effects
	Firewood collecting	3	Removal of fallen logs – major sheltering site
Spencer's Skink	Habitat clearing/fragmentation	1	

Species	Disturbance	Rank	Comments
	Grazing	1	Long term loss of basking sites
	Frequent burning	2	Stag removal, stumps/ground logs
	Wildfire	3	
	Logging (fragmentation)	3	Impact of regeneration and regrowth on basking sites – can be managed for – short-term impact

APPENDIX 4.7 DISTURBANCES IDENTIFIED FOR FROGS AND THEIR IMPACTS RANKED RELATIVE TO EACH OTHER

Key: * species that are poorly known, thus potential disturbances are difficult to rank

Species	Disturbance	Rank	Comments
Giant Burrowing Frog	Habitat clearing	1	High reliance on native vegetation
	Frequent burning	2	
	Disease	3	
	Anything resulting in siltation, eg logging, roading, development, fire	3	Sustained siltation is a problem, not short term events
	Changes in soil moisture, eg logging	3	
	Predation – cats, dogs, foxes	4	
	Logging	4	Locally significant effect; direct mortality
	Increasing UV radiation	5	
	Roadkills	5	Locally significant effect
Booroolong Frog*	Disease	2	Unknown but likely to be significant
	Anything resulting in siltation, eg logging, roading, development, fire	2	Sustained siltation is a problem, not short term events
	Anything that highly disturbs the riparian zone, eg heavy grazing	2	Stream damage and pollution potential problem/impact
	Habitat clearing	3	
	Predation – introduced fish	3	
	Pesticides	3	Potential impact because occurs in farmland
	Increasing UV radiation	4	
	Changes to hydrological regimes	4	Stream flow
	Logging	5	
Highlands Tree Frog*	Habitat clearing	1	
	Predation – introduced fish	2	
	Frequent burning	2	Particularly where associated with heath
	Disease	3	
	Logging	3	General habitat disturbanbce
	Predation – cats, foxes	4	
	Pesticides	4	Potential impact because occurs in farmland
Stuttering Barred Frog	Habitat Clearing	1	
	Disease	2	
	Logging	2	Loss of leaf litter and drying out
	Frequent burning	2	Intrusion into riparian zones and wet sclerophyll forest causing loss of habitat and leaf litter
	Anything resulting in siltation, eg logging, roading, development, fire	2	Sustained siltation is a problem, not short term events
	Predation – cats, foxes	3	
Red-crowned Toadlet	Habitat clearing	1	

Species	Disturbance	Rank	Comments
	Frequent burning	2	Loss of leaf litter and direct impact on populations
	Bush-rock collection	3	
Brown Toadlet **Experiencing rapid decline - causes uncertain**	Disease	2	
	Climate Change	2	Change in rainfall patterns may affect reproductive success, but unknown
	Weeds, eg shrubby weeds	2	Especially blackberries; potentially a serious long-term threat
	Frequent burning	2	Loss of leaf litter
	Habitat clearing	3	
	Increasing UV radiation	3	
Northern Corroboree Frog	Climate Change	1?	Change in rainfall patterns may affect reproductive success; fluctuations in water levels at the wrong time of the year can result in eggs being frozen before the tadpoles are hatched
Experiencing rapid decline in sub-alpine areas and slower decline elsewhere - causes uncertain	Frequent burning	1	Intervals of <3-5 yrs would be a problem because juveniles inhabit the litter layer and would impact on adult frogs
	Weeds	1	Especially blackberries; serious long-term threat
	Disease	2?	
	Logging	2	Linked to the spread of weeds and drying out of breeding sites
	Habitat clearing	3	.
	Increasing UV radiation	3?	This species breed in shady spots and the eggs are protected by moss - thus not likely to be as great a problem as for other species
	Pine Plantation Establishment	5	Need more information

APPENDIX 4.8 DISTURBANCES IDENTIFIED FOR AQUATIC FAUNA AND THEIR IMPACTS RANKED RELATIVE TO EACH OTHER

Species	Disturbance	Rank	Comments
Australian Grayling	Fish passage barriers	1	Including culverts, causeways, road crossings
	Siltation – Clearing for agriculture Fire Logging Roading Vegetation clearance	1	Suspended silt - affects gills, sight feeding. Sediment - fills interstices in gravel. Affects breeding and aquatic insects
	Loss of riparian vegetation	2	Supply of terrestrial insects, organic material. Dappled light on water - camouflage
	Agriculture	3	Pesticides, fertilisers
	Predation by exotics	4	Brown trout
Macquarie Perch	EHN Virus	1	Vectors are redfin, trout, piscivorous birds, anglers
	Impoundments	1	Release of water – reverses seasonal flow (now high in summer not spring) and alters temperature regime
	Siltation – Clearing for agriculture Fire	1	Suspended silt - affects gills, sight feeding. Sediment - fills interstices in

Species	Disturbance	Rank	Comments
	Logging Roading Vegetation clearance		gravel. Affects breeding and aquatic insects.
	Fish passage barriers	2	Including culverts, causeways, road crossings. Leads to fragmentation of populations
	Loss of riparian vegetation	2	Supply of snags, organic material
	Predation/ competition by exotics	2	Carp, redfin
	Agriculture	3	Pesticides, fertilisers
	Recreational fishing	4	
Trout Cod	De-snagging	1	
	Impoundments	1	Release of water – reverses seasonal flow (now high in summer not spring) and alters temperature regime
	Loss of riparian vegetation	1	Supply of snags
	Predation/ competition by exotics	1	Brown trout in upper part of catchment. Redfin, carp.
	Alienation of floodplain from river	2	Levees etc
	Fish passage barriers	2	Including culverts, causeways, road crossings. Leads to fragmentation of populations
	Recreational fishing	2	Protected, but anglers can't differentiate from Murray Cod
	Agriculture	3	Pesticides, fertilisers, algae on hard surfaces
	Siltation – Clearing for agriculture Fire Logging Roading Vegetation clearance	3	Sediment - covers hard substrates. Affects breeding and aquatic insects.
Lampray	**THREATS UNKNOWN**		
	Fish passage barriers	?	Including culverts, causeways, road crossings
	Loss of riparian vegetation	?	
	Commercial/recreational fishing	?	By-catch, reduction of fish prey(?)
Murray River Crayfish	Loss of riparian vegetation	1	Supply of organic material/ cover
	Recreational fishing	1	
	Predation/ competition by exotics	2	Brown/ rainbow trout, redfin and carp.
	Siltation – Clearing for agriculture Fire Logging Roading Vegetation clearance	2	Silt fills in interstices in rocky shelter.
	Agriculture	3	Pesticides, fertilisers
	Desnagging	3	

