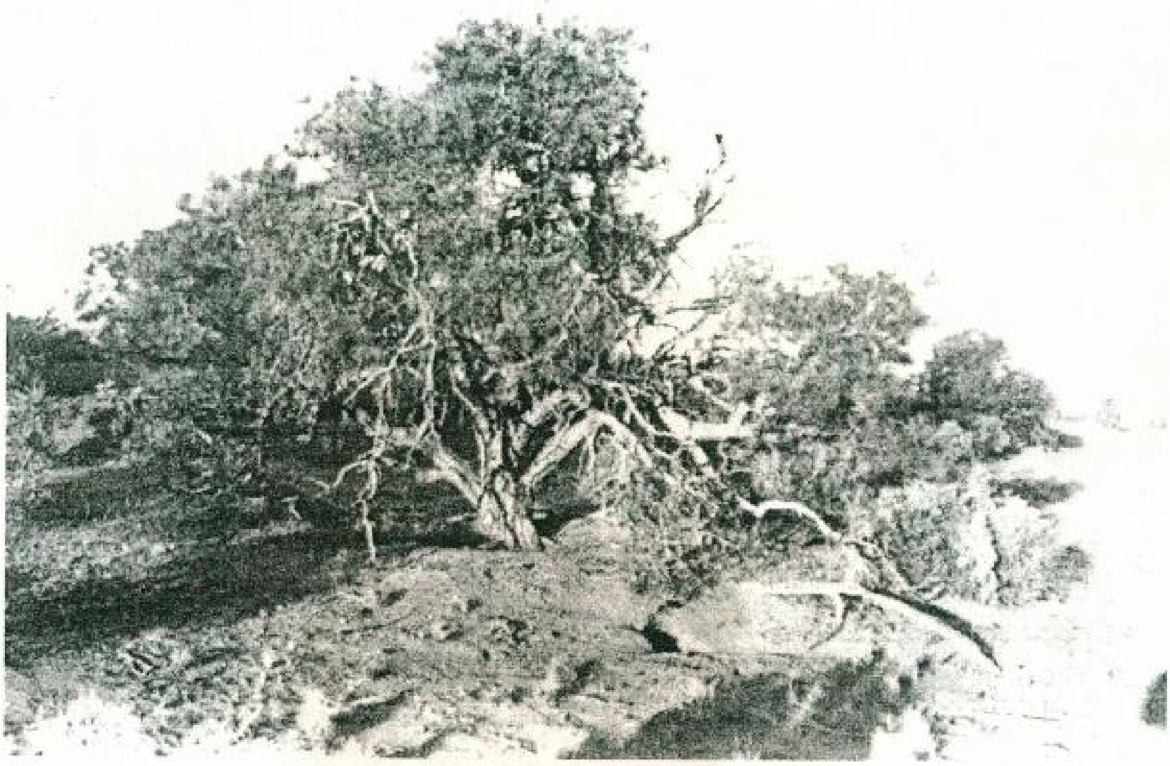
Assessing the status of threatened plants:

A new methodology and an application to the vascular flora of New South Wales



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Front Cover: *Acacia carnei* found in arid New South Wales and South Australia. The species is threatened by rabbits (note burrow in foreground), which graze on seedlings and suckers, severely limiting regeneration in all known populations.

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SUMMARY

The development of this project to prepare a listing of rare or threatened flora for New South Wales was initiated and supported by the NSW National Parks and Wildlife Service with financial assistance from The Australian Nature Conservation Agency (now Environment Australia, Biodiversity Group) under the Commonwealth Endangered Species Program (Project No. 450). As a part of this project, an pilot risk assessment scheme for vascular plants (RAVAS) was developed and tested on ferns and gymnosperms and a number of threatened taxa for which there were existing data in recovery plans or survey reports (Chalson and Keith 1995).

Subsequently, rules for the assessment of the risk of extinction in vascular plants (RAREplants) were developed from the endorsed IUCN red list criteria (IUCN 1994). Modifications to the IUCN scheme were necessary to overcome a number of limitations. The RAREplants scheme replaces the pilot RAVAS scheme, although most taxa have yet to be reassessed under RAREplants. The RAREplants criteria were tested using 68 taxa from NSW and Tasmania using available survey data.

An assessment of the conservation status of some 50% of the flora of New South Wales has been made, including most of the taxa likely to be threatened. Data used for the assessment are currently being incorporated into a database. This assessment was a significant part of the basis for the development of threatened flora schedules in the NSW Threatened Species Conservation Act of 1995 and subsequent modifications.

1. Project Objectives and Actions

Objectives

1. To define a set of criteria to determine conservation status of plant taxa in New South Wales.

2. To establish a data base for information used to determine the conservation status of each taxon examined.

3. To systematically evaluate the status of the vascular flora of New South Wales.

4. The publication of a list of rare or threatened plants for New South Wales.

Actions

1. Identify attributes of plant taxa that determine the need to address their conservation in New South Wales.

2. Design and implement a data base with appropriate fields for the storage and retrieval of attribute data.

3. Compile data from relevant sources and systematically evaluate the vascular flora of N.S.W. according to attributes defined in Action 1. The methodology will be documented, independently reviewed and published. In 1993/1994, the Pteridophyta and Gymnospermae will be assessed as a pilot study and the methodology reviewed, as necessary. The Angiospermiae will be compiled in 1994/1995 and 1995/1996, subject to extended funding.

4. Compile and publish a list of rare or threatened plant taxa for New South Wales. An interim list will be prepared for the development of the NSW Threatened Species Conservation Act.

2. Project Outcomes

2.1 Criteria to assess the conservation status of vascular plants

Red List criteria endorsed by IUCN (1994) were evaluated using a test data set comprising 68 relatively well known rare or threatened plants taxa from New South Wales and Tasmania. The study taxa were chosen to represent a broad range of risk and conservation scenarios. The main difficulties in applying IUCN (1994) criteria were:

i) Thresholds for area of occupancy and extent of occurrence were inappropriate to sessile organisms. Also there was a lack of guidance on how to measure the scale-dependent area of occupancy parameter.
ii) Biological and land use attributes such as regeneration capacity, the specificity and temporal availability of the habitat and representation in protected areas which are relevant to extinction risk in vascular plants were not explicitly addressed in the criteria.
iii) The number of subpopulations may bias the outcome of assessment in taxa with many small subpopulations (i.e. highly skewed metapopulation structure).
iv) Thresholds could be expressed in additional units to assist interpretation.
v) Interpretation of quantitative thresholds of extinction risk (Rule E) is likely to be sensitive to methodological artefact.
vi) The criteria do not directly address the number of subpopulations in relation to qualitatively defined threatening processes, a type of risk information that is available for many taxa.

Modifications to the criteria were developed and tested iteratively to overcome these limitations. Methods of evaluation and the modified set of criteria, 'RAREplants (Rules for the Assessment of the Risk of Extinction in vascular plants)' are described in Appendix 1. The RAREplants criteria supersede an earlier pilot version, "RAVAS" (Chalson and Keith 1995), which was based on a draft of the IUCN criteria.

The criteria for both RAREplants and the endorsed IUCN (1994) rules were programmed using logical functions in Microsoft Excel (copy supplied on disk). The software enables users to enter data on relevant parameters and compute risk status under the two schemes. The reasons for the status of each species may be examined by tracing the conditions that were met in each Rule. Data for each species may be saved in the worksheet and edited, allowing the status to be revised when new information becomes available.

Wide variation in data quality and reliability presented a further difficulty in the interpretation of the IUCN and RAREplants criteria. IUCN (1994) states that 'it is legitimate to apply the Precautionary Principle...[to its Red List categories by]... making due allowance for statistical and other uncertainties', but does not state explicitly how uncertainty should be handled. Uncertainty in attribute data may be treated in an explicitly precautionary manner by interpreting decision rules with a statistical confidence threshold. In other words, a criterion may be rejected only if there is, for example, 90% confidence that the true value of abundance or range was greater (or the true rate of decline was less) than the threshold specified in the rule. This method is summarised in Appendix 2 and was developed in collaboration with Dr Mark Burgman (University of Melbourne) who was funded by ANCA (Forest Biodiversity) to undertake a related project, 'Risk and uncertainty analysis procedures and protocols for forest biodiversity assessment'). The rationale will be fully documented in Dr Burgman's final report.

A further outcome of collaboration is the production of conservation assessment software, SPARC. The software allows users to compute the risk status or priority score of a taxon using any of several assessment procedures including IUCN (1994), RAREplants (Appendix 1), RAVAS (Chalson and Keith 1995) and scoring procedures developed by Milsapp et al. (1990), Lunney et al. (1996) and the Western Australian Department of Conservation and Land Management. SPARC will be made available with full documentation at the completion of Dr Burgman's project.

2.2 Database establishment

The information collated to assess the conservation status of plant species under RAREplants or RAVAS is stored in a 'Microsoft Excel' spreadsheet. Currently, this information is being transformed to a database for ease of data management. The data base software chosen for the project is 'Microsoft Access'. The data base will incorporate the data already accumulated in 'Microsoft Excel' with some modification. The 'Microsoft Access' database has been designed to allow storage of data in a range of fields. These fields represent information on: the taxon (family, genus, species etc.); populations (numbers, threats etc); location; distribution; reservation status; and a summary dealing with attributes considered in assessing a taxon under RAVAS or RAREplants.

To date approximately 60% of the data has been transferred successfully to the 'Microsoft Access' data base and validated with random checking. Version 1 of the data base is complete. Essentially the data fields in the database are complete, barring minor modifications to incorporate the rule structure in RAREplants. Modification of the user interface and report writing facilities will continue iteratively for the remainder of 1997 in order to develop user friendly and efficient data input, data verification and data management components.

2.3 Current evaluation of status of vascular flora of New South Wales

Assessment of the flora of New South Wales was carried out in the following steps.

1. A taxonomically up to date list of taxa occurring in New South Wales was compiled initially by consulting Harden (1990-93) and incorporating taxonomic revisions and new records accepted by the National Herbarium of NSW. Some informally recognised taxa were provisionally included pending further taxonomic investigation.

2. Distributional and biological data were compiled from various sources including herbarium collections, data bases, taxonomic and ecological literature and experts, including information accumulated for the production of the ROTAP list (Briggs and Leigh 1996). A complete search of taxonomic literature carried out for the period 1980-present included the Floras of Australia and NSW, *Telopea, Australian Systematic Botany, Nuytsia, Brunonia, Muellaria, Journal of the Adelaide Botanical Gardens* and *Contributions from the National Herbarium of NSW.* The data were screened to ensure a minimum standard of reliability (e.g. survey records were included in the assessment only when confirmed by an independent source). No further data were compiled for a given taxon when data from accessible sources were sufficient to confirm Low Risk status.

3. The RAVAS scheme (Chalson and Keith 1995) was used to classify the risk status of the plant taxa listed in Step 1. In due course taxa will be re-assessed using the recently developed RAREplants scheme (see Action 1). The taxa were progressively allocated to either the Low Risk category or one of the higher risk categories, with the remainder flagged as either Data Deficient or Not Evaluated. Reasons for listing each taxon were documented by recording all RAVAS rules that were met for respective risk categories.

4. After the most accessible sources of data were searched (Flora of NSW, recent revisions, herbarium data bases and recent regional assessments), the remaining unallocated taxa were assigned a priority for investigation. A short list of high priority taxa was compiled by consulting previous national, statewide and regional assessments (Appendix 3). The high priority short list consists of all taxa which were considered rare or threatened by any of the references in Appendix 3. Short-listed taxa are under further investigation, initially by consulting herbarium collections held at Canberra Botanic Gardens and Royal Botanic Gardens, Sydney.

5. A preliminary list of Presumed Extinct in the Wild, Critical, Endangered and Vulnerable vascular plant taxa was compiled at both national and state levels. Vulnerable taxa have not yet been addressed at the state level. This list forms the current schedule for the New South Wales Threatened Species Act and will be progressively amended as more information becomes available (see Action 4).

Currently, 2,720 taxa (46.8% of the total flora) have been assessed using to the RAVAS scheme (Table 1), of which about half were assigned to the Low Risk category. Of the remaining taxa currently listed as Not Evaluated, 15% are short listed with high priority for assessment.

An examination of the rules used to assign taxa to threat categories (Table 2) shows that locational information (Rule C) was the main rule used to assign threat. This reflects the lack of available population data on many taxa in NSW. Where information is available on population structure other rules were utilised. Very few taxa could be assessed using Rule E, relating to rates of decline. This indicates a lack of long-term monitoring designed to detect population changes in the flora. Some two-thirds of taxa were assigned to a threat category using a single rule while the remainder were assigned by several rules (Table 2).

Table 1: Outcomes of assessment of the New South Wales flora using RAVAS. EX- Presumed Extinct, CR- Critically Endangered, EN- Endangered, VU- Vulnerable, SU- Susceptible, PR- Priority for Investigation, LR- Low Risk.

	Number of Taxa Assessed	Number of Taxa Not Evaluated
EX	61	-
CR	104	-
EN	270	-
VU	477	-
SU	471	-
PR	62	-
LR	1275	-
Shortlisted Priority	-	475
Others	-	2611
Total	2720	3086

Table 2: Frequency with which RAVAS rules were addressed in the assessment of NSW flora. For the Susceptible category, Rules e and f refer to number of populations and reservation status, Rule a refers to population size, Rule b refers to distributional range, and Rule d refers to rate of decline. Total* taxa excludes those allocated to Low Risk and Priority for Investigation categories.

Attribute	**RAVAS Rule**	**CR**	**Number of taxa allocated EN**	**VU**	**SU**	**EX**	**% of Total***
Number of populations / reservation status	C only	75	219	449	436		85%
	C+others	14	15	10			3%
Population Size	A, B	23	38	16	2		6%
Distributional Range	D	21	21	4	2		3%
Rate of Decline	E	1	2	-	1		0.30%
1 Rule met		85	236	459	74	59	66%
multiple Rules met		19	34	18	397	2	34%

2.4 Progress in listing threatened taxa for New South Wales

New South Wales has passed legislation protecting threatened species in the state, NSW Threatened Species Conservation Act (TSCAct). This Act contains 3 schedules relating to the conservation of threatened flora and fauna:

Schedule 1 -	Part 1 Endangered species
	Part 2 Endangered populations
	Part 3 Endangered ecological communities
	Part 4 Species presumed extinct
Schedule 2	Vulnerable species
Schedule 3	Key threatening processes

The TSCAct is designed to protect species within NSW. This will include species of national significance as recognised in ANZECC 1993 or ROTAP 1996. The TSCAct also includes species considered to be threatened from a NSW state perspective. The TSCAct does give a priority to preparing and implementing the recovery of species that are nationally threatened.

During the development of the TSCAct, the RAVAS database information was used in assisting with the preparation of the flora to be listed in Schedule 1 (Parts 1 and 4) and Schedule 2. Information from the ANZECC 1993 Australian threatened flora list and a 1995 draft of the Rare or Threatened Australian plant list (ROTAP, Briggs and Leigh 1996) were also used to compile the flora to be listed in the above Schedules.

The RAVAS system was used :
1) to check current available data on nationally threatened species and hence check the appropriateness of the status of such species in NSW. In some instances, species considered to be rare or vulnerable nationally were assigned a higher threat category in NSW as most of their distribution was outside NSW.
2) to identify additional species that were restricted to NSW and considered threatened. These species had not been previously considered for inclusion on the national threatened plant listings. These species have since been nominated for inclusion on the national ANZECC threatened Australian flora listing, via the ANZECC Endangered Flora Network.
3) to identify some 100 taxa that were not currently considered endangered at a national level but were considered to be endangered from a NSW state perspective. These species are not confined to NSW, but it is important to conserve their distributions within NSW to help conserve biological diversity within the species.

A copy of the threatened flora identified in the schedules of the NSW TSCAct (as of 1/1/1996) is attached as Appendix 4.

The TSCAct established a Scientific Committee consisting of specialist scientists from government, universities and specialist scientific societies (eg. Ecological Society of Australia, Entomological Society of Australia). This committee has a number of functions, including maintenance of the Schedules in the TSCAct and listing and delisting of species on the Schedules. Since the establishment of the TSCAct at 31st December 1995, a number of additional species have been identified for potential listing through the NSW threatened flora database and the RAVAS scheme. Currently a few new plant species have been listed as endangered, several are under consideration by the Scientific Committee and a number more are being prepared for submission to the Scientific Committee. The RAREplants (and previously RAVAS) database is being used to generate most of these submissions and the Scientific Committee does consider the RAREplants (and previously RAVAS) information as part of its assessment of the status of species for listing. Consequently, the RAREplants database (and previously RAVAS) is actively being used as an ongoing measure to assess the status of plant species in NSW.

The RAREplants assessment system is also currently being considered as a system for assisting the national Australian threat assessment process.

Acknowledgements

This work was supported by both the NSW National Parks & Wildlife Service and the Biodiversity Group of Environment Australia (formerly the Australian Nature Conservation Agency). Much thanks to the efforts of Ms Jennifer Miller in assisting the collection and verification of data and to Mr Michael Bedward for the initial development of the 'Microsoft Access' database fields and helpful discussion of its use and necessary modifications. Mr Timothy Low kindly developed the interim 'Microsoft Access' database. The Directors of the National Herbarium of NSW and the Australian National Herbarium allowed access to their collections. The collaboration of Dr Mark Burgman in development and evaluation of assessment methods is gratefully acknowledged. The Australian Endangered Flora Network and Tasmanian Flora Advisory Committee gave helpful criticism of earlier drafts of the decision rules. Mr Jim Crennan drafted the tabular format of the rule set.

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Appendix 1. RAREplants (Rules for the Assessment of the Risk of Extinction in vascular plants).

An evaluation and modification of IUCN Red List criteria for classification of extinction risk in vascular plants

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Abstract: *The IUCN Red List criteria endorsed in 1994 consist of a set of decision rules based on quantitative thresholds of population size, distributional range, rates of decline and extinction risk. We evaluated these criteria using data on 68 vascular plant taxa from south-eastern Australia and found that deficiencies could be overcome with modifications that did not substantially alter the structure of the IUCN rule set. These modifications included smaller distributional thresholds appropriate to sessile organisms, inclusion of life-history and land-based attributes, an amendment to account for skewed metapopulation structure, and inclusion of a rule addressing number of populations and qualitatively defined classes of threatening processes. We reviewed the strengths and weaknesses of explicit risk classification schemes such as the one endorsed by IUCN compared with intuitively-based qualitative schemes in traditional use. We concluded that explicit schemes foster greater accuracy and precision in risk classification, are more defensible in the face of challenges and define an agenda for data collection which is essential for ongoing assessment and management of threatened species.*

Introduction

A central strand of conservation concerns itself with the identification, research and protection of species facing a high risk of extinction in the near future. Many of the world's threatened species were first identified and listed under a scheme of Red List threat categories developed by IUCN (Synge 1981). Species were allocated to a category using criteria defined qualitatively in terms of increasing danger of extinction.

The definitions of threat categories have developed over time and have been adapted for application to different taxonomic groups and different regions (see review by Munton 1987). In Australia, for example, four successive listings of threatened vascular plants have been prepared under the ROTAP system (Rare or Threatened Australian Plants, Briggs & Leigh 1996), which uses definitions of threat categories based on IUCN categories originally applied to mammals (Goodwin & Holloway 1972). The ROTAP system was one of the first in which the categories refer, at least implicitly, to levels of extinction risk and time horizons (Hartley & Leigh 1979). Most often in ROTAP and other qualitative systems, species were classified using expert knowledge without explicit guidance on the estimation of risk.

The absence of explicit listing criteria reflects upon both the accuracy and precision of risk classification outcomes. Risk categories allocated to particular taxa may not accurately reflect their risk of extinction, not only because of poor quality data, but because of methodological artefacts related to a lack of guidance on how to assess good quality data against the categories. The consequences of inaccurate listings may be waste of scarce conservation resources that could otherwise be directed with greater effect or, worse still, failure to recognise some taxa in need or urgent conservation action. It seems likely, for example, that taxa with widespread but sparse and declining populations are consistently overlooked by intuitive risk classification schemes (Rabinowitz 1981, McIntyre 1992). Explicit listing criteria also ensure a level of precision and reliability that is necessary to defend listing decisions when subject to challenge. Intuitive risk classification schemes are limited in this regard because the reasons for listing individual taxa are not transparent and there is potential for poor consistency between taxa and lack of repeatability among different assessors (Mace & Lande 1991, Rohlf 1991).

Recognising the need for more explicit risk classification criteria, new guidelines for classifying species according to their risk of extinction were recently endorsed (IUCN 1994). The new guidelines define three categories of threatened taxa (Critically Endangered, Endangered and Vulnerable), for which criteria are specified in the form of quantitative decision rules. Additional categories defined qualitatively apply to extinct taxa (Extinct and Extinct in the Wild), taxa at lower risk (Conservation Dependent, Near Threatened and Least Concern), poorly known taxa (Data Deficient) and those yet to be assessed (Not Evaluated). These qualitatively defined categories will not be discussed further here.

The decision rules defining criteria for the three threatened categories were designed to be applicable to species from the full taxonomic spectrum, excepting micro-organisms. The criteria address attributes that affect risk of extinction: population size; distributional range; and rates of decline (IUCN 1994). The decision rules specify thresholds in these parameters which must be met if a species is to qualify for one of the three threatened categories (Rules A-D, IUCN 1994). Burgman et al. (in press) demonstrated how rule thresholds may be interpreted in a probablistic manner so that uncertainty in biological data may be treated explicitly in a precautionary fashion. Rules B and C have subrules based on additional attributes, some of which must also be met if a species is to qualify for a given threatened category. These subrules refer to qualitative evidence of decline, metapopulation structure (number of subpopulations, size of largest subpopulation) and population fluctuation. Rule E specifies a threshold of extinction probability within a given time interval for each threatened category, estimated from quantitative analysis of extinction risk (IUCN 1994).

No formal analysis of the IUCN (1994) criteria has yet been published, though they have already been applied to a wide range of taxa (e.g. Baillie et al. 1995, Green 1996). In this paper we apply the IUCN (1994) guidelines to a sample of vascular plant taxa from Australia. Vascular plants possess special features that present both challenges and opportunities for application of the IUCN (1994) criteria, particularly in relation to their diverse life histories, episodically driven mortality and recruitment, sessile mature phases and range of dispersal capabilities. We identify the main limitations in applying the IUCN (1994) criteria to vascular plant taxa and suggest amendments to overcome these limitations without altering the overall structure of the rule set or the relationship of the risk categories to one another.

Methods

Compilation and assessment of attribute data

Data on population size and structure, distributional range, rates of decline, metapopulation structure, life history and habitat requirements were compiled for two sets of plant taxa. The first included 56 plant taxa from New South Wales for which surveys had been carried out since 1990. A few of these taxa had distributions extending across state borders, however their occurrences in other states were not included in the data set. Relevant data were extracted from available survey reports and recovery plans. The second data set included 13 perennial shrub taxa endemic to Tasmania belonging to the genus *Epacris*. A field survey was designed and carried out to estimate population and distributional parameter values and their confidence limits from random samples of known populations. Together, the two data sets include plant taxa representing a wide range of life history and habitat characteristics including rainforest trees, semi-arid perennials, shrubs of fire-prone habitats, clonal shrubs and grasses, disturbance opportunists, ephemeral herbs of grasslands, and annual wetland herbs. To examine relationships among attributes used to assess extinction risk the taxa were plotted on axes representing population size, extent of occurrence, area of occupancy, number of populations and annual rate of population decline. Pearson Correlation Coefficients were calculated between all pairwise combinations of these variables. The significance of correlations was assessed using a Bonferroni adjustment for Type I errors (Wilkinson et al. 1992).

Assessment of decision rules

The IUCN (1994) decision rules were programmed using logical functions in Microsoft Excel and the threat status of each taxon was computed. Uncertainty in the attribute data was treated in an explicitly precautionary manner by interpreting decision rules with a statistical confidence threshold (Burgman et al. in press). Thus, a rule was rejected only if there was

90% confidence that the true value of abundance or range was greater (or the true rate of decline was less) than the threshold specified in the rule.

Application and interpretation of the IUCN rule set identified several deficiencies. To address these deficiencies, an amended rule set was developed by programming and evaluating modifications including additional attributes, alternative rule structures and different thresholds. Modification and evaluation was carried out iteratively by: comparing the distribution of taxa among computed threat categories to the pattern of variation in the primary attribute data; by examining the cause of discrepancies between the computed threat status and the intuitively determined status listed on Rare or Threatened Australian Plants (ROTAP, Briggs & Leigh 1996); and by consulting botanists experienced in the assessment of these and other rare plant taxa.

The threat categories of the ROTAP list were equated to those of IUCN (1994) as follows: Endangered in ROTAP corresponds to Critical and Endangered combined in IUCN (1994); Rare in ROTAP corresponds to Lower Risk (Near Threatened) in IUCN(1994); and the Vulnerable category is unchanged. The ROTAP status codes were based on the national distributions of the taxa, whereas the status codes derived from IUCN (1994) and the modified rule set in this study were based only on state-wide distributions. Five taxa with distributions extending substantially outside N.S.W. were therefore excluded from the comparisons with ROTAP status codes. The 13 taxa in the second data set were also excluded from these comparisons because substantially more data was used to compute threat status in this study than was available at the time the ROTAP status codes were determined.

Results

The combined data set of 68 taxa from NSW and Tasmania included a reasonably even spread of taxa across the ranges of all pairwise combinations of the five core attributes of extinction risk (Fig. 1). The five core attributes used in the assessment of risk varied independently of one another ($P>0.05$) with two exceptions: population size was correlated with area of occupancy ($r=0.69$, $P<0.001$); and extent of occurrence was correlated with number of populations ($r=0.41$, $P<0.01$).

The final version of the modified rule set, RAREplants (Rules for Assessment of the Risk of Extinction in plants), is given in Appendix 1 and differs from the rule set endorsed by IUCN (1994) as follows.

i) Thresholds for area of occupancy and extent of occurrence were reduced so that they were appropriate to sessile organisms. Area of occupancy was interpreted as the field-estimated area of habitat occupied by standing plants summed over all subpopulations.

ii) Biological and land use attributes appropriate to extinction risk in vascular plants were incorporated as additional subrules so that 3 out of 5 subrules are required to be met under both Rule B (distributional range) and Rule C (population size). The additional subrules refer to regeneration capacity, the specificity and temporal availability of the habitat, and representation in protected areas.

iii) The number of subpopulations accounting for 90% of mature individuals was substituted for the total number of locations to exclude small subpopulations from the count in taxa with a highly skewed metapopulation structure.

iv) A new rule (Rule F) was added to assess the number of subpopulations in relation to qualitatively defined categories of threatening processes.

Notes were added to explain new terms and express thresholds in additional units to assist interpretation. Population reductions were expressed as annual rates of continuing decline by assuming a constant exponential rate of change. Distributional ranges were expressed as linear distances by converting extent of occurrence by assuming approximately circular distribution patterns.

Risk categories computed from the RAREplants and IUCN schemes and those listed on ROTAP are given in Appendix 2. The intuitively based ROTAP list allocated slightly fewer taxa (60% cf. 69% and 65%,. respectively) to the highest risk category and slightly more to the lower categories than the IUCN and RAREplants rule sets (Table 1). Only the ROTAP scheme allocated any of the sample taxa to the lowest risk category. The IUCN rule set resulted in a relatively polarised distribution of taxa among the risk categories, with a small number in the Endangered category and much larger numbers in the Critical and Vulnerable categories. This polarisation appears to be due to distributional thresholds in Rule B, which are inappropriately large for vascular plants.

Thirty-nine of 68 taxa (57%) were allocated to the same status by the IUCN and RAREplants schemes, agreement being poorest in the Endangered category (Table 2a). Twenty-five of the remaining 29 taxa were allocated to a higher risk category (usually Critical) by the IUCN scheme. There was 68% agreement (34 out of 50 taxa) between ROTAP and both rule-based schemes (Table 2b & c). The remaining taxa were distributed evenly between higher and lower status categories.

The high frequency with which Rule B determined the status of taxa reflects the high proportion of taxa with restricted distributions in the data set, whereas the low frequency with which Rule A was invoked reflects a scarcity of data on rates of decline (Table 3). There were no quantitative estimates available on extinction risk, precluding use of Rule E. However, there were sufficient locality data and qualitative site-based information on threats to assess RAREplants Rule F, the outcomes of which agreed with at least one other rule in 23 of 25 cases where Rule F supported the overall status (Table 3). In those taxa whose overall status was determined by a single rule, Rule B was most frequently the deciding rule in both RAREplants and IUCN, although more frequently invoked in RAREplants. Rule D was relatively frequently the sole deciding rule in the IUCN scheme (Table 3).

In the RAREplants scheme over half the taxa were allocated to a risk category on the basis of more than one rule, compared with one-quarter in the IUCN scheme (Table 4), even when Rule F was excluded from consideration. Notwithstanding the introduction of Rule F, this was due largely to Rule B although the other three rules were also invoked at slightly higher frequencies in RAREplants than IUCN (Table 3). In RAREplants decisions to allocate taxa to the Vulnerable category were generally supported by more rules than were decisions to allocate taxa to the higher risk categories (Table 4). This pattern was not evident in the IUCN scheme.

Discussion

Modifications to the IUCN rule set

IUCN (1994) sought to address all taxa except micro-organisms through the assessment of every taxon against at least one of the five rules. Although it is true that vascular plants can be assessed against several, if not all rules, relatively minor modifications to the rules suggested in Appendix 1 produced risk classification outcomes that were more robust and more logically consistent with the primary data. First, RAREplants produced an even spread of taxa among the categories, whereas the relatively polarised outcome of IUCN was not reflected in the even distribution of primary attribute values used in both schemes (Fig. 1). Second, the overall status of taxa was more often supported by multiple rules in RAREplants than in IUCN (Table 4), suggesting greater parity among rules in RAREplants and a more robust outcome if data for some rules are missing. Finally, the risk classifications produced by both RAREplants and IUCN were on balance no more and no less stringent than those determined by qualitative assessment in ROTAP (Table 2), even though one-third of the taxa were allocated to higher or lower risk categories.

Some of the suggested modifications are applicable to all biota (e.g. for skewed metapopulation structure), while others are more specific to vascular plants and biologically similar taxa (e.g. distributional thresholds, regeneration capacity). In the latter case it may be possible to suggest modifications that are appropriate for the life history and behavioural characteristics of other biotic groups, while maintaining the overall structure of the IUCN (1994) rule set.

Distributional thresholds

IUCN (1994) recognised that distributional parameters were dependent on spatial scales and suggested that the most appropriate spatial scale should be determined by 'relevant biological aspects of the taxon'. For example, it would seem inappropriate to estimate area occupied by sessile and highly mobile organisms using the same spatial scale. Nonetheless, a grid size of about 1 kilometre is implicit in the occupancy thresholds of IUCN's (1994) Rule B. Unlike some mobile animals, many plant populations actually occupy only a small fraction of a kilometre grid square. Estimates based on such large grids are therefore likely to overestimate any biologically meaningful interpretation of the area occupied. Instead, the area occupied by populations of standing plants and other sessile organisms may be estimated in the field by calculating the area of a minimum convex polygon that includes all individuals. When estimated in this way, areas of occupancy for individual populations of the study species were recorded at scales of hectares or square metres and only one of the 68 taxa examined had an area of occupancy greater than the Critically Endangered threshold (10 km^2). Many plants that would otherwise be considered 'Low Risk' would fail to exceed this threshold.