APPENDIX 5

APPENDIX 5.1 RESERVATION PRIORITY RANKS FOR GROUND DWELLING MAMMALS

Species	Final Rank
Smoky Mouse	1
Southern-brown Bandicoot	1
Spotted-tailed Quoll	2
Long-nosed bandicoot	2
Long-nosed potoroo	3
Broad-toothed Rat	3
Brush-tailed rock Wallaby	3
White-footed Dunnart	4

APPENDIX 5.2 RESERVATION PRIORITY RANKS FOR ARBOREAL MAMMALS

Species	Final Rank
Koala	1
Brush-tailed Phascogale	1
Greater Glider	2
Yellow-bellied Glider	2
Squirrel Glider – tablelands	1
Squirrel Glider - coastal	2
Eastern Pygmy Possum	3

APPENDIX 5.3 RESERVATION PRIORITY RANKS FOR NOCTURNAL BIRDS

Species	Final Rank
Barking Owl	1
Sooty Owl	1
Bush Stone Curlew	1
Powerful Owl	2
Masked Owl	2

APPENDIX 5.4 RESERVATION PRIORITY RANKS FOR DIURNAL BIRDS

Species	Final Rank
Swift Parrot	1
Hooded Robin	1
Superb Parrot	1
Regent Honeyeater	1
Glossy Black Cockatoo	2
Brown Treecreeper	2
Painted Honeyeater*	2
Crested Shrike-tit	2
Black-chinned Honeyeater	2
Turquoise Parrot	2
Dollar Bird	3
Spotted Quail-thrush	3
Red-browed Treecreeper	3
Square-tailed Kite	3
Yellow-tailed Black Cockatoo	4
Eastern Bristlebird	4
Pink Robin	4
Yellow-throated scrub wren	4
Olive Whistler	5

*Painted Honeyeater was added later, with Rick Webster as independent expert.

APPENDIX 5.5 RESERVATION PRIORITY RANKS FOR BATS

* Experts considered it to be important that different reservation rankings be given to maternity and foraging habitat for *Miniopterus schreibersii* to reflect the relative importance of maintaining these different habitats for the species.

Species	Final Rank
*Miniopterus schreibersii** – roosts	1
Kerivoula papuensis	2
Pteropus poliocephalus	2
Rhinolophus megaphyllus	2
Scoteanax rueppellii	2
Chalinolobus dwyeri	3
Falsistrellus tasmaniensis	3
*Miniopterus schreibersii** – foraging	3
Mormopterus norfolkensis	3
Mormopterus sp. 1	3
Myotis macropus	3
Pteropus scapulatus	4
Saccolaimus flaviventris	4

APPENDIX 5.6 RESERVATION PRIORITY RANKS FOR REPTILES

* Experts considered that the Diamond python in the region represented two species, the Diamond Python in the coastal area and the Carpet Python in the tablelands.

[1] The Heath Monitor has two distinct disjunct populations in the region – southern and northern. Each population was given a separate reservation ranking.

Species	Final Rank
Carpet Python*	1
Heath Monitor – southern[1]	1
Common Death Adder	2
Broad-headed Snake	2
Maccoy's Skink	2
Diamond Python*	3
Heath Monitor – northern[1]	3
Spencer's Skink	4

APPENDIX 5.7 RESERVATION PRIORITY RANKS FOR FROGS

Species	Final Rank
Giant Burrowing Frog	1
Highlands Tree Frog	1
Stuttering Barred Frog	1
Booroolong Frog	2
Northern Corroboree Frog	3
Brown Toadlet	4
Red-crowned Toadlet	5

APPENDIX 5.8 RESERVATION PRIORITY RANKS FOR AQUATIC FAUNA

Species	Final Rank
Australian Grayling	1
Macquarie Perch	2
Lampray	3
Murray River Crayfish	4
Trout Cod	5

APPENDIX 6

APPENDIX 6.1 ESTIMATES OF REPRODUCTIVE LONGEVITY AND TROPHIC LEVEL FOR GROUND MAMMALS

Species	Reproductive Life Span			Trophic
	Min	Max	Mean	level (T)
Spotted-tailed Quoll	2	3	2	2
Southern-brown Bandicoot	0.5	3.5	2	6
Broad-toothed Rat	1	3	1.5	4
Brush-tailed Rock Wallaby	1.5	10	5.5	4
Long-nosed Bandicoot	0.5	3	2	4.5
Long-nosed Potoroo	1	6	2	4
Smoky Mouse	1	2	1.5	7
White-footed Dunnart	1	2	1.5	4

APPENDIX 6.2 ESTIMATES OF REPRODUCTIVE LONGEVITY AND TROPHIC LEVEL FOR ARBOREAL MAMMALS

Species	Reproductive Life Span			Trophic
	Min	Max	Mean	level (T)
Eastern Pygmy Possum	1	3	1.5	4
Greater Glider	1	9	4	3
Yellow-bellied Glider	1	6	3	2
Koala	1	13	5	3.5
Squirrel Glider	1	6	2.5	2
Brush-tailed Phascogale	1	2	1	2

APPENDIX 6.3 ESTIMATES OF REPRODUCTIVE LONGEVITY AND TROPHIC LEVEL FOR NOCTURNAL BIRDS

Species	Reproductive Life Span			Trophic
	Min	Max	Mean	level (T)
Powerful Owl	1	15	7	1
Sooty Owl	1	15	7.5	1
Masked Owl	1	12	6	1.5
Barking Owl	1	10	5	1.5
Bush Stone Curlew	1	10	4	3

APPENDIX 6.4 ESTIMATES OF REPRODUCTIVE LONGEVITY AND TROPHIC LEVEL FOR DIURNAL BIRDS

Species	Reproductive Life Span			Trophic
	Min	Max	Mean	level (T)
Yellow-tailed Black Cockatoo	1	30	20	4
Glossy-black-cockatoo	1	30	20	4
Spotted Quail-thrush	1	10	7	2
Red-browned Treecreeper	1	12	7	2
Browned Treecreeper	1	10	7	2
Eastern Bristlebird	1	10	3	3
Dollar Bird	1	15	10	2
Crested Shrike-tit	1	10	4	2
Painted Honeyeater	1	15	10	4
Swift Parrot	1	15	10	3
Square-tailed Kite	1	15	12	1
Hooded Robin	1	10	4	2
Black-chinned Honeyeater	1	10	4	2
Turquoise Parrot	1	10	3	8
Olive Whistler	1	10	3	2
Pink Robin	1	10	4	2
Superb Parrot	1	15	10	6
Yellow-throated scrub wren	1	10	4	2
Regent Honeyeater	1	10	3	3