The distributional thresholds in IUCN (1994) were responsible for the polarised allocation of the sample plant taxa to the Critical and Low Risk categories in Rule B (Table 1). Subrules B2 and B3 are identical for the three risk categories, but subrule B1 has a varying threshold number of subpopulations. Thus if the Critical threshold for area of occupancy is always met, taxa will be always be allocated to Critical if subrules B2 and B3 are met or otherwise allocated to Low Risk unless there are 1-10 subpopulations and only one of subrules B2 and B3 are met. Indeed, all 67 taxa with areas of occupancy less than the Critically Endangered threshold were allocated to either the Critical or Low Risk categories by IUCN Rule B.

Reducing the thresholds of area of occupancy and extent of occurrence to values suggested in Appendix 1 produced a more even spread of taxa among the risk categories allocated by Rule B. An even distribution of taxa among risk categories is consistent with the distribution of the primary attribute values (Fig. 1).

Skewed metapopulation structure

Some taxa have a highly skewed metapopulation structure comprising several very small subpopulations and one or few larger subpopulations. The number of small subpopulations may result in some taxa, such as *Acronychia littoralis,* exceeding thresholds for Rules B1, C2 and E. *A. littoralis* has 34 subpopulations of which the 10 largest include more than 90% of mature individuals and 21 have fewer than 10 mature individuals (Fig. 2). In contrast, *Kunzea rupestris*, a species with a larger total population size, has 9 subpopulations with a relatively even size distribution, such that 8 are required to represent 90% of mature individuals (Fig. 2). The bias caused by highly skewed metapopulation structure was thus corrected by including the number of subpopulations accounting for 90% of the total number of mature individuals in Rules B1, C2 and E (Appendix 1, Fig. 2).

Life history and habitat attributes

The IUCN (1994) rule set lacks direct reference to life history attributes and habitat characteristics that are related to the risk of extinction. These were addressed by new subrules B4 and C4 in the modified rule set (Appendix 1). Some taxa have life history syndromes that limit reproduction or recruitment so that their populations have limited capacity to recover after a decline or catastrophe. In demographic terms, such taxa have very low intrinsic rates of population growth and hence a high risk of extinction (Gilpin & Soule 1986). Examples from the NSW data set include *Haloragodendron lucassii*, which is unable to produce fertile pollen so that reproduction is limited to local vegetative spread, and *Grevillea caleyi* an obligate seeder in a fire-prone habitat in which accumulation of a seed bank is limited by extreme rates of seed predation. These sources of extinction risk may only be addressed by indirect and restrictive interpretations of the IUCN (1994) rules. For example affected taxa must either be considered as subject to a projected reduction in population size (Rules A2, B2 and C2) or, as suggested by Baillie et al. (1995), mature individuals must be excluded from estimates of population size (Rule C) unless they are 'capable of producing young that reach the age of maturity'. A more explicit solution is to include a qualitative attribute addressing life history attributes that limit regeneration capacity (Rules B4a and C4a, Appendix 1). Qualitative definition of the regeneration attribute allows wider application than a rule with quantitative thresholds for the rate of population growth.

Habitat specificity has long been recognised as an important component of rarity and extinction risk in both plants (Rabinowitz 1981) and animals (Milsapp et al. 1989, Lunney et al. 1996). A highly specialised habitat suggests limited carrying capacity which ultimately limits population growth rate (Harper 1977) and therefore increases extinction risk (Burgman et al. 1993). Species with highly specialised habitats include those whose occurrence has high fidelity to rare landscape features (e.g. rock outcrops, mound springs, waterfalls, etc., Rabinowitz 1981) and those with dependence on rare cohabiting organisms (e.g. pollinators, hosts, etc.). Suitable habitat conditions may appear rarely in time, as in gap-dependent species (Harper 1981). To meet the additional subrules B4b and C4b for the Vulnerable category, a taxon must occupy a habitat that is rare in space, whereas for Critical and Endangered the habitat must also be rare in time (Appendix 1).

Land use and tenure attributes

Many deterministic threatening processes are linked to land use and tenure. The effects of habitat loss or degradation may be especially severe for sessile organisms with limited dispersal capability. These threats may be addressed implicitly in the IUCN (1994) rule set by estimating projected reductions in population size, habitat extent or quality. Two modifications are proposed to address land-related threats more explicitly (Appendix 1). Rules B5 and C5 define thresholds in the numbers of mature individuals and subpopulations protected on reserved land tenures. The rules provide for two levels of protected tenures, the thresholds being lower for reserves with the strongest forms of legal protection. In either case, populations should only be considered reserved if managed in a way that mitigates threatening processes.

Rule F (Appendix 1) requires threatening processes to be assigned to qualitatively defined classes based on the pattern of population or habitat decline they are likely to cause (sudden *cf.* gradual) and the feasibility of mitigation. Under Rule F, taxa that have few subpopulations in total and few or no subpopulations or mature individuals that are free from Class I and/or Class II threats (Appendix 1) qualify for one of the risk categories. The nature of threats may be deduced from location, land use and tenure data which are generally available from collections, literature and maps. Rule F therefore allows taxa to be assigned to a risk category when population-level data are scarce or incomplete.

Quantitative estimates of extinction probability

Mace & Lande (1991) put forward compelling reasons why the Critical, Endangered and Vulnerable categories should reflect decreasing probability of extinction over increasing time intervals. The relationship between the categories is reflected in the thresholds for each category in Rule E: at least 50% chance of extinction within 10 years for Critical; at least 20% chance of extinction within 20 years for Endangered; and at least 10% chance of extinction within 100 years for Vulnerable. While the definition of the risk categories in terms of extinction probability over varied time scales provides an important conceptual framework for risk classification, the practical application of quantitative analyses to calculate extinction probability as proposed in Rule E is problematic.

Firstly, there are few species with sufficient data on which to base a formal viability analysis (Mace and Lande 1991). There are no such analyses for any of taxa addressed in this study and data on species from other regions appear to be similarly limited (e.g. Tear et al. 1995). Nonetheless, Mace & Lande (1991) point out that data acquisition and model development should allow more of the biota to be treated with quantitative viability analyses.

Secondly, values of extinction probability computed by different models are not necessarily comparable, as is implicit in Rule E (IUCN 1994). This is because computed values of extinction probability are sensitive to uncertainty in parameter estimates (Taylor 1995) and to the structure and assumptions of different models (Lindenmayer et al. 1995, Ferson & Burgman 1995). Population viability analyses are therefore most useful in evaluation and ranking of alternative conservation and management scenarios examined by a single model (Burgman et al. 1993, Possingham 1995).

Uniformity in model structure and data quality is thus desireable to reduce the influence of methodological artefacts in the application of Rule E. However, a range of modelling approaches is necessary to accommodate the wide range of extrinsic and intrinsic factors pertinent to extinction risks in different species (Mace & Lande 1991), as well as interactions between these factors that may produce complex cumulative or synergistic effects on extinction probability. The need for varied modelling approaches is particularly relevant to vascular plant species, among which there are widely varied life histories. It would therefore seem ill-advised either to constrain application of Rule E to models of a particular (standard) structure or to assess Rule E by comparing absolute values of extinction probability derived from structurally different models. Thus, in the few cases where data are sufficient to allow assessment of Rule E, the sensitivity of absolute values of extinction probability to parameter estimates and model assumptions warrants careful consideration.

Advantages of decision rules over intuitive risk assessment

A major advantage of quantitative, systematic risk classification schemes such as decision rules over traditional intuitive methods (e.g. Synge 1981, Briggs & Leigh 1996) is that their more explicit decision process fosters greater accuracy and precision in risk assessment. Intuitive classifications are inherently somewhat circular, highly subjective and therefore open to widely diverging outcomes (Mace & Lande 1991), even with wide consultation among experts.

The many disagreements between the rule-based and intuitive classifications (32% of taxa examined) may be illustrated with a comparison of two closely related species from the NSW data set, *Grevillea beadleana* and *G. rivularis*. RAREplants allocated *G. beadleana* to Vulnerable and *G. rivularis* to Endangered, the reverse of the ROTAP listings, while IUCN allocated both to Vulnerable (Appendix 2). The two species are likely to have very similar life history characteristics, recruitment and mortality being linked to the occurrence of fires. *G. rivularis* occupies a specialised riparian habitat at a single location, of which about 20% is in a legally gazetted conservation reserve adjacent to a popular tourist attraction. Its total population includes 600-900 mature individuals. *G. beadleana* occupies a more widespread forest habitat at 4 locations over a range of 3000-3500 km^2, though 90% of mature individuals occur at a single location. Its total population includes 3000-5000 mature individuals. One subpopulation of 160-200 mature individuals is represented in a legally gazetted conservation reserve, while the largest subpopulation is on leasehold land potentially threatened by grazing and frequent fire (Class II threats, Appendix 1). It seems reasonable to conclude on the basis of these data that *G. rivularis* has a greater, or at least similar, risk of extinction in the short term than *G. beadleana*. This conclusion is least consistent with the ROTAP listing and most consistent with the status categories computed from the RAREplants rule set. The example shows that the use of explicit decision rules focuses judgements on testable hypotheses about biological attributes which may be supported or refuted by data and knowledge of life history and habitat biology.

Clearly, it is neither possible nor desirable to remove all elements of subjective judgement from risk classification. Both the IUCN and RAREplants rule sets rely on subjective judgement to interpret biological attributes referred to in the rules. Nonetheless if experts believe, for example, that *G. beadleana* is at greater risk than *G. rivularis*, a rule-based assessment challenges them to produce evidence supporting their case, either in the form of new information or an arguement supporting an alternative interpretation of the attributes. Operational definitions and explanations of terms given in IUCN (1994) and Appendix 1 assist repeatable interpretations of attributes and rules.

Explicit rule-based classification schemes, provided they address all the major risk factors, are likely to avoid biases in the kinds of rarity and threat that are identified. It has been suggested that endangered species lists based on intuitive risk classification under-represent the number of widespread species with relatively large but highly fragmented, sparse and/or declining populations (Rabinowitz 1981, McIntyre 1992). Decision rules (particularly A and F, Appendix 1) provide a prompt to force consideration of these factors where they might otherwise be overlooked.

IUCN (1994) recommend that all rules and subrules supporting the overall risk category should be recorded for each taxon. The circumstances in which changes in the rate of decline, population size or distribution warrant a change in risk status are explicitly defined in the rule thresholds. Rohlf (1991) outlined compelling legal needs for such transparency. The rules also suggest a course by which conservation actions may reduce the risk of extinction. For example, in both RAREplants and IUCN the Critically Endangered status of *Epacris barbata* is supported only by Rule A, while other rules suggest Vulnerable status (Appendix 2). Revision of *E. barbata* to Vulnerable could therefore be achieved if the disease that causes its high rate of decline could be mitigated. Similarly, the status of several other taxa could be revised by meeting thresholds for representation and effective management in reserves (Rules B and D).

The assessment of risk status by explicit rule sets promotes the collection of quantitative data that is crucial to ongoing assessment and management of threatened species (Mace & Lande 1991). Data on the size of populations and their rates of decline are essential for these purposes, but often neglected in surveys and monitoring studies undertaken as part of recovery projects (Tear et al. 1995, Keith in review). Monitoring schemes such as the one proposed by Menges & Gordon (1996) are designed to supply reliable data of this type, both for continuing assessment and management of threatened species.

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Appendix 1: RAREplants (Rules for the Assessment of Risk of Extinction in vascular plants) modified from the rule set endorsed by IUCN (1994). The basic rules endorsed by IUCN (1994) are in ordinary type, with amendments in bold italics.

Definitions

Subpopulations are defined by IUCN (1994) as geographically or otherwise distinct groups in the total population between which there is little exchange, typically less than one migrant per year or less. It is suggested that dispersal of propagules is more important to the viability of plant populations than dispersal of gametes because the latter usually do not contribute to rescue or recolonisation events. Propagule dispersal rates in many vascular plant species are unlikely to be greater than one migrant per year between occurrences separated by distances of more than 1 km, since dispersal distances are generally in the order of metres (e.g. Lamont 1985, Primack & Miao 1992). Geographic discontinuities of more than 1 km are therefore suggested as a rule of thumb for delineating subpopulations of plants. Species with propagules that are buoyant on air or water (e.g. Menges 1990), or dispersal by wide-ranging vertebrates (e.g. Eby 1991) may warrant a broader concept of subpopulations. Consistent with popular Australian usage, the terms 'total population' and 'population' have been substituted for IUCN terms 'population' and 'subpopulation', respectively.

Regeneration capacity is a surrogate attribute representing the rate of intrinsic population growth. Taxa with limited regeneration capacity have life history syndromes that may reduce the rate or magnitude of recovery after a population reduction by limiting recruitment to low levels relative to the background level of mortality among established plants. Examples include low levels of viability of seed or pollen, persistently low levels of seed set, high levels of mortality or predation among seeds or seedlings, etc.

Habitat specificity is a surrogate attribute representing carrying capacity. It represents the extent to which a species is restricted to rare environmental or biological conditions. Examples include species whose occurrence has high fidelity to rare landscape features (e.g. rock outcrops, mound springs, waterfalls, etc., Rabinowitz 1981) and those with dependence on rare cohabiting organisms (e.g. pollinators, hosts, etc.). The size of habitat patches should be assessed relative to the size of the organism. Larger organisms require more space and resources and therefore require larger habitat patches.

Habitat availability refers to the suitability of habitat conditions through time (Harper 1981). A habitat is not continuously fit for occupation if conditions suitable for occupation (*cf.* recruitment) may occur rarely in time relative to the longevity of the organism. Examples include gap colonisers, some mid-successional species and species whose establishment and survival is dependent on transient climatic or soil conditions.

Legally gazetted conservation reserves are protected areas that may only be revoked by an act of parliament. To be considered reserved, processes threatening the population must be successfully mitigated by ongoing management actions.

Other protected areas are those without formal legislative status, but in which conservation of biodiversity the primary aim of management. This management goal should be stated explicitly in a plan of management. Examples from Australia include Forest Preserves, Conservation and Protected Areas, and areas subject to legally binding agreements between the landholder and government (Conservation Agreements and Covenants). To be considered reserved, processes threatening the population must be successfully mitigated by ongoing management actions.

Class I threats are processes capable of causing sudden, substantial and irreversible loss of individuals or habitat. An example is vegetation clearance followed by land use change.

Class II threats are processes capable of causing gradual, substantial and possibly irreversible loss of individuals or habitat. Examples include habitat degradation due pollution and urban runoff, overgrazing and consequent soil loss, widely dispersed and contagious disease (e.g. *Phytophthora cinnamomi*). These processes may be reversible, but mitigation may be technically difficult or expensive to achieve.

Near Threatened taxa do not qualify as Conservation Dependent, but are close to qualifying as Vulnerable (IUCN 1994). Generally, this may include taxa known from 20 or less localities, taxa whose habitat has been depleted more than 75% since settlement or taxa with fewer than 5 populations known to be represented in legally gazetted reserves.

A taxon is CRITICALLY ENDANGERED when it is facing and extremely high risk of extinction in the wild in the immediate future as defined by any of the following criteria (A to E):

A. Population reduction in form of either of the following:

1. An observed, estimated, inferred or suspected rate of decline equal to or greater than 80% reduction over the last 10 years or 3 generations *(Note 1a)* whichever is longer based on and specifying any of the following:
   (a) direct observation
   (b) an index of abundance appropriate for the taxon;
   (c) a decline in area of occupancy, ***geographic range*** or extent of occurrence;
   (d) ***extent or*** quality of habitat;
   (e) actual or potential levels of exploitation; or
   (f) the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.
2. A reduction of at least 80% projected or expected to be met within the next 10 years or 3 generations whichever is longer *(Note 2a)* based on (and specifying) any of (b), (c), (d), (e) (f).