APPENDIX 6.5 ESTIMATES OF REPRODUCTIVE LONGEVITY AND TROPHIC LEVEL FOR BATS

Species	Reproductive Life Span			Trophic
	Min	Max	Mean	level (T)
Chalinolobus dwyeri	1	8	2.5	3
Falsistrellus tasmaniensis	1	6	2.5	2
Kerivoula papuensis	1	5	2	3
Miniopterus schreibersii	1	18	5	2
Mormopterus norfolkensis	1	8	2.5	3
Mormopterus sp. 1	1	8	2.5	3
Myotis macropus	1	6	2	3
Pteropus poliocephalus	1	10	3	4
Pteropus scapulatus	1	8	3	4
Rhinolophus megaphyllus	1	8	2.5	2
Saccolaimus flaviventris	1	9	4	3
Scoteanax rueppellii	1	6	2.5	2
Scotorepens sp.	1	8	2.5	2

APPENDIX 6.6 ESTIMATES OF REPRODUCTIVE LONGEVITY AND TROPHIC LEVEL FOR REPTILES

Species	Reproductive Life Span			Trophic
	Min	Max	Mean	level (T)
Common Death Adder	1	10	8	1
Broad-headed Snake	1	11	5	1
Diamond Python	1	15	10	1
Carpet Python	1	15	10	1
Heath Monitor	1	11	8	1
Maccoy's Skink	1	2	1.2	2
Spencer's Skink	1	3	2	2

APPENDIX 6.7 ESTIMATES OF REPRODUCTIVE LONGEVITY AND TROPHIC LEVEL FOR FROGS

Species	Reproductive Life Span			Trophic
	Min	Max	Mean	level (T)
Giant Burrowing Frog	1	10	6	2
Booroolong Frog	1	3	2	2
Highlands Tree Frog	1	4	3	2
Stuttering Barred Frog	1	8	4	2
Red-crowned Toadlet	1	4	2	2
Brown Toadlet	1	4	2	2
Northern Corroboree Frog	1	5	2	2

APPENDIX 7

APPENDIX 7.1 THE DENSITY ESTIMATED IN EACH HABITAT CLASS FOR GROUND MAMMALS

Species	SETA	Region	Core	Intermediate	Marginal
Spotted-tailed Quoll	1	C/T	0.0005 / 0.0004	0.0002 / 0.0002	0 / 0
Broad-toothed Rat	1	T	0.05	0.005	0
Southern Brown Bandicoot	1	C	0.1	0	0
Brush-tailed Rock Wallaby	1	C	0.2	0	0
Brush-tailed Rock Wallaby	2	T	N/A	N/A	N/A
Long-nosed Bandicoot	1	C	0.2	0.1	0.05
Long-nosed Bandicoot	2	T	0.05	0	0
Long-nosed Bandicoot	3	T	0.04	0.02	0.005
Long-nosed Potoroo	1	C	0.15	0.0075	0.00375
Smoky Mouse	1	C	1	0.1	0.001
Smoky Mouse	2	T	N/A	N/A	N/A
White-footed Dunnart	1	C	1	0.1	0.005

APPENDIX 7.2 THE DENSITY ESTIMATED IN EACH HABITAT CLASS FOR ARBOREAL MAMMALS

Species	SETA	Region	Core	Intermediate	Marginal
Greater Glider	1	C	1	0.5	0.1
Greater Glider	2	T	1	0.5	0.1
Greater Glider	3	T	1	0.5	0.1
Yellow-bellied Glider	1	C	0.05	0.02	0.001
Yellow-bellied Glider	2	T	0.05	0.02	0.001
Squirrel Glider	1	C	0.1	0.04	0
Squirrel Glider	2	T	0.1	0.04	0.001
Koala	1	C	0.01	0	0
Koala	2	T	0.01	0.005	0.001

APPENDIX 7.3 THE DENSITY ESTIMATED IN EACH HABITAT CLASS FOR NOCTURNAL BIRDS

Species	SETA	Region	Core	Intermediate	Marginal
Powerful Owl	1	C/T	0.002 / 0.0015	0.002 / 0.001	0.0001 / 0.0001
Masked Owl	1	C	0.001	0.0005	0.0001
Sooty Owl	1	C/T	0.002 / 0.0015	0.002 / 0	0.0001 / 0

APPENDIX 7.4 THE DENSITY ESTIMATED IN EACH HABITAT CLASS FOR DIURNAL BIRDS

Species	SETA	Region	Core	Intermediate	Marginal
Yellow-tailed Black Cockatoo	1	C/T	0.065 / 0.065	0.0325 / 0.0325	0 / 0.0163
Glossy Black Cockatoo	1	C	0.012	0.006	0
Spotted Quail-thrush	1	C/T	0.1 / 0.1	0 / 0	0 / 0
Red-browed Treecreeper	1	C/T	0.15 / 0.15	0.075 / 0	0 / 0
Brown Treecreeper	1	C/T	0.01 / 0.1	0.005 / 0.05	0 / 0
Eastern Bristlebird	1	C	0.1	0.05	0
Dollarbird	1	C/T	0.01 / 0.01	0 / 0.005	0 / 0
Crested Shrike-tit	1	C/T	0.026 / 0.04	0.0182 / 0	0 / 0
Painted Honeyeater	1	T	0.02	0	0
Swift Parrot	1	C/T	0 / 0.004	0.004 / 0	0 / 0
Square-tailed Kite	1	C/T	0 / 0	0.000017 / 0.000017	0 / 0
Hooded Robin	1	C	0.066667	0.01	0
Hooded Robin	2	T	0.0667	0.03	0
Turquoise Parrot	1	C/T	0 / 0.05	0.001 / 0.01	0 / 0
Olive Whistler	1	C/T	0.125 / 0.125	0.0625 / 0	0 / 0
Pink Robin	1	C/T	0 / 0	0.002 / 0.002	0 / 0
Yellow-throated scrub wren	1	C	0.5	0	0
Superb Parrot	1	T	0.05	0	0
Regent Honeyeater	1	C/T	0 / 0.008	0.008 / 0.002	0 / 0
Black-chinned Honeyeater	1	T	0.03	0.015	0

APPENDIX 7.5 THE DENSITY ESTIMATED IN EACH HABITAT CLASS FOR BATS

Species	SETA	Region	Core	Intermediate	Marginal
Chalinolobus dwyeri	1	C/T	0.05 / 0.05	0.02 / 0.02	0 / 0
Falsistrellus tasmaniensis	1	C/T	0.02 / 0.02	0.005 / 0.005	0.002 / 0.002
Kerivoula papuensis	1	C	0.015	0.01	0
Miniopterus schreibersii	1	C/T	0.1 / 0.1	0.05 / 0.05	0.02 / 0.02
Mormopterus norfolkensis	1	C/T	0.02 / 0.02	0.01 / 0.01	0.005 / 0.005
Mormopterus sp. 1	1	C	0.02	0.01	0.005
Myotis macropus	1	T	N/A	N/A	N/A
Pteropus poliocephalus	1	C/T	0.05 / 0.05	0.0125 / 0.0125	0.005 / 0.005
Pteropus scapulatus	1	C/T	0.01 / 0.05	0.0025 / 0.0125	0.001 / 0.005
Rhinolophus megaphyllus	1	C	0.1	0.03	0.01
Rhinolophus megaphyllus	2	T	0.05	0.015	0.005
Scoteanax rueppellii	1	C	0.01	0.003	0.001

APPENDIX 7.6 THE DENSITY ESTIMATED IN EACH HABITAT CLASS FOR REPTILES

Species	SETA	Region	Core	Intermediate	Marginal
Common Death Adder	1	C	N/A	N/A	N/A
Diamond Python	1	C	0.02	0	0
Carpet Python	1	T	0.01	0.005	*0.0049
Broad-headed Snake	1	C	0.02	0	0
Broad-headed Snake	2	C	0.02	0	0
Maccoy's Skink	1	C	5	1.25	0

Species	SETA	Region	Core	Intermediate	Marginal
Maccoy's Skink	2	C	5	1.25	0
Maccoy's Skink	3	C	5	1.25	0
Maccoy's Skink	4	T	5	*4.9	0
Spencer's Skink	1	C	10	1.25	0
Spencer's Skink	2	C	10	1.25	0
Spencer's Skink	3	T	10	0	0
Spencer's Skink	4	T	10	0	0
Heath Monitor	1	C/T	0.01 / 0.01	0.005 / 0.005	0 / 0
Heath Monitor	2	C	0.01	0	0

*Minor adjustments were made to these density figures to direct C-Plan to select higher grade habitat first.

APPENDIX 7.7 THE DENSITY ESTIMATED IN EACH HABITAT CLASS FOR FROGS

Species	SETA	Region	Core	Intermediate	Marginal
Heleioporus australiacus	1	C	0.1	0.04	0
Heleioporus australiacus	2	C	0.05	0.02	0
Litoria booroolongensis	1	T	0.1	0.01	0
Litoria booroolongensis	2	T	0.1	0.01	0
Litoria littlejohni	1	C	N/A	N/A	N/A
Mixophyes balbus	1	C	0.01	0	0
Pseudophryne bibronii	1	T	0.1	0	0
Pseudophryne pengilleyi	1	T	0.1	0	0
Pseudophryne pengilleyi	2	T	0.1	0	0
Pseudophryne pengilleyi	3	T	0.1	0	0

N/A indicates density could not be estimated – target area was based on area of buffers rather than calculated using species equity formula.

C = Coastal population, T = Tablelands population, C/T = one population across Coast and Tablelands.

Coast and Tablelands were modelled separately. Where a single population occurs across both Coast and Tablelands, density was estimated separately for each subregion. Differences in value indicate either differences in modelling or a real difference in density.

APPENDIX 8

APPENDIX 8.1 THE SPECIES EQUITY TARGET AREA (SETA) IN EACH HABITAT CLASS FOR GROUND MAMMALS

Species	SETA	Region	Core (ha)	Intermediate (ha)	Marginal (ha)
Spotted-tailed Quoll	1	C/T	1,697,056 / 1,414,214	4,242,641 / 2,828,427	- / -
Broad-toothed Rat	1	T	65,320	653,197	-
Southern Brown Bandicoot	1	C	42,426	-	-
Brush-tailed Rock Wallaby	1	C	11,547	-	-
Brush-tailed Rock Wallaby	2	T	12,065	-	-
Long-nosed Bandicoot	1	C	15,910	31,820	63,640
Long-nosed Bandicoot	2	T	63,640	-	-
Long-nosed Bandicoot	3	T	79,550	159,099	636,396
Long-nosed Potoroo	1	C	18,856	377,124	754,247
Smoky Mouse	1	C	5,715	57,155	5,715,476
Smoky Mouse	2	T	11,172	-	-
White-footed Dunnart	1	C	3,266	32,660	653,197

APPENDIX 8.2 THE SPECIES EQUITY TARGET AREA (SETA) IN EACH HABITAT CLASS FOR ARBOREAL MAMMALS

Species	SETA	Region	Core (ha)	Intermediate (ha)	Marginal (ha)
Greater Glider	1	C	1,500	3,000	15,000
Greater Glider	2	T	1,500	3,000	15,000
Greater Glider	3	T	1,500	3,000	15,000
Yellow-bellied Glider	1	C	23,094	57,735	1,154,701
Yellow-bellied Glider	2	T	23,094	57,735	1,154,701
Squirrel Glider	1	C	12,649	31,623	-
Squirrel Glider	2	T	12,649	31,623	1,264,911
Koala	1	C	156,525	-	-
Koala	2	T	156,525	313,050	1,565,248

APPENDIX 8.3 THE SPECIES EQUITY TARGET AREA (SETA) IN EACH HABITAT CLASS FOR NOCTURNAL BIRDS

Species	SETA	Region	Core (ha)	Intermediate (ha)	Marginal (ha)
Powerful Owl	1	C/T	151,186 / 50,395	151,186 / 75,593	3,023,716 / 755,929
Masked Owl	1	C	612,372	1,224,745	6,123,724
Sooty Owl	1	C/T	178,923 / 4,869	178,923 / -	3,578,454 / -