A taxon is ENDANGERED when it is not Critically Endangered but is facing a very high risk of extinction in the wild in the near future, as defined by any of the following criteria (A to E):

A. Population reduction in form of either:

1. An observed, estimated, inferred or suspected rate of decline equal to or greater than 50% reduction over the last 10 years or 3 generations whichever is longer *(Note 1b)* based on and specifying any of the following:
   (a) direct observation
   (b) an index of abundance appropriate for the taxon;
   (c) a decline in area of occupancy, ***geographic range*** or extent of occurrence;
   (d) ***extent or*** quality of habitat;
   (e) actual or potential levels of exploitation; or
   (f) the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.
2. A reduction of at least 50% projected or expected to be met within the next 10 years or 3 generations whichever is longer *(Note 2b)* based on (and specifying) any of (b), (c), (d), (e) or (f) above.

A taxon is VULNERABLE when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future, as defined by any of the following criteria (A to E):

A. Population reduction in form of either:

1. An observed, estimated, inferred or suspected rate of decline equal to or greater than 20% reduction over the last 10 years or 3 generations whichever is longer *(Note 1c)* based on and specifying any of the following:

   (a) direct observation
   (b) an index of abundance appropriate for the taxon;
   (c) a decline in area of occupancy, ***geographic range*** or extent of occurrence;
   (d) ***extent or*** quality of habitat;
   (e) actual or potential levels of exploitation; or
   (f) the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.
2. A reduction of at least ~~50~~% projected or expected to be met within the next 10 years or 3 generations whichever is longer *(Note 1c)* based on (and specifying) any of (b), (c), (d), (e) or (f) above].

CRITICALLY ENDANGERED

B. Extent of occurrence estimated to be less than ***10 km²*** ***(equivalent to linear geographic range less than 10 km)*** OR area of occupancy estimated to be less than ***1 ha AND any three of the following five conditions exist***:

1. Severely fragmented ***(i.e. no population contains more than 50 mature individuals) OR at least 90% of mature individuals*** known to exist at only a single location.
2. Continuing decline observed, inferred or projected in any of the following:
   (a) extent of occurrence ***or geographic range***;
   (b) area of occupancy;
   (c) area, extent and/or quality of habitat;
   (d) number of locations or populations;
   (e) number of mature individuals.
3. Extreme fluctuations in any of the following
   (a) extent of occurrence;
   (b) area of occupancy;
   (c) number of locations or populations;
   (d) number of mature individuals.
4. ***Either***
   (a) there is limited capacity to regenerate after a population reduction or decline; OR
   (b) habitat requirements are highly specialised AND the habitat is not continuously fit for occupation.
5. ***There are no populations represented (Note 3) in legally gazetted conservation reserves or other protected areas (i.e. with conservation as primary management aim, but without legal reservation status).***

ENDANGERED

B. Extent of occurrence estimated to be less than ***500 km²*** ***(equivalent to linear geographic range less than 20 km)*** OR area of occupancy estimated to be less than ***10 ha AND any three of the following five conditions exist***:

1. Severely fragmented ***(i.e. no population contains more than 250 mature individuals) OR at least 90% of mature individuals*** known to exist at no more than five locations.
2. Continuing decline observed, inferred or projected in any of the following:
   (a) extent of occurrence ***or geographic range***;
   (b) area of occupancy;
   (c) area, extent and/or quality of habitat;
   (d) number of locations or populations;
   (e) number of mature individuals.
3. Extreme fluctuations in any of the following
   (a) extent of occurrence;
   (b) area of occupancy;
   (c) number of locations or populations;
   (d) number of mature individuals.
4. ***Either***
   (a) there is limited capacity to regenerate after a population reduction or decline; OR
   (b) habitat requirements are highly specialised AND the habitat is not continuously fit for occupation.
5. ***Representation in protected areas comprises no more than:***
   (a) one population or 250 mature individuals represented (Note 3) in legally gazetted conservation reserves only; OR
   (b) 5 populations or 2500 mature individuals represented (Note 3) in legally gazetted conservation reserves and other protected areas (i.e. with conservation as primary management aim, but without legal reservation status).

VULNERABLE

B. Extent of occurrence estimated to be less than ***2000 km²*** ***(equivalent to linear geographic range less than 50 km)*** OR area of occupancy estimated to be less than ***50 ha AND any three of the following five conditions exist***:

1. Severely fragmented ***(i.e. no population contains more than 1000 mature individuals) OR at least 90% of mature individuals*** known to exist at no more than ten locations.
2. Continuing decline observed, inferred or projected in any of the following:
   (a) extent of occurrence ***or geographic range***;
   (b) area of occupancy;
   (c) area, extent and/or quality of habitat;
   (d) number of locations or populations;
   (e) number of mature individuals.
3. Extreme fluctuations in any of the following
   (a) extent of occurrence;
   (b) area of occupancy;
   (c) number of locations or populations;
   (d) number of mature individuals.
4. ***Either***
   (a) there is limited capacity to regenerate after a population reduction or decline; OR
   (b) habitat requirements are highly specialised AND ~~the habitat is not continuously fit for occupation.~~
5. ***Representation in protected areas comprises no more than:***
   (a) 5 populations or 2500 mature individuals represented (Note 3) in legally gazetted conservation reserves only; OR
   (b) 10 populations or 10000 mature individuals represented (Note 3) in conservation reserves and other protected areas (i.e. with conservation as primary management aim, but without legal reservation status).

CRITICALLY ENDANGERED

C. ***Total*** population estimated to number less than 250 mature individuals ***AND three of the following five conditions exist***:

1. An estimated continuing decline of at least 25% within 3 years or one generation whichever is longer *(Note 4a)*;
2. A continuing decline observed, projected or inferred, in the number of mature individuals AND population structure in the form of either:
   (a) severely fragmented (i.e. no population contains more than 50 mature individuals);
   (b) ***at least 90% of mature*** individuals are in a single population.
3. *Extreme fluctuations in any of the following*
   (a) extent of occurrence;
   (b) area of occupancy;
   (c) number of locations or populations;
   (d) number of mature individuals.
4. *Either*
   (a) there is limited capacity to regenerate after a population reduction or decline; OR
   (b) habitat requirements are highly specialised AND the habitat is not continuously fit for occupation.
5. *There are no populations represented in legally gazetted conservation reserves or other protected areas (i.e. with conservation as primary management aim, but without legal reservation status).*

ENDANGERED

C. ***Total*** population estimated to number less than 2500 mature individuals ***AND three of the following five conditions exist***::

1. An estimated continuing decline of at least 20% within 5 years or 2 generation whichever is longer *(Note 4b);*
2. A continuing decline, observed, projected or inferred, in the number of mature individuals AND population structure in the form of either:
   (a) severely fragmented (i.e. no population contains more than 250 mature individuals);
   (b) ***at least 90% of mature*** individuals are in a single population.
3. *Extreme fluctuations in any of the following*
   (a) extent of occurrence;
   (b) area of occupancy;
   (c) number of locations or populations;
   (d) number of mature individuals.
4. *Either*
   (a) there is limited capacity to regenerate after a population reduction or decline; OR
   (b) habitat requirements are highly specialised AND the habitat is not continuously fit for occupation.
5. *Representation in protected areas comprises a maximum of*
   (a) one population or 250 mature individuals represented (Note 3) in legally gazetted conservation reserves only; AND
   (b) 5 populations or 2500 mature individuals represented (Note 3) in legally gazetted conservation reserves and other protected areas (i.e. with conservation as primary management aim, but without legal reservation status).

VULNERABLE

C. ***Total*** population estimated to number less than 10000 mature individuals ***AND three of the following five conditions exist***:

1. **An estimated** continuing decline of **at least** 10% **within** 10 years or three generation whichever is longer *(Note 4c);*
2. A continuing decline observed, projected or inferred, in the number of mature individuals AND population structure in the form of either:
   (a) severely fragmented (i.e. no population contains more than 1000 mature individuals);
   (b) ***at least 90% of mature*** individuals are in a single population.
3. *Extreme fluctuations in any of the following*
   (a) extent of occurrence;
   (b) area of occupancy;
   (c) number of locations or populations;
   (d) number of mature individuals.
4. *Either*
   (a) there is limited capacity to regenerate after a population reduction or decline; OR
   (b) habitat requirements are highly specialised AND ~~the habitat is not continuously fit for occupation.~~
5. *Representation in protected areas comprises a maximum of*
   (a) 5 populations or 2500 mature individuals represented (Note 3) in legally gazetted conservation reserves only; OR
   (b) 10 populations or 10000 mature individuals represented (Note 3) in conservation reserves and other protected areas (i.e. with conservation as primary management aim, but without legal reservation status).

CRITICALLY ENDANGERED	ENDANGERED	VULNERABLE
D. The total population includes less than 50 mature individuals	D. The total population includes less than 250 mature individuals	D. Population very small or restricted in the form of either of the following: 1. Total population estimated to number less than 1000 mature individuals. 2. Restricted area of occupancy (typically less than ***10 ha***) or small number of populations (typically ***no more than*** 5).
E. Quantitative analysis showing the probability of extinction in the wild is at least 50% within 10 years or 3 generations, whichever is the longer.	E. Quantitative analysis showing the probability of extinction in the wild is at least 20% within the next 20 years or 5 generations, whichever is the longer.	E. Quantitative analysis showing the probability of extinction in the wild is at least 10% within 100 years.
F. 90% of all mature individuals are contained in a single population ***AND it occurs on land that is subject to Class I threats (processes potentially causing sudden and irreversible loss of individuals or habitat, e.g. on land available for clearing).***	***F. 90% of all mature individuals are contained within no more than 5 populations*** ***AND no populations on land that is free from Class I threats (processes potentially causing sudden and irreversible loss of individuals or habitat, e.g. on land available for clearing).***	***F. 90% of all mature individuals are contained within no more than 10 populations AND either*** ***1. No more than one population or 250 mature individuals occur on land that is free from Class I threats (processes potentially causing sudden and irreversible loss of individuals or habitat, e.g. on land available for clearing).*** ***2. No more than two populations or 2500 mature individuals occur on land free from both Class I and Class II threats (processes causing sudden or gradual, substantial and possibly irreversible loss of individuals or habitat, e.g. severe habitat degradation).***

NOTES

Critically Endangered

1a. Equivalent to 15% per year over an appropriate time scale during the last 10 years or 40% per generation if generation time is longer than 3-4 years).

2a. Equivalent to 15% per year over an appropriate time scale during the next 10 years or 40% per generation if generation time is longer than 10 years.

3. Populations should only be regarded as 'reserved' if reservation and management entails mitigation of threatening processes.

4a. Equivalent to 9% per year or 25% per generation if generation time is longer than 3 years

Endangered

1b. Equivalent to 7% per year over an appropriate time scale during the last 10 years or 20% per generation if generation time is longer than 3-4 years

2b. Equivalent to 7% per year over an appropriate time scale during the next 10 years or 20% per generation if generation time is longer than 3-4 years

3. Populations should only be regarded as 'reserved' if reservation and management entails mitigation of threatening processes.

4b. Equivalent to 4% per year or 10% per generation if generation time is longer than 3 years

Vulnerable

1c. Equivalent to 2% per year over an appropriate time scale during the last 10 years or 7% per generation if generation time is longer than 3-4 years

2c. Equivalent to 2% per year over an appropriate time scale during the last 10 years or 7% per generation if generation time is longer than 3-4 years

3. Populations should only be regarded as 'reserved' if reservation and management entails mitigation of threatening processes.

4c. Equivalent to 1% per year or 3% per generation if generation time is longer than 3 years

Appendix 2: Risk status of 55 taxa from New South Wales and 13 taxa from Tasmania derived from RAREplants rule set (Appendix 1), IUCN rule set (IUCN 1994) and ROTAP list (Briggs and Leigh 1996). Nomenclature follows Harden (1990-93) and Buchanan (1995). Overall status is the highest category returned by any of the rules. CR- Critical Endangered, EN and E- Endangered, VU and V- Vulnerable, R- Rare, LR- Low Risk, NL- Not Listed. * indicates taxa with distributions substantially outside NSW.

	RAREplants						IUCN					ROTAP
	Overall	RuleA	RuleB	RuleC	RuleD	RuleF	**Overall**	RuleA	RuleB	RuleC	RuleD	**Overall**
Acacia carnei	**VU**	LR	LR	VU	VU	LR	**VU**	LR	LR	VU	VU	**V**
Acacia curranii	**VU**	LR	LR	LR	VU	LR	**VU**	LR	LR	LR	VU	**V**
Acronychia littoralis	**EN**	VU	EN	VU	VU	VU	**CR**	VU	CR	VU	VU	**E**
Acrophyllum australe	**VU**	VU	VU	VU	VU	LR	**VU**	VU	LR	VU	VU	**V**
Allocasuarina defungens	**EN**	VU	EN	LR	VU	VU	**VU**	VU	LR	LR	VU	**E**
Allocasuarina portuensis	**CR**	CR	CR	CR	CR	CR	**CR**	CR	CR	CR	CR	**E**
Apatophyllum constablei	**VU**	LR	LR	LR	VU	VU	**VU**	LR	LR	LR	VU	**E**
Asterolasia elegans	**VU**	LR	VU	LR	VU	VU	**VU**	LR	LR	LR	VU	**E**
Blandfordia cunninghamii	**VU**	LR	VU	LR	VU	VU	**VU**	LR	LR	LR	VU	**R**
Cadelia pentastylis	**VU**	LR	LR	LR	VU	VU	**EN**	LR	EN	LR	VU	**R**
Callitris oblonga	**VU**	LR	VU	LR	VU	VU	**CR**	LR	CR	LR	VU	**V**
Chorchorus cunninghamii	**CR**	VU	CR	CR	EN	VU	**CR**	VU	CR	EN	EN	**E**
Cynachum elegans	**VU**	LR	LR	VU	VU	LR	**CR**	LR	CR	VU	VU	**E**
Digitaria porrecta	**EN**	LR	LR	LR	VU	EN	**CR**	LR	CR	LR	VU	**E**
Diplogottis campbellii	**CR**	LR	EN	VU	CR	VU	**CR**	LR	CR	CR	CR	**E**
Elaeocarpus williamsianus	**EN**	LR	VU	LR	EN	VU	**EN**	LR	LR	LR	EN	**E**
Epacris hamiltonii	**VU**	VU	VU	VU	VU	VU	**EN**	VU	LR	EN	VU	**E**
Eriocaulon carsonii	**CR**	VU	CR	EN	VU	VU	**CR**	VU	CR	EN	VU	**E**
Eucalyptus parvula	**EN**	LR	EN	VU	VU	VU	**CR**	LR	CR	LR	VU	**V**
Eucalyptus paliformis	**VU**	LR	LR	LR	VU	VU	**VU**	LR	LR	LR	VU	**R**
Fontania oraria	**CR**	LR	CR	VU	CR	CR	**CR**	LR	CR	CR	CR	**E**
Gentiana wingecarribiensis	**CR**	CR	CR	CR	EN	VU	**CR**	CR	CR	CR	EN	**E**
Grevillea beadleana	**VU**	LR	VU	LR	VU	VU	**VU**	LR	LR	LR	VU	**E**
Grevillea caleyi	**EN**	VU	EN	EN	VU	VU	**CR**	VU	CR	EN	VU	**E**
Grevillea iaspicula	**CR**	LR	EN	CR	EN	VU	**CR**	LR	CR	LR	EN	**E**