APPENDIX 8.4 THE SPECIES EQUITY TARGET AREA (SETA) IN EACH HABITAT CLASS FOR DIURNAL BIRDS

Species	SETA	Region	Core (ha)	Intermediate (ha)	Marginal (ha)
Yellow-tailed Black Cockatoo	1	C/T	6,880 / 6,880	13,760 / 13,760	- / 27,521
Glossy Black Cockatoo	1	C	74,536	149,071	-
Spotted Quail-thrush	1	C/T	3,780 / 3,780	- / -	- / -
Red-browed Treecreeper	1	C/T	2,016 / 3,024	4,032 / -	- / -
Brown Treecreeper	1	C/T	22,678 / 5,292	45,356 / 10,583	- / -
Eastern Bristlebird	1	C	17,321	34,641	-
Dollarbird	1	C/T	25,298 / 37,947	- / 75,895	- / -
Crested Shrike-tit	1	C/T	15,385 / 15,000	21,978 / -	- / -
Painted Honeyeater	1	T	63,246	-	-
Swift Parrot	1	C/T	- / 142,302	94,868 / -	- / -
Square-tailed Kite	1	C/T	- / -	121,244 / 51,962	- / -
Hooded Robin	1	C	15,000	100,000	-
Hooded Robin	2	T	15,000	33,333	-
Turquoise Parrot	1	C/T	- / 83,138	461,880 / 415,692	- / -
Olive Whistler	1	C/T	3,695 / 5,543	7,390 / -	- / -
Pink Robin	1	C/T	- / -	100,000 / 150,000	- / -
Yellow-throated scrub wren	1	C	2,000	-	-
Superb Parrot	1	T	37,947	-	-
Regent Honeyeater	1	C/T	- / 151,554	64,952 / 606,218	- / -
Black-chinned Honeyeater	1	T	33,333	66,667	-

APPENDIX 8.5 THE SPECIES EQUITY TARGET AREA (SETA) IN EACH HABITAT CLASS FOR BATS

Species	SETA	Region	Core (ha)	Intermediate (ha)	Marginal (ha)
Chalinolobus dwyeri	1	C/T	18,974 / 18,974	47,434 / 47,434	- / -
Falsistrellus tasmaniensis	1	C/T	31,623 / 31,623	126,491 / 126,491	316,228 / 316,228
Kerivoula papuensis	1	C	141,421	212,132	-
Miniopterus schreibersii	1	C/T	6,708 / 6,708	13,417 / 13,417	33,541 / 33,541
Mormopterus norfolkensis	1	C/T	90,125 / 4,743	180,250 / 9,487	360,500 / 18,974
Mormopterus sp. 1	1	C	94,868	189,737	379,473
Myotis macropus	1	T	9,296	8,729	-
Pteropus poliocephalus	1	C/T	36,950 / 9,238	147,802 / 36,950	369,504 / 92,376
Pteropus scapulatus	1	C/T	161,658 / 13,856	646,632 / 55,426	1,616,581 / 138,564
Rhinolophus megaphyllus	1	C	12,649	42,164	126,491
Rhinolophus megaphyllus	2	T	25,298	84,327	252,982
Scoteanax rueppellii	1	C	126,491	421,637	1,264,911

APPENDIX 8.6 THE SPECIES EQUITY TARGET AREA (SETA) IN EACH HABITAT CLASS FOR REPTILES

Species	SETA	Region	Core (ha)	Intermediate (ha)	Marginal (ha)
Common Death Adder	1	C	4987	-	-
Diamond Python	1	C	15,811	-	-
Carpet Python	1	T	31,623	63,246	*64,536
Broad-headed Snake	1	C	22,361	-	-
Broad-headed Snake	2	C	22,361	-	-
Maccoy's Skink	1	C	1,826	7,303	-

Species	SETA	Region	Core (ha)	Intermediate (ha)	Marginal (ha)
Maccoy's Skink	2	C	1,826	7,303	-
Maccoy's Skink	3	C	1,826	7,303	-
Maccoy's Skink	4	T	1,826	*1,863	-
Spencer's Skink	1	C	707	5,657	-
Spencer's Skink	2	C	707	5,657	-
Spencer's Skink	3	T	707	-	-
Spencer's Skink	4	T	707	-	-
Heath Monitor	1	C/T	21,213 / 14,142	42,426 / 28,284	- / -
Heath Monitor	2	C	35,355	-	-

*Minor adjustments were made to these target areas to direct C-Plan to select higher grade habitat first.

APPENDIX 8.7 THE SPECIES EQUITY TARGET AREA (SETA) IN EACH HABITAT CLASS FOR FROGS

Species	SETA	Region	Core (ha)	Intermediate (ha)	Marginal (ha)
Heleioporus australiacus	1	C	24,495	61,237	-
Heleioporus australiacus	2	C	16,330	40,825	-
Litoria booroolongensis	1	T	14,142	141,421	-
Litoria booroolongensis	2	T	28,284	282,843	-
Litoria littlejohni	1	C	77	-	-
Mixophyes balbus	1	C	100,000	-	-
Pseudophryne bibronii	1	T	70,711	-	-
Pseudophryne pengilleyi	1	T	14,142	-	-
Pseudophryne pengilleyi	2	T	14,142	-	-
Pseudophryne pengilleyi	3	T	14,142	-	-

'-' indicates no target in habitat class

C = Coastal population, T = Tablelands population, C/T = one population across Coast and Tablelands.

Coast and Tablelands were modelled separately. Where a single population occurs across both Coast and Tablelands, the area of the target for each subregion is shown.