	RAREplants						IUCN					ROTAP
	Overall	RuleA	RuleB	RuleC	RuleD	RuleF	**Overall**	RuleA	RuleB	RuleC	RuleD	**Overall**
Grevillea kennediana	**VU**	LR	LR	VU	VU	LR	**VU**	LR	LR	VU	VU	**V**
Grevillea rivularis	**EN**	LR	EN	VU	VU	VU	**VU**	LR	LR	LR	VU	**V**
Grevillea wilkinsonii	**CR**	LR	CR	CR	EN	CR	**CR**	LR	CR	CR	EN	**E**
Haloragodendron lucassii s.str. (genets)	**CR**	LR	CR	EN	CR	VU	**CR**	LR	CR	CR	CR	**E**
Haloragodendron lucassii s.str. (ramets)	**EN**	LR	EN	LR	VU	VU	**CR**	LR	CR	EN	VU	**E**
Homopholis belsonii	**EN**	LR	LR	LR	VU	EN	**CR**	LR	CR	LR	VU	**R**
Kunzea rupestris	**VU**	LR	VU	LR	VU	VU	**VU**	LR	LR	LR	VU	**V**
Lepidium aschersonii	**VU**	VU	VU	VU	VU	VU	**CR**	VU	CR	VU	VU	**V**
Leptospermum thompsonii	**VU**	LR	LR	LR	VU	VU	**VU**	LR	LR	LR	VU	**V**
Melaleuca deanei	**VU**	LR	VU	LR	VU	LR	**VU**	LR	LR	LR	VU	**R**
Microstrobos fitzgeraldii	**VU**	LR	VU	LR	VU	VU	**VU**	LR	LR	LR	VU	**E**
Olearia flocktonii	**EN**	VU	EN	EN	VU	VU	**EN**	VU	LR	EN	VU	**E**
Phaius australis	**EN**	EN	EN	EN	EN	VU	**CR**	EN	CR	CR	EN	**V***
Phaius tankervilliae	**EN**	LR	EN	VU	VU	VU	**CR**	LR	CR	EN	VU	**V***
Phebalium lachnaeoides	**VU**	LR	VU	LR	VU	VU	**VU**	LR	LR	LR	VU	**E**
Pimelea spicata	**EN**	LR	EN	VU	LR	VU	**CR**	LR	CR	VU	LR	**E**
Pterostylis gibbosa	**CR**	EN	CR	EN	VU	VU	**CR**	EN	CR	EN	VU	**E**
Pultenaea parrisiae	**VU**	LR	VU	LR	VU	VU	**VU**	LR	LR	LR	VU	**V**
Rutidolepis leptorhynchoides	**EN**	VU	EN	LR	VU	VU	**CR**	VU	CR	LR	VU	**E**
Swainsona plagiotropis	**EN**	LR	EN	LR	VU	VU	**CR**	LR	CR	LR	VU	**V**
Swainsona recta	**EN**	EN	EN	EN	VU	VU	**CR**	EN	CR	EN	VU	**E**
Thesium australe	**EN**	VU	LR	EN	VU	VU	**CR**	VU	CR	EN	VU	**V***
Velliea perfoliata	**VU**	LR	VU	VU	VU	VU	**VU**	LR	LR	VU	VU	**V**
Wollemia nobilis	**CR**	LR	VU	LR	CR	CR	**CR**	LR	LR	LR	CR	**E**
Xerothamnella parviflora	**EN**	LR	LR	LR	EN	VU	**EN**	LR	LR	LR	EN	**V***
Zieria 'baeuerlenii' ms	**CR**	VU	CR	CR	EN	CR	**CR**	VU	CR	CR	EN	**E**
Zieria citriodora	**EN**	LR	EN	LR	EN	VU	**EN**	LR	LR	LR	EN	**V***
Zieria granulata	**EN**	VU	EN	VU	VU	LR	**CR**	VU	CR	LR	VU	**V**

	RAREplants						IUCN					ROTAP
	Overall	RuleA	RuleB	RuleC	RuleD	RuleF	**Overall**	RuleA	RuleB	RuleC	RuleD	**Overall**
Zieria involucrata	**VU**	LR	VU	LR	VU	VU	**VU**	LR	LR	LR	VU	**V**
Zieria 'prostrata' ms	**CR**	VU	CR	EN	VU	VU	**CR**	VU	CR	VU	VU	**E**
Epacris acuminata	**VU**	LR	VU	LR	VU	LR	**CR**	LR	CR	LR	VU	**V**
Epacris apsleyensis	**EN**	VU	EN	LR	VU	VU	**VU**	VU	LR	LR	VU	**V**
Epacris barbata	**CR**	CR	VU	LR	VU	VU	**CR**	CR	LR	LR	VU	**E**
Epacris exserta s.str.	**EN**	LR	EN	VU	VU	VU	**CR**	LR	CR	VU	VU	**V**
Epacris sp. aff. exserta 'Union Bridge'	**EN**	VU	EN	VU	VU	VU	**CR**	VU	CR	VU	VU	**V**
Epacris sp. aff. exserta 'Mt Cameron'	**EN**	VU	EN	VU	VU	VU	**VU**	VU	LR	VU	VU	**V**
Epacris glabella	**EN**	LR	EN	LR	VU	VU	**CR**	LR	CR	LR	VU	**V**
Epacris grandis	**VU**	LR	VU	LR	VU	VU	**VU**	LR	LR	LR	VU	**V**
Epacris limbata	**CR**	CR	EN	LR	VU	VU	**CR**	CR	CR	LR	VU	**V**
Epacris stuartii	**CR**	CR	EN	EN	VU	VU	**CR**	CR	LR	EN	VU	**E**
Epacris virgata s.str. 'Beaconsfield'	**EN**	VU	EN	LR	VU	VU	**CR**	VU	CR	LR	VU	**NL**
Epacris virgata 'Kettering form'	**EN**	VU	EN	LR	VU	VU	**CR**	VU	CR	LR	VU	**NL**
Epacris virgata 'var. autumnalis'	**CR**	CR	CR	VU	VU	VU	**CR**	CR	CR	EN	VU	**NL**

Table 1: Number (%) of taxa allocated to respective risk categories according to three assessment schemes.

Risk Status	Critical	Endangered	Vulnerable	Near Threatened/Rare
Scheme				
RAREplants	17(25)	27(40)	24(35)	0(0)
IUCN	40(59)	6(9)	22(32)	0(0)
ROTAP	[30(60)]		15(30)	5(10)

Table 2: Pairwise agreement in risk status between three assessment schemes. Agreements are indicated in bold.

a) RAREplants and IUCN

	RAREplants status			
	Critical	Endangered	Vulnerable	Near Threatened
IUCN status				
Critical	**17**	19	4	0
Endangered	0	**4**	2	0
Vulnerable	0	4	**18**	0
Near Threatened	0	0	0	0

b) RAREplants and ROTAP

	RAREplants status		
	Critical & Endangered	Vulnerable	Near Threatened
ROTAP status			
Endangered	**23** (13CR+10EN)	7	0
Vulnerable	4 (0CR+4EN)	**11**	0
Rare	1 (0CR+1EN)	4	0

c) IUCN and ROTAP

	IUCN status		
	Critical & Endangered	Vulnerable	Near Threatened
ROTAP status			
Endangered	**24** (21CR+3EN)	**6**	0
Vulnerable	5 (5CR+0EN)	10	0
Rare	2 (1CR+1EN)	3	0

Table 3: Number of taxa in which Rules A-F support overall risk status determined by RAREplants and IUCN schemes.

	Scheme	Rule A	Rule B	Rule C	Rule D	Rule E	Rule F
Number of taxa in which rule is only one supporting overall status	RAREplants	3	20	2	4	0	2
	IUCN	2	26	3	20	0	-
Number of taxa in which rule is one of several supporting overall status	RAREplants	8	29	16	29	0	23
	IUCN	8	11	12	10	0	-
Total	RAREplants	11	49	18	33	0	25
	IUCN	10	37	15	30	0	-

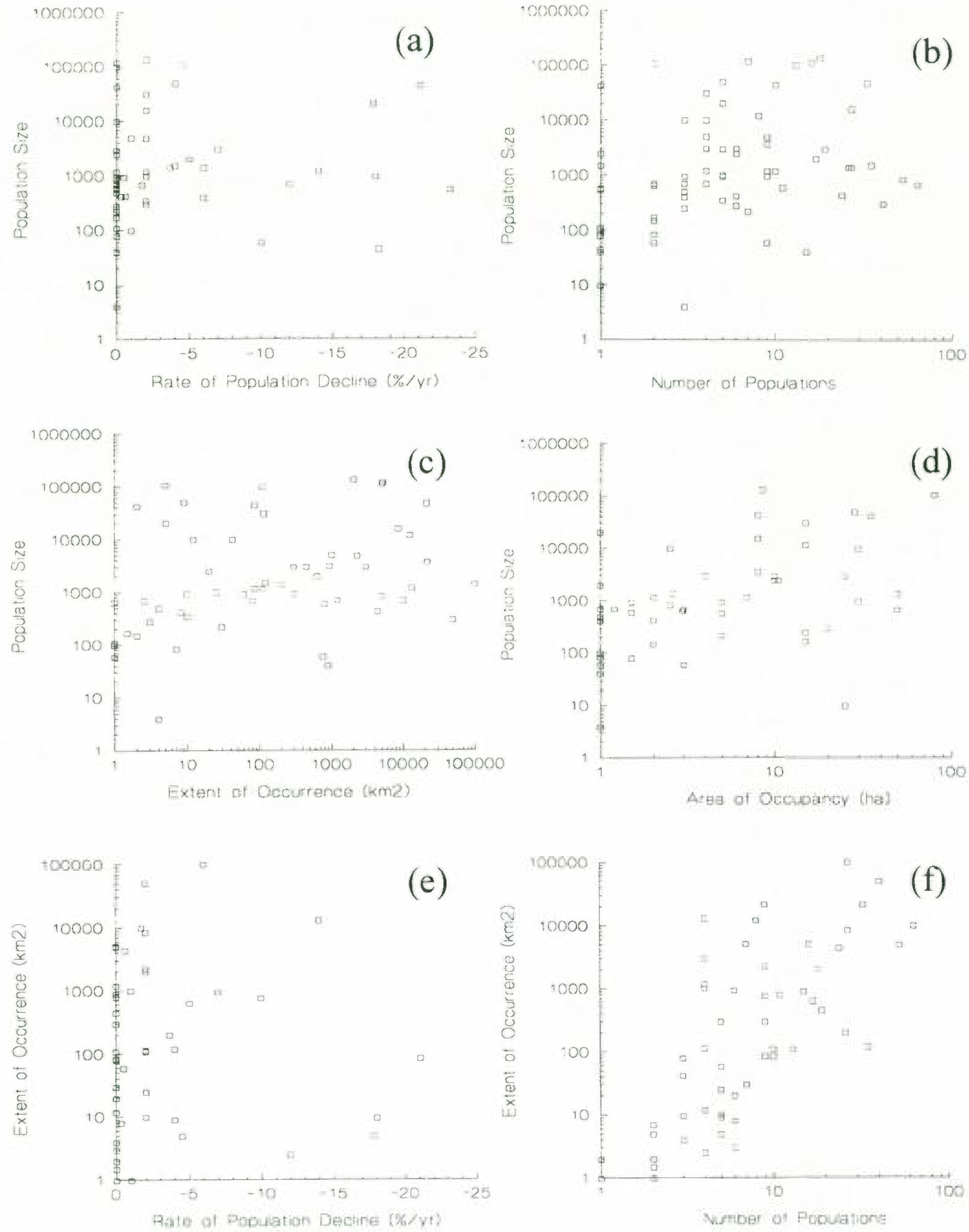
Table 4: Number of taxa with 1-5 rules supporting their overall risk status determined by RAREplants and IUCN rule sets.

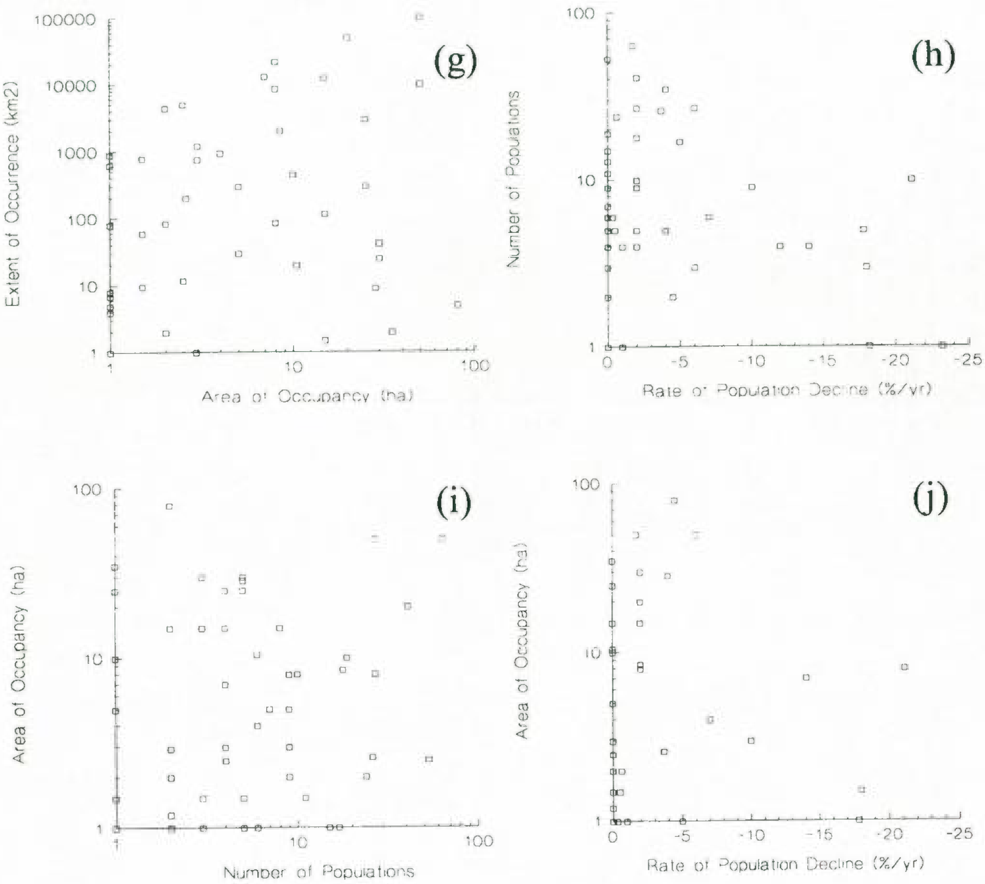
		Status Category			
		Critical	Endangered	Vulnerable	Total taxa(%)
Scheme	No. rules				
RAREplants	1	8	22	1	31(46)
	2	4	3	9	16(24)
	3	4	1	10	15(22)
	4	0	1	2	3(4)
	5	1	0	2	3(4)
IUCN	1	30	6	15	51(75)
	2	6	0	4	10(15)
	3	4	0	2	6(9)
	4	1	0	0	1(1)
	5	0	0	0	0(0)

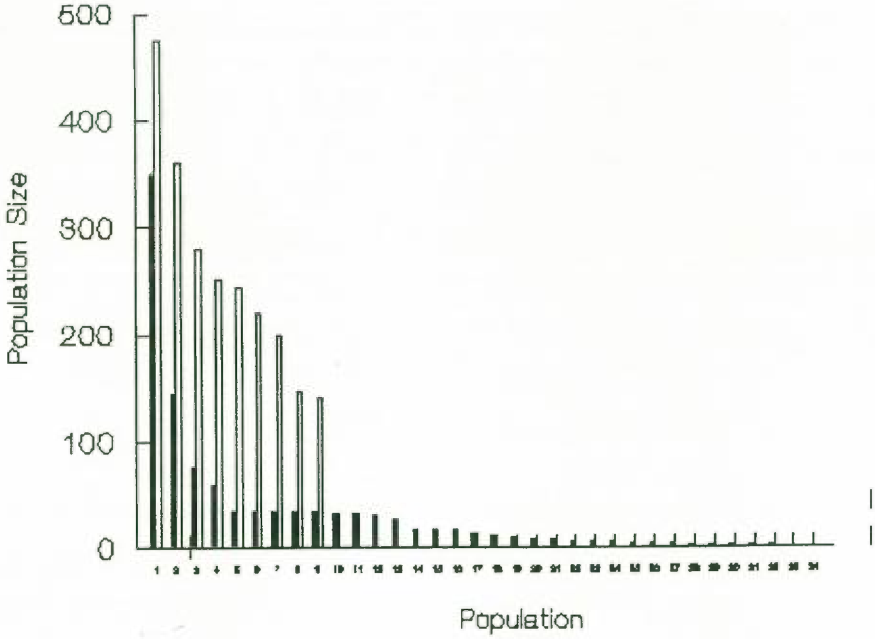
Figure captions

Fig. 1. Distribution of 68 sample taxa in relation to five primary extinction risk attributes: population size; number of subpopulations; rate of population decline; extent of occurrence; and area of occupancy.

Fig. 2. Size distribution of subpopulations in *Kunzea rupestris* (open bars) and *Acronychia littoralis* (solid bars).


(a)
Population Size
Rate of Population Decline (%/yr)
(b)
Population Size
Number of Populations
(c)
Population Size
Extent of Occurrence (km2)
(d)
Population Size
Area of Occupancy (ha)
(e)
Extent of Occurrence (km2)
Rate of Population Decline (%/yr)
(f)
Extent of Occurrence (km2)
Number of Populations


(g)
Extent of Occurrence (km2)
Area of Occupancy (ha)
(h)
Number of Populations
Rate of Population Decline (%/yr)
(i)
Area of Occupancy (ha)
Number of Populations
(j)
Area of Occupancy (ha)
Rate of Population Decline (%/yr)


600
400
300
200
100
0
Population Size
Population

Appendix 2: Probabilistic classification rules for setting conservation priorities.

PROBABILISTIC CLASSIFICATION RULES FOR SETTING CONSERVATION PRIORITIES

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Abstract

Decision rule sets are used widely to classify the conservation status of species. These classifications are intended to approximate the relative degree of threat faced by different species. They are important because they play a role in setting conservation priorities. It is suggested that such rule sets should take into account estimates of the statistical distribution and confidence intervals reported for each of the parameters. Examples are provided for three threatened Australian plant species.

Keywords: conservation status, decision rules, extinction risk, priorities

INTRODUCTION

In the early 1970s the International Union for the Conservation of Nature adapted a set of qualitative criteria for the classification of conservation status that made reference to levels of risk and time horizons (Holt, 1987). For example, endangered species were defined as those which face a high risk of extinction within one or two decades if present causal factors continue to operate. Mace and Lande (1991) suggested conservation status should be assessed quantitatively. For example, they defined critically endangered species as those facing a 50% probability of extinction within five years. Akçakaya (1992) recognised the classification of risk involves three parameters, namely, time, probability of decline and percent decline. Threat may then be seen as a combination of the magnitude of the impending decline within some time frame, and the probability that a decline of that magnitude will occur.

The IUCN (1994) defined a set of categories for conservation status supported by decision rules based on thresholds of parameters such as distributional range, population size, and population history. Each of the categories may be addressed by an appropriate quantitative analysis.

Decision rule sets are attractive because of their wide applicability, objectivity, and simplicity of use (Mace and Lande, 1991). By necessity, the choice of thresholds that delimit categories of risk are somewhat arbitrary (Chalson and Keith 1995). Other threat assessment schemes also make use of thresholds to assign scores but differ by summing these scores over a number of attributes to indicate overall conservation status or priority (e.g. Milsapp *et al.*, 1990).

Rule sets ignore uncertainty associated with each of the parameters. Rarely, if ever, will we know the exact population size or range of a species, because of measurement error and natural variation. The information for different species varies greatly, but the rules or scores used to assess species are blind to the amount and quality of the data. The purpose of this paper is to describe a simple change to the definition approach to the interpretation of rule sets that allows accounts for the uncertainty associated with parameters. A similar approach would be applicable to the interpretation of scores.

PROBABILISTIC RULE SETS

Often, agreement or disagreement with one of the thresholds in a rule set is based on the best estimate of the parameter. For example, the IUCN (1994) rules ask if a population consists of fewer than 50 mature individuals. Effectively, only two responses are possible. The structure of the question implies that there will be no error in the answer. When best estimates are used, the interpretation ignores whatever information is available regarding the reliability of the estimate, although the IUCN (1994) states that 'In cases where a wide variation in estimates is found, it is legitimate to apply the precautionery principle and use the estimate (providing it is credible) that leads to listing in the highest category of risk.' Allowances for statistical uncertainty could be made by basing judgements on a confidence bound. For example, to be 90% certain that no threatened species have been overlooked, then the 10th percentile for population size would provide a more effective means for ranking the relative risks faced by different species than using the best estimate for population size. The best point estimate for threat is still the mean. Using the confidence limits does not provide a better measure for degree of threat, but it provides a means of being more certain that taxa that may be threatened are not overlooked.

Consider the situation in Fig. 1 in which there are two species, for each of which there is an estimate of population size. Under judgements based on the best estimate, neither species A nor species B would be considered critically endangered, at least on the basis of the total number of mature individuals in the population (Criterion D, IUCN 1994). If the best estimate of population size is used as a guide to rank the species, then protection would be afforded to Species A before Species B.

Each estimate of population size is accompanied by some uncertainty. Uncertainty may be the result of many things including measurement error, year to year variation in population sizewhich is caused by variation in the environment, variation which results from demographic accidents, or taxonomic uncertainty. Some populations fluctuate in a regular fashion, following diurnal, seasonal or longer term weather patterns, or because of their interactions with predators or competitors. Natural variation in the environment and measurement error will overlay any other natural or human caused patterns, trends or cycles in population size. In the hypothetical example here, species A represents a case in which the estimate for a species is based on a carefully designed study involving stratified random samples from which the form of the distribution and its variance could be estimated. Species B represents a case in which the estimate for a species is a best guess by experts who were able to specify only upper and lower bounds for population size.

Despite differences in the kinds and quality of information from which inferences may be made, there is no guidance on how to interpret such variation even though the IUCN (1994) expresses the intent of precaution in the face of uncertainty. Instead of asking, which species have population sizes less than 50, we could ask, which species are we least confident have population sizes greater than 50. Alternatively, we could ask, which species are less than 10% likely to have population sizes less than 50. These latter two questions make use of both the central tendency and the dispersion of the estimate, and therefore require the use of more information than the questions currently applied in rule sets.

The mean is the best estimate of population size. Populations with larger means are more likely to have larger population sizes. Confidence limits give the range of hypotheses which cannot be rejected. So if a limit extends below 50, we cannot rule out the possibility the population size is below 50.

An appreciable proportion of the distribution that describes our knowledge of the population size of Species B falls below the threshold of 50 mature individuals (25%) (Fig. 1). Less of the distribution for Species A (15%) falls below the same threshold. Intuitively, Species B may be considered more at risk than Species A, simply because there is a greater chance that the true population size for this species is fewer than 50 individuals. If we interpret the 5th percentile of each distribution, we can be 95% certain that the population size of species A is greater than 40, and 95% certain that the population size of species B is greater than 25.

The priorities for protecting the species may be reversed when we consider the additional information associated with the uncertainty in the estimate of population size. By asking questions in this way, one may create an incentive for the acquisition of better data and the formulation of more reliable assessments of conservation status. Probabilistic questions impose a feedback between the reliability of the assessment and the consequences of that assessment and represent one practical implementation of the Precautionary Principle in conservation biology.

CASE STUDIES

Population and distribution data for three rare plant species from New South Wales are recorded in Table 1. *Phaius australis* is an orchid that grows in northern New South Wales and southern Queensland. There is some doubt about the accuracy of determinations of the species in the field. Because of this taxonomic uncertainty, it is possible that as many as 1500 mature individuals exist scattered among as many as 12 populations in New South Wales. Both the number of mature plants and the number of populations have declined over the last few years, mainly because of horticultural collecting pressure and habitat destruction, but the magnitude of the decline is uncertain. *Zieria 'baeuerlenii*, a perennial shrub, occurs within an urban landscape and the total population size and distribution are relatively well known. The annual decline in population size is attributable to the pressures of living in an urban environment, including mortality from trampling and habitat loss. *Gentiana wingecarribiensis* is an annual herb growing in swamps adjacent to developed pastures. There are two known populations; one of these has been surveyed for four years, and the other for two years. The estimate of population size in 1996 and rate of decline over the last four years (Table 1) are based on direct sampling and include both measurement error and year-to-year variation. The estimates of the confidence intervals for all other parameters were based on expert judgement.

The data for all three species indicate areas of occupancy which one may be more than 90% certain are less than 10 km^2 and substantial continuing declines in the number of individuals have been observed or inferred. While their areas of occupancy are very small, there have been no changes in extent or area of occurrence or the number of populations, and there are very likely to be more than 50 individuals.

Interpretation of the 90% percentiles for population size suggest that *P. australis* could have the smallest population, followed by *G. wingecarribiensis* then *Z. 'baeuerlenii'*. This interpretation is contrary to the conclusion one would reach if one were to rank the point estimates for population size; the order of *G. wingecarribiensis* and *Z. 'baeuerlenii'* would be reversed. Overall, given current knowledge summarised in Table 1, *P.australis* might be considered the highest priority for conservation action because it could have the smallest population size, fastest decline in range and number of populations and second fastest decline in population size. *Zieria 'baeuerlenii'* would be of least concern because its population is less likely to be smaller and its rate of decline is less likely to be faster than the other two species. The data on extent of occurrence, area of occupancy and number of populations suggest that *Z. 'baeuerlenii'* is of greatest concern and *P. australis* is of least concern, but given the spatially ubiquitous nature of the threats to *P. australis* (clearing and collecting), these could be considered less important indicators of extinction risk than population size and trend.

An examination of the sources of uncertainty in population sizes and trends reveals the information needed most urgently to set priorities more reliably. If the taxonomic determination of the largest population of *Phaius* could be confirmed as *P. australis*, we could be 90% certain its total population was greater than 800 mature individuals. Continuing the annual census of *G. wingecarribiensis* for another 2-3 years may provide sufficient statistical power to distinguish annual fluctuations from a continuing decline with 90% confidence. With these additional data and reduced uncertainty, *Z. 'baeuerlenii'* may prove to be the species most in need of conservation management, though clearly all three species qualify as Endangered (IUCN 1994) and therefore warrant urgent conservation action.

DISCUSSION

Usually, the autecological data and demographic studies necessary to make a direct estimate of the threat of extinction faced by a species are unavailable. The procedures above are compromises in which population size, geographic range, number of populations, kinds of threats and so on act as surrogates for estimates of the risk of extinction. However, even these data usually are not available. In the absence of data, it is not possible to do anything except use expert value judgements and biological intuition. There are no guarantees that experts will provide reliable or consistent judgements (Lunney *et al.* 1996). Even where there is consistency, it is weak evidence of reliability. Moreover, sources of bias are difficult to identify where status is intuitively determined.

All of the current methods for setting conservation priorities have one feature in common. They do not expicitly account for uncertainty and reliability in the data. IUCN (1994) suggested applying the precautionery principle when faced with uncertainty. A probabilistic approach to setting priorities is one way of implementing the principle. It has the advantages that it uses more information than approaches that ignore uncertainty, it is sufficiently flexible to facilitate the use of both quantitative and qualitative field information, as well as expert judgement, and it provides the means to infer levels of threat and to establish ranks for conservation action that account for the amount and quality of data.

The specification of reliabilities for parameters can sometimes be seen as problematic. A person may make a judgement about the magnitude of a population's decline based on a set of extensive population censuses. In such circumstances, the statistical distribution of the population's size may be fully specified, including measurement error and natural year to year variation, and the specification of reliability demands no more than computing a confidence interval. In many other cases, a person will make judgements based on less complete information. For example, judgements concerning reduction in population size may be based on the frequency of opportunistic, random sightings of a species during field trips, on anecdotal information from local people, or on extrapolation from changes observed in other species with similar life-history attributes.

Even in the absence of formal statistical information, it is possible in many circumstances to quantify the reliability of estimates in the form of a range (the magnitude of the decline is unlikely to be less than x or greater than y). It is always possible to furnish some kind of reliability estimate for a parameter. Even if there are no measurements, expert judgement may be used to provide an estimate. One can always do better than to assume the parameter is known exactly which is implied when reliability is ignored, as it is in many applicatons of rule sets and point scoring procedures.

In its simplest form, the probabilistic interpretation of decision thresholds suggests that if there are no data for a species (beyond a single taxonomic collection), then it should be given the highest level of protection. From the perspective of conservation, this seems more reasonable than the converse, which is to assume that a species is safe until such time that we are quite certain that it is critically endangered.

Of course, such a recommendation raises the spectre of a flood of unwarranted classifications, resulting in unnecessary and counter-productive constraints on the use of natural resources. Most regulatory agencies allocate scarce resources at least in part on the basis of the relative threat faced by different species. All of the poorly known species would be equally threatened, and there would be no way to rank them in terms of priorities for conservation.

There is no need to assume such dire consequences. For example, one may use current protocols to decide which species are threatened, or to decide which are critically endangered, endangered or vulnerable. One may then use bounds of confidence intervals to rank species within these classes. Probabilistic rules simply make better use of information, and they need not precipitate drastic changes in the current lists of threatened species.

The allocation of resources to conservation is not governed exclusively by estimates of threat. Ranking species based on bounds derived from confidence intervals is just one of many potential strategies for decision making and there are numerous alternatives that account for the kinds of uncertainty and the importance of avoiding risk (e.g., Raiffa, 1968; Morgan and Henrion, 1990). Giving appropriate weight to various management options means evaluating the risks associated with each (Russell and Gruber, 1987). In so far as population size and trend act as surrogates for the risks of extinction of species, setting priorities based on the bounds of these parameters will provide a better strategy for avoiding extinction than will the interpretation of point estimates of these parameters. It will have the effect of giving greater weight to those species which are less well studied, but the weight will depend on the way in which interpretation of bounds is implemented.

The IUCN (1994) suggested that in most circumstances, their decision rules should not, on their own, provide a basis for the allocation of resources. Any system for assessing priorities for action should include many factors including costs, logistics, chances of success, and taxonomic distinctiveness, among others not included in Table 1. The intention in suggesting revised procedures for interpreting the IUCN (1994) rules is to make better use of available information. Even if probabilistic thresholds are employed, they would be only one part of the process for setting priorities for conservation. The efficient allocation of scarce conservation resources depends on the development of objective, transparent and repeatable methods, the resolution and detail of which are commensurate with well defined aims and consistent with the reliability of our knowledge.