APPENDIX 9

APPENDIX 9.1 NUMBER OF SETAS FOR EACH SPECIES, OR PERCENTAGE OF SINGLE SETA TO BE APPLIED TO EACH SUBREGION

Species	Coastal SETAs	Tableland SETAs	Comments
Spotted-tailed Quoll	1: 60%	1: 40%	One SETA throughout.
Broad-toothed Rat	-	1	Tablelands species
Southern Brown Bandicoot	1	-	Coastal species
Brush-tailed Rock Wallaby	1	1	Isolated pockets
Long-nosed Bandicoot	1	2	Barriers of unsuitable habitat between populations
Long-nosed Potoroo	1	-	Coastal species
Smoky Mouse	1	1	Isolated pockets
White-footed Dunnart	1	-	Coastal species
Greater Glider	1	2	Relatively immobile. Barriers of unsuitable habitat
Yellow-bellied Glider	1	1	Barriers of unsuitable habitat
Squirrel Glider	1	1	Barriers of unsuitable habitat
Koala	1	1	Barriers of unsuitable habitat
Powerful Owl	1: 80%	1: 20%	One SETA throughout.
Masked Owl	1	-	Coastal SETA only
Sooty Owl	1: 98%	1: 2%	One SETA throughout.
Yellow-tailed Black Cockatoo	1: 50%	1: 50%	One SETA throughout.
Glossy Black Cockatoo	1	-	Coastal target only. No Tablelands target set.
Spotted Quail-thrush	1: 50%	1: 50%	One SETA throughout.
Red-browed Treecreeper	1: 40%	1: 60%	One SETA throughout.
Brown Treecreeper	1: 30%	1: 70%	One SETA throughout.
Eastern Bristlebird	1	-	Coastal species
Dollarbird	1: 40%	1: 60%	One SETA throughout.
Crested Shrike-tit	1: 40%	1: 60%	One SETA throughout.
Painted Honeyeater	-	1	Tablelands species
Swift Parrot	1: 40%	1: 60%	One SETA throughout.
Square-tailed Kite	1: 70%	1: 30%	One SETA throughout.
Hooded Robin	1	1	Relatively immobile – barriers of unsuitable habitat
Turquoise Parrot	1: 10%	1: 90%	One SETA throughout.
Olive Whistler	1: 40%	1: 60%	One SETA throughout.
Pink Robin	1: 40%	1: 60%	One SETA throughout.
Yellow-throated scrub wren	1	-	Coastal species
Superb Parrot	-	1	Tablelands species
Regent Honeyeater	1: 30%	1: 70%	One SETA throughout.
Black-chinned Honeyeater	-	1	Tablelands species
Chalinolobus dwyeri	1: 50%	1: 50%	One SETA throughout.
Falsistrellus tasmaniensis	1: 50%	1: 50%	One SETA throughout.
Kerivoula papuensis	1	-	Coastal species
Miniopterus schreibersii	1: 50%	1: 50%	One SETA throughout.

Species	**Coastal SETAs**	**Tableland SETAs**	**Comments**
Mormopterus norfolkensis	1: 95%	1: 5%	Coastal species
Mormopterus sp. 1	1	-	Coastal species
Myotis macropus	-	1	Buffer around known roost – Tablelands SETA only.
Pteropus poliocephalus	1: 80%	1: 20%	One SETA throughout.
Pteropus scapulatus	1: 70%	1: 30%	One SETA throughout.
Rhinolophus megaphyllus	1	1	Separate SETAs Coastal and Tablelands – relatively immobile
Scoteanax rueppellii	1	-	Coastal SETA only
Common Death Adder	1	-	Buffer around known records
Diamond Python	1	-	Coastal species
Carpet Python	-	1	Tablelands species
Broad-headed Snake	2	-	Coastal species – barrier at Shoalhaven River
Maccoy's Skink	3	1	Barriers of unsuitable habitat between populations
Spencer's Skink	2	2	Barriers of unsuitable habitat between populations
Heath Monitor - southern	1: 40%	1: 60%	SETA 1 shared with Tablelands.
Heath Monitor - northern	1	-	Lower reservation priority than SETA 1.
Heleioporus australiacus	2	-	2 Coastal SETAs – likely separate species
Litoria booroolongensis	-	2	Barriers of unsuitable habitat between populations
Litoria littlejohni	1	-	Coastal species. Buffer around known records
Mixophyes balbus	1	-	Coastal SETA only
Pseudophryne bibronii	-	1	Tablelands SETA only
Pseudophryne pengilleyi	-	3	Barriers of unsuitable habitat between populations

APPENDIX 10

APPENDIX 10.1 PRIORITY FLORA SPECIES FOR SOUTHERN REGION

Species	Conservation Rank	Reservation Priority Rank	Target Type	Conservation Target	No. of points	No. of polygons	Cwlth. ESP Act	NSW TSC Act	NSW TSC Act recommendations	ROTAP
Acacia chalkeri	C2	R1	Point	100%	3					2RC-
Acacia costiniana	C2	R2	Point	80%	1					
Acacia dallachiana	C2	R3	Point	60%	12					3RC-
Acacia flocktoniae	C1	R3	Point	80%	2		V	V		2VC-
Acacia jonesii	C2	R3	Point	60%	7					3RCa
Acacia lucasii	C2	R3	Point	60%	4					3RCa
Acacia phasmoides	C1	R1	Point	100%	1		V	V		2VC-
Ammobium craspedioides (Forest ecotype)	C1	R3 (JB R2)	Buffered point	80%	9		V	V		2V
Ammobium craspedioides (Grassy ecotype)	C1	R1	Buffered point	100%	19		V	V		2V
Astrotricha sp nov Deua	C2	R2	Point	80%	3					
Bertya brownii	C2	R3	Point	60%	4					2RC-
Burnettia cuneata	C2	R2	Point	80%	1					3RC-
Caladenia aestiva	C2	R2	Point	80%	1					
Caladenia clarkiae	C2	R1	Point	100%	1					3KC-

Species	Conservation Rank	Reservation Priority Rank	Target Type	Conservation Target	No. of points	No. of polygons	Cwlth. ESP Act	NSW TSC Act	NSW TSC Act recommendations	ROTAP
Caladenia ssp Burrinjuck (concolor)	C1	R1	Point	100%	2		V	E1	Proposed for TSC-E	3VCi
Caladenia tessellata	C1	R1	Point	100%	4			V		3V
Callitris oblonga ssp corangensis	C1	R1	Mapped area	100%		14		V		2VCa?
Calotis glandulosa	C1	R3	Buffered point	80%	47		V	V		3VC-
Chionogentias sylvicola	C2	R3	Point	60%	5					2RC-
Correa baeuerlenii	C1	R4	Point	60%	14		V	V		3VCi
Corybas undulatus	C2	R2	Point	80%	2					3KC-
Cryptostylis hunteriana	C1	R2	Point	100%	6		V	V		3VC-
Cynanchum elegans	C1	R1	Point	100%	4		E	E1		3ECi
Dampiera scottiana	C2	R2	Point	80%	12					
Daphnandra sp C (sp 1 Illawarra)	C1	R1	Point	100%	6		E	E1		2VCi
Darwinia briggsiae	C2	R3	Point	60%	3					2RC-
Deyeuxia microseta	C2	R2	Point	80%	1					3KC-
Dillwynia glaucula	C1	R2	Point	100%	7				Currently proposed as TSC-E	
Dillwynia stipulifera	C2	R3	Point	60%	6					3RCa
Discaria nitida	C1	R3	Point	80%	1			E1		3RC-
Diuris aequalis	C1	R1	Point	100%	6		V	V		3VC-
Drabastrum alpestre	C2	R4	Point	20%	10					3RC-
Drabastrum alpestre (low-altitude meta-popn)	C2	R4	Point	100%	2					
Epacris coriacea	C2	R4	Point	20%	2					3RC-
Eriostemon scaber ssp latifolius	C3	R4	Point	10%	19					
Eucalyptus aggregata	C1	R2	Point	100%	22				Proposed for TSC	
Eucalyptus aquatica	C1	R1	Mapped area	100%		2	V	V		2VCa
Eucalyptus badjensis	C2	R3 (DB R4)	Point	60%	12					2RCi