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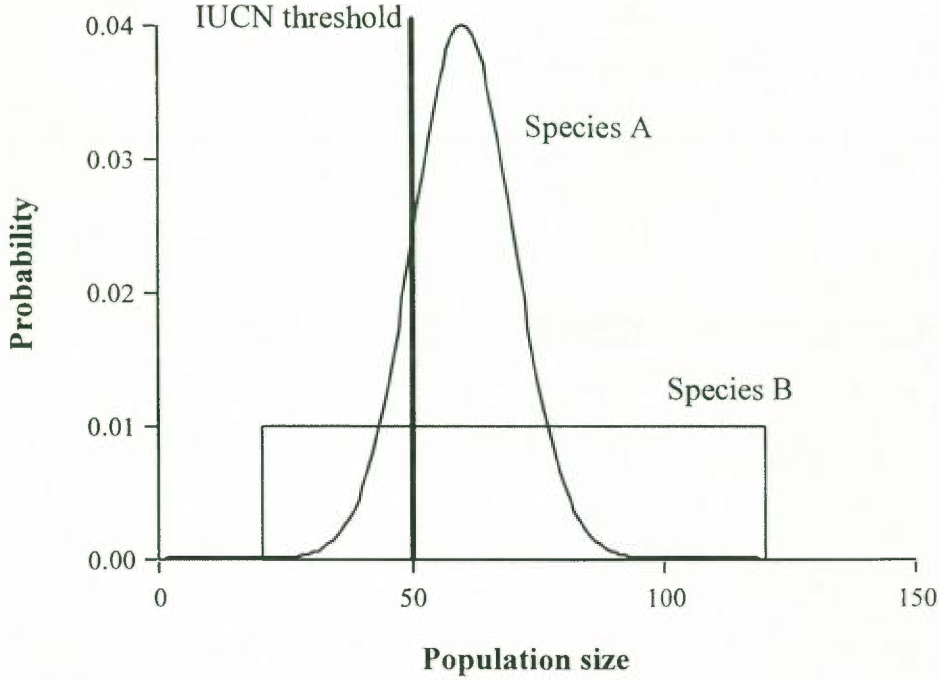

Fig. 1. Diagrammatic representation of the best estimates for the total number of mature individuals of two hypothetical species (A=60 and B=70), together with the probability distributions that describe the reliability of each estimate. The IUCN (1994) threshold of population size below which species may be considered critically threatened, equals 50 mature individuals (Rule D). The distribution for species B is uniform and ranges between 20 and 120. The distribution for species A is normal with a standard deviation of 10.

Table 1. Population data from three threatened Australian plant species in 1995. All confidence intervals except for the population size of *Gentiana wingecarribiensis* are based on subjective judgement. Data were compiled from surveys undertaken during recovery projects for NSW National Parks and Wildlife Service.

Attribute	*Phaius australis*	*Zieria 'bauerlenii'*	*Gentiana wingecarribiensis*
Number of mature plants	90	120	145
90% confidence interval	60-1500	100-150	84-234
Extent of occurrence (km^2)	1200	1	12
90% confidence interval	760-3875	1-2	7-24
Area of occupancy (km^2)	3	1	2
90% confidence interval	3-10	1-3	1-3
Number of populations	9	1	2
90% confidence interval	6-12	1-1	2-3
Decline in population size	4	2	11.5
(% per year)	2-10	1-4	0-46
Decline in extent (% per	2	0	0
year)	0-5	0-6	0-1
Decline in number of	2	0	0
populations (% per year)	0-5	0-6	0-1

Appendix 3: References Consulted for the Priority Short List of Potentially Threatened Plant Species

Adam, P	1987	NSW Rainforests The nomination for the World Heritage List	Publ. NSW NPWS
ANZECC	1993	Threatened Australian Flora	Australian Nature Conservation Agency
Benson, D H & McDougall, L	1993	Ecology of sydney Plant Species. Pt 1. Ferns, fern allies, cycads, conifers and dicotyledon families, Acanthaceae to Asclepiadaceae	Cunn. 3 (2)
Benson, D H & McDougall, L	1995	Ecology of sydney Plant Species. Pt 3. Dicotyledon families Cabombaceae to Eupomatiaceae	Cunn. 4 (2)
Benson, D H & McDougall, L	1994	Ecology of sydney Plant Species. Pt 2. Dicotyledon families Asteraceae to Buddlejaceae	Cunn. 3 (4)
Bowen, P F & Pressey, R L	1993	Localities and habitats of plants with restricted distributions in the western division of NSW	NSW NPWS Occasional Paper 17
Briggs, J D & Leigh, J H	1988	Rare or threatened Australian Plants	Australian NPWS Special Publ. 14
Briggs, J D & Leigh, J H	in prep	Rare or threatened Australian Plants List	
Briggs, J D & Leigh, J H	1996	Rare or threatened Australian Plants	CSIRO Australia
Crisp, M D	1985	Conservation of the genus Daviesia	Aust. Nat. Bot. Gardens Occasional Paper 6
various	1981 - 1996	Flora of Australia	ANCA
	1992	Nomination of Central Eastern Rainforests of Australia for inclusion on the World Heritage List	
Hnatiuk, R J	1990	Census of Australian Vascular Plants	Aust. Flora & Fauna Series No 1 i Bureau of Flora & Fauna Canb. An AGPS Press Publ. Aust. Govert Publ. Service Canb
Hunter, J	1996	Flora nominated as of special concern in Severn River Nature Reserve	
Keith, D & Ashby, E	1992	Vascular Plants of Conservation Significance in the South East Forests of NSW	Occasional Paper 11 NSW NPWS
Leigh, J H & Briggs, J D	1992	Threatened Australian Plants	

Mills, K	1988	Illawarra Vegetation Studies	Occasional Paper 1 Kevin Mills and Associates PO Box 54 Woonona NSW 2517
Mills, K	1989	Rainforest plant species of southern NSW and their southern limits of distribution	Occasional Paper 2 Occ. Pap. on the vegetation of the Illawarra Region
Sherringham, P	1994	Rare, Threatened and Significant Vascular Plant Taxa in Upper North Eastern NSW Interim Report, Progress to date 15 Dec 1994	NSW NPWS Interim Report Dec 1994
	1995	Vegetation Survey & Mapping of Upper North-Eastern New South Wales	NSW NPWS NRAC Report March 1995
Quinn, FC; Williams, JB; Gross, CL & Bruhl, JJ	1995	Report on Rare and Threatened Plants of North-eastern New South Wales	Report prepared for New South Wales National Parks & Wildlife Service and Australian Nature Conservation Agency
Sheringham, PR & Westerway	1993	Significant Vascular Plants of Upper North-Eastern New South Wales	Report to NSW NPWS
National Herbarium of NSW	1995	World Heritage Blue Mts Species List Blue Mts	

Appendix 4. Threatened Species Schedules (flora only) from NSW Threatened Species Conservation Act 1995.

THREATENED SPECIES CONSERVATION ACT SCHEDULES 1, 2 AND 3

Flora only, as at 31st December 1995
* On Commonwealth ESP Schedule

Schedule 1: Endangered species, populations and ecological communities

Part 1 Endangered species

Plants

Acanthaceae
Calophanoides hygrophiloides (F. Muell.) R. Barker
Dipteracanthus australasicus subsp. *corynothecus* (F. Muell. ex Benth.) R. Barker
**Isoglossa eranthemoides* (F. Muell.) R. Barker
Xerothamnella parvifolia C. White
Anthericaceae
Caesia parviflora var. minor R.J.F. Hind.
Apiaceae
Gingidia montana (Forster & Forster f.) J. Wyndham Dawson
Trachymene saniculifolia Stapf
Apocynaceae
Ochrosia moorei (F. Muell.) F. Muell. ex Benth.
Araliaceae
**Astrotricha roddii* Makinson
Araucariaceae
Wollemia nobilis W. Jones, K. Hill & J. Allen
Asclepiadaceae
**Cynanchum elegans* (Benth.) Domin
**Marsdenia longiloba* Benth.
**Tylophora linearis* P. Forster
**Tylophora woollsii* Benth.
Asteraceae
Calotis moorei P. Short
Cratystylis conocephala (F. Muell.) S. Moore
Erodiophyllum elderi F. Muell.
Kippistia suaedifolia F. Muell.
Leptorhynchos waitzia Sonder
**Olearia flocktoniae* Maiden & E. Betche
**Rutidosis leptorrhynchoides* F. Muell.
Senecio spathulatus A. Rich.
Senecio squarrosus A. Rich.
Brassicaceae
Irenepharsus magicus Hewson
Irenepharsus trypherus Hewson
**Lepidium hyssopifolium* Desv.
**Lepidium monoplocoides* F. Muell.
Lepidium pseudopapillosum Thell.

Campanulaceae
Wahlenbergia scopulicola Carolin ex P.J. Smith
Capparaceae
Capparis loranthifolia var. *loranthifolia* Lindley
Caryophyllaceae
Polycarpaea spirostylis subsp. *glabra* (C. White & Francis) Pedley
Casuarinaceae
**Allocasuarina defungens* L. Johnson
Allocasuarina glareicola L. Johnson
**Allocasuarina portuensis* L. Johnson
Casuarina obesa Miq.
Celastraceae
**Apatophyllum constablei* McGillivray
Chenopodiaceae
Atriplex rhagodioides F. Muell.
Atriplex sturtii S. Jacobs
Dysphania platycarpa Paul G. Wilson
Dysphania plantaginella F. Muell.
Osteocarpum scleropterum (F. Muell.) Volkens
Threlkeldia inchoata (J. Black) J. Black
Convolvulaceae
Ipomoea diamentinensis J. Black
Ipomoea polymorpha Roemer & Schultes
Cupressaceae
Callitris baileyi C. White
Cyperaceae
Carex raleighii Nelmes
Cyperus aquatilis R. Br.
Cyperus conicus (R. Br.) Boeck
Davalliaceae
Arthropteris palisotii (Desv.) Alston
Davidsoniaceae
Davidsonia pruriens var. jerseyana Bailey
**Davidsonia* sp. A Mullumbimby-Currimbin Ck (A.G. Floyd 1595)
Dilleniaceae
Hibbertia hexandra C. White
Hibbertia procumbens (Labill.) DC.
Droseraceae
Aldrovanda vesiculosa L.
Dryopteridaceae
Lastreopsis hispida (Sw.) Tind.
Ebenaceae
**Diospyros mabacea* (F. Muell.) F. Muell.
Diospyros major var. *ebenus* (Sprengel) Bakh.
Elaeocarpaceae
Elaeocarpus sp. Rocky Creek (G. Read AQ 562114)
**Elaeocarpus williamsianus* Guymer
Epacridaceae
Epacris hamiltonii Maiden & E. Betche
Leucopogon confertus Benth.
Melichrus hirsutus J.B. Williams ms
Monotoca rotundifolia J.H. Willis
Eriocaulaceae
**Eriocaulon carsonii* F. Muell.
Euphorbiaceae
Acalypha eremorum Muell. Arg.
Bertya ingramii T. James
Euphorbia sarcostemmoides J.H. Willis

**Fontainea oraria* Jessup & Guymer
Monotaxis macrophylla Benth.
Phyllanthus maderaspatanus L.
Pseudanthus ovalifolius F. Muell.
Sauropus albiflorus subsp. *microcladus* (Muell. Arg.) Airy Shaw

Fabaceae
Acacia acanthoclada F. Muell.
Acacia acrionastes Pedley
Acacia jucunda Maiden & Blakely
Acacia macnuttiana Maiden & Blakely
Acacia notabilis F. Muell.
Acacia petraea Pedley
Acacia pubifolia Pedley
Acacia rivalis J. Black
Acacia ruppii Maiden & E. Betche
Almaleea cambagei (Maiden & E. Betche) Crisp & P. Weston
Crotalaria cunninghamii R. Br.
Desmodium campylocaulon F. Muell.
Indigofera efoliata F. Muell.
Indigofera helmsii Peter G. Wilson
Indigofera leucotricha E. Pritzel
Indigofera longibractea J. Black
**Psoralea parva* F. Muell.
Pultenaea parrisiae subsp. *elusa* J.D. Briggs & Crisp
Pultenaea parviflora Sieber ex DC.
Senna acclinis (F. Muell.) Randell
Swainsona adenophylla J. Black
Swainsona colutoides F. Muell.
Swainsona flavicarinata J. Black
**Swainsona recta* A. Lee
Swainsona viridis J. Black

Gentianaceae
**Gentiana baeuerlenii* L. Adams
**Gentiana wingecarribiensis* L. Adams

Goodeniaceae
Goodenia occidentalis Carolin
Scaevola collaris F. Muell.
Velleia perfoliata R. Br.

Grammitaceae
Grammitis stenophylla B.S. Parris

Haloragaceae
Haloragodendron lucasii (Maiden & E. Betche) Orch.

Lamiaceae
Plectranthus alloplectus S.T. Blake
Plectranthus nitidus P. Forst.
Prostanthera sp. Somersby (B.J. Conn 4024)
Westringia kydrenis Conn

Lauraceae
**Endiandra floydii* B. Hyland
Endiandra muelleri subsp. *bracteata* B. Hyland

Lindsaeaceae
Lindsaea brachypoda (Baker) Salomon
Lindsaea fraseri Hook.
Lindsaea incisa Prent.

Loranthaceae
Amyema scandens (Tieghem) Danser
Muellerina myrtifolia (Cunn. ex Benth.) Barlow

Malvaceae
Sida rohlenae Domin
Marattiaceae
Angiopteris evecta Hoffm.
Marsileaceae
Pilularia novae-hollandiae A. Braun
Menispermaceae
Tinospora smilacina Benth.
Monimiaceae
Daphnandra sp. C Illawarra (R. Schodde 3475)
Myrtaceae
**Austromyrtus fragrantissima* (F. Muell. ex Benth.) Burret
Baeckea camphorata R. Br.
Choricarpia subargentea (C. White) L. Johnson
Eucalyptus approximans Maiden
Eucalyptus camphora subsp. *relicta* L. Johnson & K. Hill
Eucalyptus copulans L. Johnson & K. Hill
Eucalyptus imlayensis Crisp & Brooker
Eucalyptus microcodon L. Johnson & K. Hill
Eucalyptus pachycalyx Maiden & Blakely
**Eucalyptus recurva* Crisp
Eucalyptus saxatilis Kirkpatr. & Brooker
Eucalyptus sp. Howes Swamp Creek (M. Doherty 19/7/85, NSW 207054)
**Kunzea rupestris* Blakely
**Uromyrtus australis* A.J. Scott
Orchidaceae
**Caladenia rosella* G.W. Carr
Diuris pedunculata R. Br.
**Genoplesium rhyoliticum* D.L. Jones & M.A. Clem.
Phaius tankervilliae (Banks ex L'Her.) Blume
Prasophyllum affine Lindl.
**Prasophyllum petilum* D.L. Jones & R.J. Bates
**Prasophyllum uroglossum* Rupp
**Pterostylis gibbosa* R. Br.
Pterostylis sp. Botany Bay (A. Bishop J221/1-13)
Platyzomataceae
Platyzoma microphyllum R. Br.
Poaceae
Deyeuxia appressa Vickery
**Digitaria porrecta* S.T. Blake
Stipa nullanulla J. Everett & S.W.L. Jacobs
Stipa wakoolica Vickery, S.W.L. Jacobs & J. Everett
Podocarpaceae
Microstrobos fitzgeraldii (F. Muell.) J. Garden & L. Johnson
Polygalaceae
Polygala linariifolia Willd.
Primulaceae
Lysimachia vulgaris var. *davurica* (Ledeb.) Knuth
Proteaceae
Grevillea acanthifolia subsp. *paludosa* Makinson & Albrecht
**Grevillea beadleana* McGillivray
**Grevillea caleyi* R. Br.
Grevillea guthrieana P. Olde & N. Marriott
**Grevillea iaspicula* McGillivray
Grevillea masonii P. Olde & N. Marriott
Grevillea mollis P. Olde & Molyneux
Grevillea molyneuxii McGillivray

Grevillea obtusiflora R. Br.
Grevillea rivularis L. Johnson & McGillivray
**Grevillea wilkinsonii* R. Makinson
**Hakea pulvinifera* L. Johnson
Hakea sp. B Kowmung River (M. Doherty 17-24)
Persoonia mollis subsp. *maxima* Krauss & L. Johnson
**Persoonia nutans* R. Br.

Psilotaceae
Psilotum complanatum Sw.

Rhamnaceae
Discaria nitida Tortosa
**Pomaderris cotoneaster* Wakef.
Pomaderris elachophylla F. Muell.
Pomaderris queenslandica C. White
Pomaderris sericea Wakef.

Rubiaceae
Dentella minutissima C. White & Francis
Hedyotis galioides F. Muell.
**Randia moorei* F. Muell. ex Benth.
Tarenna cameronii (C.T. White) Ali & Robbr.

Rutaceae
**Acronychia littoralis* T. Hartley & J. Williams
**Asterolasia elegans* McDougall & Porteners
**Boronia granitica* Maiden & E. Betche
**Boronia repanda* (F. Muell. ex E. Betche) Maiden & E. Betche
Geijera paniculata (F. Muell.) Druce
Phebalium glandulosum subsp. *eglandulosum* (Blakely) Paul G. Wilson
**Phebalium lachnaeoides* Cunn.
Zieria adenodonta (F. Muell.) J.A. Armstrong ms
Zieria adenophora Blakely
**Zieria baeuerlenii* J.A. Armstrong ms
**Zieria buxijugum* J. Briggs & J.A. Armstrong ms
Zieria covenyi J.A. Armstrong ms
Zieria floydii J.A. Armstrong ms
**Zieria formosa* J. Briggs & J.A. Armstrong ms
Zieria granulata (F. Muell.) C. Moore ex Benth.
Zieria ingramii J.A. Armstrong ms
Zieria lasiocaulis J.A. Armstrong ms
**Zieria obcordata* Cunn.
**Zieria parrisiae* J. Briggs & J.A. Armstrong ms
**Zieria prostrata* J.A. Armstrong ms

Santalaceae
Santalum murrayanum (Mitchell) Gardner

Sapindaceae
**Diploglottis campbellii* Cheel
Dodonaea microzyga var. *microzyga* F. Muell.
Dodonaea sinuolata subsp. *acrodentata* J. West

Scrophulariaceae
**Euphrasia collina* subsp. *muelleri* (Wettst.) W.R. Barker

Simaroubaceae
**Quassia* sp. *Mooney Creek* (J. King s.n., 1949)

Sinopteridaceae
Cheilanthes sieberi subsp. *pseudovellea* H. Quirk & T.C. Chambers

Stackhousiaceae
Stackhousia clementii Domin

Sterculiaceae
Rulingia prostrata Maiden & Betche

Thymelaeaceae
Pimelea elongata Threlfall
Pimelea serpyllifolia subsp. *serpyllifolia* R. Br.
**Pimelea spicata* R. Br.
Pimelea venosa Threlfall
Tiliaceae
**Corchorus cunninghamii* F. Muell.
Urticaceae
Dendrocnide moroides (Wedd.) Chew
Violaceae
Viola cleistogamoides (L. Adams) Seppelt
Zamiaceae
Macrozamia moorei F. Muell.

Part 4 Species presumed extinct

Plants

Acanthaceae
Rhaphidospora bonneyana (F. Muell.) R. Barker
Aizoaceae
Glinus orygioides F. Muell.
**Trianthema cypseloides* (Fenzl) Benth.
Amaranthaceae
Ptilotus extenuatus Benl
Asteraceae
Acanthocladium dockeri F. Muell.
Blumea lacera (Burman f.) DC.
**Olearia oliganthema* F. Muell. ex Benth.
Senecio behrianus Sonder & F. Muell.
**Senecio georgianus* DC.
Stemmacantha australis (Gaudich.) Dittr.
Brassicaceae
Lepidium foliosum Desv.
**Lepidium peregrinum* Thell.
Stenopetalum velutinum F. Muell.
Chenopodiaceae
Atriplex acutiloba R. Anderson
Maireana lanosa (Lindley) Paul G. Wilson
Osteocarpum pentapterum (F. Muell. & Tate) Volkens
Cyperaceae
Eleocharis tetraquetra Nees
Dennstaedtiaceae
Hypolepis elegans Carruth.
Euphorbiaceae
Amperea xiphoclada var. *pedicellata* R.F.J. Hend.
Gyrostemonaceae
Codonocarpus pyramidalis (F. Muell.) F. Muell.
Haloragaceae
Haloragis stricta R. Br. ex Benth.
Myriophyllum implicatum Orch.
Lamiaceae
Prostanthera marifolia R. Br.
Lobeliaceae
**Hypsela sessiliflora* F. Wimmer
Myrsinaceae
**Rapanea* sp. A Richmond River (J.H. Maiden & J.L. Boorman NSW 26751)
Orchidaceae
Diuris bracteata Fitzg.
Thelymitra epipactoides F. Muell.
Polygalaceae
Comesperma scoparium Drummond
Polypodiaceae
Drynaria rigidula (Sw.) Beddome
Proteaceae
Grevillea nematophylla F. Muell.
Persoonia laxa L. Johnson & P. Weston
Rhamnaceae
Pomaderris oraria F. Muell. ex Reisseck
Rosaceae

Aphanes pentamera Rothm.
Rubiaceae
Galium australe DC.
Knoxia sumatrensis (Retz.) DC.
Rutaceae
Eriostemon angustifolius subsp. *angustifolius* Paul G. Wilson
Micromelum minutum (Forster f.) Wight & Arn.
Sapindaceae
Dodonaea stenophylla F. Muell.
Scrophulariaceae
**Euphrasia arguta* R. Br.
**Euphrasia* sp. Tamworth (Rupp s.n., -/09/1904)
Tremandraceae
Tetratheca pilosa subsp. *pilosa* Labill.

Schedule 2: Vulnerable species

Plants

Apocynaceae
Parsonsia dorrigoensis J.B. Williams ms
Araliaceae
Astrotricha crassifolia Blakely
Asteliaceae
Neoastelia spectabilis J.B. Williams
Asteraceae
Ammobium craspedioides Benth.
Brachycome muelleroides G. Davis
Brachycome papillosa G. Davis
Calotis glandulosa F. Muell.
Euchiton nitidulus (Hook. f.) A. Anderb.
Olearia cordata Lander
Ozothamnus tesselatus (Maiden & R. Baker) Anderberg
Picris evae Lack
Rutidosis heterogama Philipson
Rutidosis leiolepis F. Muell.
Senecio garlandii F. Muell. ex Belcher
Brassicaceae
Lepidium aschersonii Thell.
Callitrichaceae
Callitriche cyclocarpa Hegelm.
Casuarinaceae
Allocasuarina simulans L. Johnson
Chenopodiaceae
Atriplex infrequens Paul G. Wilson
Maireana cheelii (R. Anderson) Paul G. Wilson
Sclerolaena napiformis Paul G. Wilson
Corokiaceae
Corokia whiteana L.S. Smith
Corynocarpaceae
Corynocarpus rupestris subsp. *rupestris* Guymer
Cunoniaceae
Acrophyllum australe (Cunn.) Hoogl.
Cupressaceae
Callitris oblonga A. Rich. & Rich.
Cyperaceae

Eleocharis obicis L.A.S. Johnson & O.D. Evans
Dilleniaceae
Hibbertia marginata Conn
Epacridaceae
Budawangia gnidioides (Summerh.) Telford
Epacris sparsa R. Br.
Leucopogon exolasius (F. Muell.) F. Muell. ex Benth.
Styphelia perileuca J. Powell
Ericaceae
Gaultheria viridicarpa subsp. *merinoensis* J.B. Williams ms
Gaultheria viridicarpa subsp. *viridicarpa* J.B. Williams ms
Eriocaulaceae
Eriocaulon australasicum (F. Muell.) Korn.
Euphorbiaceae
Baloghia marmorata C. White
Bertya sp. A Cobar-Coolabah (Cunningham & Milthorpe s.n., 2/8/73)
Fontainea australis Jessup & Guymer
Fabaceae
Acacia baueri subsp. *aspera* (Maiden & E. Betche) Pedley
Acacia bynoeana Benth.
Acacia carnei Maiden
Acacia clunies-rossiae Maiden
Acacia constablei Tind.
Acacia courtii Tind. & Herscovitch
Acacia curranii Maiden
Acacia flocktoniae Maiden
Acacia georgensis Tind.
Acacia phasmoides J.H. Willis
Acacia pubescens (Vent.) R. Br.
Acacia pycnostachya F. Muell.
Bossiaea oligosperma A. Lee
Desmodium acanthocladum F. Muell.
Dillwynia tenuifolia Sieber ex DC.
Kennedia retrorsa Hemsley
Phyllota humifusa Benth.
Pultenaea aristata Sieber ex DC.
Pultenaea baeuerlenii F. Muell.
Pultenaea campbellii Maiden & E. Betche
Pultenaea glabra Benth.
Pultenaea parrisiae subsp. *parrisiae* J.D. Briggs & Crisp
Pultenaea stuartiana Williamson
Sophora fraseri Benth.
Swainsona murrayana Wawra
Swainsona plagiotropis F. Muell.
Swainsona pyrophila J. Thompson
Gentianaceae
Gentiana bredboensis L. Adams
Gentiana wissmannii J. Williams
Goodeniaceae
Goodenia macbarronii Carolin
Haloragaceae
Haloragis exalata subsp. *exalata* F. Muell.
Haloragis exalata subsp. *velutina* Orch.
Lamiaceae
Prostanthera cineolifera R. Baker & H.G. Smith
Prostanthera cryptandroides Cunn. ex Benth.
Prostanthera densa A.A. Ham.

Prostanthera discolor R. Baker
Prostanthera staurophylla F. Muell.
Prostanthera stricta R. Baker
Prostanthera sp. Strickland State Forest (J.H. Maiden s.n., 07/1915)
Prostanthera sp. Bundjalung National Park (B.J. Conn 3471)
Westringia davidii Conn

Lauraceae
Cryptocarya foetida R. Baker
Endiandra hayesii Kosterm.

Meliaceae
Owenia cepiodora F. Muell.

Menispermaceae
Tinospora tinosporoides (F. Muell.) Forman

Myrtaceae
Angophora robur L. Johnson & K. Hill
Baeckea sp. Pyramids (W.J. McDonald 357)
Darwinia biflora (Cheel) B. Briggs
Eucalyptus alligatrix subsp. *miscella* Brooker, Slee & J.D. Briggs ms
Eucalyptus aquatica (Blakely) L. Johnson & K. Hill
Eucalyptus benthamii Maiden & Cambage
Eucalyptus caleyi subsp. *ovendenii* L. Johnson & K. Hill
Eucalyptus camfieldii Maiden
Eucalyptus cannonii R. Baker
Eucalyptus glaucina Blakely
Eucalyptus kartzoffiana L. Johnson & Blaxell
Eucalyptus langleyi L. Johnson & Blaxell
Eucalyptus mckieana Blakely
Eucalyptus nicholii Maiden & Blakely
Eucalyptus parramattensis subsp. *decadens* L. Johnson & Blaxell
Eucalyptus parvula L. Johnson & K. Hill
Eucalyptus pulverulenta Sims
Eucalyptus pumila Cambage
Eucalyptus robertsonii subsp. *hemisphaerica* L. Johnson & K. Hill
Eucalyptus rubida subsp. *barbigerorum* L. Johnson & K. Hill
Eucalyptus rubida subsp. *canobolensis* L. Johnson & K. Hill
Eucalyptus sturgissiana L. Johnson & Blaxell
Eucalyptus tetrapleura L. Johnson
Homoranthus darwinioides (Maiden & E. Betche) Cheel
Homoranthus lunatus Craven & S.R. Jones
Homoranthus prolixus Craven & S.R. Jones
Kunzea cambagei Maiden & E. Betche
Leptospermum deanei J. Thompson
Leptospermum thompsonii J. Thompson
Melaleuca groveana Cheel & C. White
Micromyrtus blakelyi J. Green
Micromyrtus minutiflora (F. Muell.) Benth.
Syzygium hodgkinsoniae (F. Muell.) L. Johnson
Syzygium moorei (F. Muell.) L. Johnson
Syzygium paniculatum Gaertner

Olacaceae
Olax angulata A.S. George

Orchidaceae
Bulbophyllum globuliforme Nicholls
Caladenia concolor Fitzg.
Caladenia tesselata Fitzg.
Cryptostylis hunteriana Nicholls

Diuris aequalis F. Muell. ex Fitzg.
Diuris praecox D.L. Jones
Diuris shaeffiana Fitzg.
Diuris venosa Rupp
Phaius australis F. Muell.
Prasophyllum fuscum R. Br.
Prasophyllum morganii Nicholls
Pterostylis cobarensis M.A. Clem.
Pterostylis cucullata R. Br.
Pterostylis nigricans L. Jones & M.A. Clem.
Pterostylis pulchella Messmer
Sarcochilus fitzgeraldii F. Muell.
Sarcochilus hartmannii F. Muell.
Sarcochilus weinthalii (F.M. Bailey) Dockrill

Poaceae
Amphibromus fluitans Kirk
Arthraxon hispidus (Thunb.) Makino
Bothriochloa biloba S.T. Blake
Dichanthium setosum S.T. Blake
Erythranthera pumila (Kirk) Zotov
Plinthanthesis rodwayi (C.E. Hubb.) S.T. Blake
Stipa metatoris J. Everett & S.W.L. Jacobs

Polygonaceae
Persicaria elatior (R. Br.) Sojak

Proteaceae
Floydia praealta (F. Muell.) L. Johnson & B. Briggs
Grevillea banyabba P. Olde & N. Marriott
Grevillea evansiana McKee
Grevillea kennedyana F. Muell.
Grevillea quadricauda P. Olde & N. Marriott
Grevillea rhizomatosa P. Olde & N. Marriott
Grevillea scortechinii subsp. *sarmentosa* (Blakely & McKie) McGillivray
Grevillea shiressii Blakely
Hakea fraseri R. Br.
Hakea trineura F. Muell.
Hakea sp. Manning River SF-Broken Bago SF (P. Hind 4662)
Hicksbeachia pinnatifolia F. Muell.
Isopogon fletcheri F. Muell.
Macadamia tetraphylla L. Johnson
Persoonia acerosa Sieber ex Schultes & Schultes f.
Persoonia bargoensis P. Weston & L. Johnson
Persoonia glaucescens Sieber ex Sprengel
Persoonia marginata Cunn. ex R. Br.

Ranunculaceae
Clematis fawcettii F. Muell.
Ranunculus anemoneus F. Muell.

Restionaceae
Restio longipes L.A.S Johnson & O.D. Evans

Rhamnaceae
Pomaderris brunnea Wakef.
Pomaderris gilmourii var. *cana* N. Walsh
Pomaderris pallida Wakef.
Pomaderris parrisiae N. Walsh

Rubiaceae
Asperula asthenes Airy Shaw & Turrill

Rutaceae
Boronia deanei Maiden & E. Betche

Boronia umbellata P. Weston
Bosistoa selwynii T. Hartley
Bosistoa transversa J. Bailey & C. White
Correa baeuerlenii F. Muell.
Eriostemon ericifolius Cunn. ex Benth.
Phebalium ralstonii (F. Muell.) Benth.
Phebalium rhytidophyllum Albrecht & N. Walsh
Phebalium sympetalum Paul G. Wilson
Zieria citriodora J.A. Armstrong ms
Zieria involucrata R. Br. ex Benth.
Zieria murphyi Blakely
Zieria tuberculata J.A. Armstrong unpub

Santalaceae
Thesium australe R. Br.

Sapindaceae
Dodonaea procumbens F. Muell.

Sapotaceae
Amorphospermum whitei Aubrev.

Scrophulaceae
Euphrasia bella S. T. Blake
Euphrasia bowdeniae W.R. Barker

Solonaceae
Solanum karsense Symon

Sterculiaceae
Lasiopetalum longistamineum Maiden & Betche
Rulingia procumbens Maiden & Betche

Surianaceae
Cadellia pentastylis F. Muell.

Symplocaceae
Symplocos baeuerlenii R. Baker

Tremandraceae
Tetratheca glandulosa Smith
Tetratheca juncea Smith

Winteraceae
Tasmannia glaucifolia J. Williams
Tasmannia purpurascens (Vick.) A.C. Smith