Species	Conservation Rank	Reservation Priority Rank	Target Type	Conservation Target	No. of points	No. of polygons	Cwlth. ESP Act	NSW TSC Act	NSW TSC Act recommendations	ROTAP
Eucalyptus gregsoniana	C2	R3	Point	60%	7					3RCa
Eucalyptus kartzoffiana	C1	R1	Point	100%	29		V	V		2VCi
Eucalyptus langleyi	C1	R1 (JB R2; DB R3)	Buffered point	100%	26		V	V		2V
Eucalyptus macarthuri	C2	R2	Point	80%	2					2RCi
Eucalyptus parvula	C1	R1	Mapped area	100%		11	V	V		2VCi
Eucalyptus pulverulenta	C1	R2	Mapped area	100%		18	V	V		3V
Eucalyptus recurva	C1	R1	Point	100%	2		E	E1		2E
Eucalyptus saxatilis	C1	R3	Point	80%	5			E1	Downgrade to TSC-V	3RC-
Eucalyptus sturgissiana	C1	R2	Point	100%	7			V		2RCa
Eucalyptus triflora	C2	R4	Point	20%	18					3RCa
Genoplesium despectans	C2	R2	Point	80%	1					2K
Genoplesium plumosum	C1	R1	Point	100%	8		E	E1		
Genoplesium vernalis	C1	R2	Buffered point	80%	18		E		Proposed for TSC	
Gentiana wingecarribiensis	C1	R2	Point	100%	1		E	E1		2E
Geranium graniticola	C2	R4	Point	20%	12					3RC-
Gonocarpus longifolia	C2	R2	Point	80%	1					
Goodenia glomerata	C2	R4	Point	20%	15					2RCa
Grevillea alpina	C2	R3	Point	60%	5					
Grevillea barklayana ssp macleayana	C2	R3	Point	60%	5					3RC-
Grevillea baueri ssp asperula	C3	R4	Point	10%	10					
Grevillea brevifolia var brevifolia	C2	R2	Point	80%	1					
Grevillea iaspicula	C1	R1	Point	100%	9		E	E1		2E
Grevillea imberbis	C2	R2	Point	80%	3					
Grevillea molyneuxii	C1	R2	Point	100%	6		E	E1		2K
Grevillea oxyantha ssp ecarinata	C2	R4	Point	20%	3					

Species	Conservation Rank	Reservation Priority Rank	Target Type	Conservation Target	No. of points	No. of polygons	Cwlth. ESP Act	NSW TSC Act	NSW TSC Act recommendations	ROTAP
Grevillea rhyolitica ssp rhyolitica	C2	R3	Point	60%	5					
Grevillea rhyolitica ssp semivestita	C2	R2	Point	80%	2					
Grevillea rivularis	C1	R1	Point	100%	4		E	E1		2VCi
Grevillea wilkinsonii	C1	R1	Point	100%	1		E	E1		2E
Hakea dohertyi	C1	R3	Point	80%	6		E	E1	Downgrade to TSC-V	2ECi
Haloragis exalata ssp exalata var exalata	C1	R1	Point	100%	1			V		3VCa
Helichrysum calvertianum	C2	R1	Point	100%	1					2KC-
Irenepharsus trypherus	C1	R1	Point	100%	3		E	E1		2ECi
Kunzea cambagei	C1	R2	Point	100%	4		V	V		2VCa
Leptospermum epacridoideum	C2	R3	Point	60%	23					2RC-
Leptospermum sejunctum	C1	R1	Point	100%	36				Proposed for TSC	2K
Leptospermum thompsonii	C1	R3	Buffered point	80%	9		V	V		2V
Lindsaea trichomanoides	C2	R2	Point	80%	3					3RC-
Melaleuca biconvexa	C1	R1	Mapped area	100%		34		V		
Monotaxis macrophylla	C1	R3	Point	80%	2			E1		
Monotoca rotundifolia	C1	R1	Point	100%	1			E1		3RCi
Myoporum bateae	C2	R4 (DB R5)	Point	20%	19					3RC-
Olearia burgessii	C2	R1	Point	100%	1					3K
Olearia lasiophylla	C2	R3	Point	60%	13					2RC-T
Ozothamnus adnatus	C2	R2	Point	80%	2					3KC-
Persoonia glaucescens	C1	R1	Point	100%	1		V	V		2V
Persoonia microphylla	C2	R2	Point	80%	14					
Persoonia mollis ssp caleyi	C3	R4	Point	10%	77					
Persoonia oxycoccoides	C2	R2	Point	80%	9					2RCa
Persoonia subvelutina	C3	R4	Point	10%	13					
Phebalium ellipticum	C2	R3	Point	60%	5					2RCa
Phyllota humifusa	C1	R1	Mapped area	100%		28	V	V		2VCa
Platysace stephensonii	C2	R2	Point	80%	1					3RC-

Species	Conservation Rank	Reservation Priority Rank	Target Type	Conservation Target	No. of points	No. of polygons	Cwlth. ESP Act	NSW TSC Act	NSW TSC Act recommendations	ROTAP
Plinthanthesis rodwayi	C1	R1	Point	100%	2		V	V		2VC-T
Pomaderris betulina ssp actensis	C1	R3	Point	80%	2				Proposed for TSC	
Pomaderris brogoensis	C2	R2 (DB R3)	Point	80%	1					3RC-
Pomaderris costata	C2	R3 (MD R2; JB R4)	Point	60%	3					3RC-
Pomaderris cotoneaster	C1	R2	Point	100%	4		E	E1		3ECi
Pomaderris delicata	C1	R1	Point	100%	1				Proposed for TSC	
Pomaderris gilmourii var cana	C1	R2	Point	100%	2		V	V		2VCiT
Pomaderris gilmourii var gilmourii	C1	R2	Point	100%	1				Proposed for TSC	
Pomaderris pallida	C1	R2	Point	100%	6		V	V		2VCi
Pomaderris pauciflora	C2	R2	Point	80%	2					3RC-
Pomaderris sericea	C1	R1	Point	100%	1		V	E1		3VCi
Pomaderris subcapitata	C2	R3	Point	60%	8					
Pomaderris virgata	C2	R3	Point	60%	2					3RC-
Prasophyllum affine	C1	R1	Point	100%	1		E	E1		2E
Prasophyllum petilum	C1	R1	Point	100%	1		E	E1		2EC-
Prostanthera densa	C1	R2	Point	100%	20		V	V		3VC-
Prostanthera rugosa	C2	R2	Point	80%	5					
Prostanthera rugosa (Two Sticks meta-popn)	C2	R1	Point	100%	1					
Pterostylis gibbosa	C1	R1	Buffered point	100%	21		E	E1		2E
Pterostylis hians	C1	R1	Point	100%	1				Proposed for TSC	
Pultenaea humilis	C2	R1	Point	100%	1					
Pultenaea rosmarinifolia	C3	R3 (DB R4)	Point	40%	14					
Pultenaea sp D	C2	R3	Point	60%	4					
Restio longipes	C1	R2	Point	100%	5		V	V		3VC-
Rulingia prostrata	C1	R1	Point	100%	1		E	E1		2ECi

Species	Conservation Rank	Reservation Priority Rank	Target Type	Conservation Target	No. of points	No. of polygons	Cwlth. ESP Act	NSW TSC Act	NSW TSC Act recommendations	ROTAP
Rutidosis leiolepis (Cooma-Adamininby meta-popn)	C1	R1	Buffered point	100%	5				Proposed for TSC	
Rutidosis leiolepis (Kosciusko meta-popn)	C1	R2	Point	100%	19		V	V		2VC-
Rutidosis leptorrhynchoides	C1	R1	Point	100%	4		E	E1		3ECa
Senecio macranthus	C2	R4	Point	20%	4					3RC-
Styphelia adscendens	C1	R1	Point	100%	5				Proposed for TSC	
Syzygium paniculatum	C1	R1	Buffered point	100%	11		V	V		3RCi
Telopea mongaensis	C2	R2	Point	100%	11					
Telopea oreades	C2	R2 (MD R1)	Point	100%	4					
Tetratheca neglecta	C2	R4	Point	20%	2					3RC-
Thesium australe	C1	R2	Point	100%	12		V	V		3VCi
Trachymene saniculifolia	C2	R1	Point	100%	1			E1		2VCiT
Triplarina nowraensis	C1	R1	Mapped area	100%		14	E	E1		
Westringia kydrensis	C1	R1	Point	100%	1		E	E1		2KC-
Zieria adenophora	C1	R1	Point	100%	1		E	E1		2E
Zieria baeuerlenii	C1	R1	Point	100%	6		E	E1		2E
Zieria citriodora	C1	R1	Buffered point	100%	2		V	V		3VC-
Zieria granulata	C1	R1	Point	100%	2		E	E1		2VCi
Zieria murphyi	C1	R2	Point	100%	6		V	V		2VC-
Zieria tuberculata	C1	R1	Mapped area	100%		8	V	V		2VCi

APPENDIX 11

APPENDIX 11.1 NOTES ON THE DERIVATION OF BUFFERS AND MAPPED AREA POLYGONS FOR FLORA

Species	Target Type	Treatment Notes
Ammobium craspedioides (Forest ecotype)	Buffered point	Buffered according to population size - populations of 1-10 individuals = 10ha, 11-25 =20ha, 26-99 = 50ha, 100-249 = 100ha, 250+ = 200
Ammobium craspedioides (Grassy ecotype)	Buffered point	Buffered according to population size - populations of 1-10 individuals = 10ha, 11-25 =20ha, 26-99 = 50ha, 100-249 = 100ha, 250+ = 200
Callitris oblonga ssp corangensis	Mapped area	Digitised mapped area supplied by K McDougall (from a report by Benson?). High and medium habitat quality. Carrying capacity as defined in workshop was 1 for high and 0.5 for medium.
Calotis glandulosa	Buffered point	100 Ha for 5 populations identified by R. Rehwinkel. Area target approved by workshop panel. (other populations given 0.1 ha buffers)
Eucalyptus aquatica	Mapped area	Digitised two swamps around Penrose Sate Forest. Digitised from swamp areas marked on 1:25,000 Wingello mapsheet.
Eucalyptus langleyi	Buffered point	Pops buffered according to number of individuals (100s, 200+ = 200ha, 100, 100+ = 100ha, <100 = number of plants, <10 = 10ha).
Eucalyptus parvula	Mapped area	Digitised mapped areas as defined in J.D. Briggs informal report. High and medium habitat areas identified. Carrying capacity as defined by J.D. Briggs was 1 for high and 0.5 for medium.
Eucalyptus pulverulenta	Mapped area	Digitised mapped areas as defined in Brigg, J.D. and Leigh, J.H., "Delineation of important habitats of threatened plant species in South-eastern NSW." Research report to the Australian Heritage Commission. CSIRO Division

Species	**Target Type**	**Treatment Notes**
		of Plant Industry, GPO Box 1600, Canberra, ACT, 2601. December 1990.
Genoplesium vernalis	Buffered point	Buffered according to population size - populations of less than 10 individuals given a default of 10ha
Leptospermum thompsonii	Buffered point	Buffered according to population size
Melaleuca biconvexa	Mapped area	Used high, medium and low quality habitat polygons as defined in Marchant, B. and Lawrence, S., "Distribution and abundance of *Melaleuca biconvexa* north of St Geoges Basin, Jervis Bay, NSW" Report prepared for NSW National Parks and Wildlife Service, Threatened Species Unit, 17th May 1999. Carrying capacity as defined by B. Marchant was 1 for high, 0.5 for medium and 0.1 for low.
Phyllota humifusa	Mapped area	Digitised mapped areas as defined in Benson, J., "Survey and assessment of the conservation status of the endangered plant Phyllota humifusa", National Parks and Wildlife Service, March, 1986.
Pterostylis gibbosa	Buffered point	Buffered according to population size - populations of 1-10 individuals = 10ha, 11-49 =20ha, 50-100 = 50ha, >100 = 100ha
Rutidosis leiolepis (Cooma-Adamininby meta-popn)	Buffered point	Buffer according to population size (5 populations). 5000 individuals = 200ha, 1000 = 100ha, 500 = 50ha, 50 - 60 = 10ha
Syzygium paniculatum	Buffered point	Buffered according to population size
Triplarina nowraensis	Mapped area	Digitised mapped areas as defined in S. Clark informal report.
Zieria citriodora	Buffered point	Buffered according to population size
Zieria tuberculata	Mapped area	Digitised mapped areas as defined in Briggs, J.D. and Leigh, J.H., "Delineation of important habitats of threatened plant species in South-eastern NSW." Research report to the Australian Heritage Commission. CSIRO Division of Plant Industry, GPO Box 1600, Canberra, ACT, 2601. December 1990.