The biogeographical attributes of the threatened flora of New South Wales

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The geographic distribution, community distribution, taxonomy, and growth form of the flora listed as threatened under Schedules 1 and 2 of the New South Wales *Threatened Species Conservation Act 1995* were examined. The North Coast and Central Coast Botanical Divisions have the highest number of threatened plant species, with both these divisions having significantly more threatened plant species than expected. A large disparity between the east and the west of the state was found, with the eastern divisions generally containing larger numbers and higher proportions of threatened plant species than the western divisions. Rainforest, sclerophyll forest and sclerophyll woodland communities were all found to contain large numbers of threatened plant species, with woodland containing more threatened plant species than expected. Some large families and genera contain significantly more threatened plant species than expected (e.g. Myrtaceae, Proteaceae, *Grevillea* and *Zieria*), while others contain significantly fewer (e.g. Asteraceae, Poaceae and Cyperaceae). The analysis of habit showed that fewer than expected threatened plant species were herbs. Possible explanations for the apparent distribution of threatened flora are discussed.

Introduction

The identification and protection of species facing a high risk of extinction in the near future is one of the central objectives of modern conservation (Keith 1998). In New South Wales, the *Threatened Species Conservation Act 1995* provides for the identification of threatened species, endangered ecological communities and endangered populations, as well as the implementation of mechanisms to restrict further extinction of species and to reverse the processes which have caused threat.

The listing of a species as threatened under the *Threatened Species Conservation Act 1995* serves to trigger a range of mechanisms aimed at protecting that species, including preparation of recovery plans, requirements for species impact statements and preparation of threat abatement plans (Smith 1997). The development of threatened species lists in itself is also useful, as they can function as a resource document for conservation, as important tools for legislative purposes, as sources of information in increasing public awareness of conservation issues and as a focus for research planning (McIntyre 1992). In NSW, species, populations, ecological communities and key threatening processes are listed on purely scientific grounds by the independent NSW Scientific Committee. This represents a significant strength of the *Threatened Species Conservation Act 1995* (Adam et al. 1997).

The criteria for listing on the Schedules of the *Threatened Species Conservation Act 1995* are defined in the legislation (for Endangered species s.10, for species presumed extinct s.13, and for Vulnerable species s.14). The criteria are expressed in broad terms, but are not incompatible with the more detailed criteria established by the International Union for the Conservation of Nature (IUCN 1994), which address attributes affecting the risk of extinction of a species, including rates of decline, distributional range and population size. Particular challenges are faced in identifying threatened vascular plant species due to features of their life history, including variable dispersal range and sessile mature phase (Keith 1998). The inclusion of species with restricted ranges on threatened species lists may be favoured over species with widespread but declining ranges (McIntyre 1992). Despite this, widely distributed plant species which are declining as a result of human activities may be those species which can most effectively be conserved through modification of land-use practices and management (McIntyre 1992).

'Threatened' is often popularly regarded as a synonym of rare. Rarity is an important characteristic of most threatened plant species, which may result in a greater susceptibility to threats. Rabinowitz (1981) identified seven broad forms of natural rarity which a plant species may possess, based on three attributes of a species: geographic range, habitat specificity, and local population size. Species with a small geographic range and narrow habitat specificity (local endemics) are those species most commonly identified as being rare, and often receive a disproportionately high level of conservation attention. In contrast, less attention is given to those species with small geographical ranges and wide habitat specificity, or to species with large geographical ranges and narrow habitat specificity. Finally, some species are common in certain areas but may be seen to display aspects of rarity in other areas. The rarer populations may represent unique genotypes (Cropper 1993), and form an important component of biodiversity worthy of conservation (listing an endangered population is an appropriate mechanism provided for by the *Threatened Species Conservation Act 1995*). Threatened flora fall into the various forms of rarity, however the rarest species may not necessarily be those at the greatest risk of extinction. Rabinowitz's (1981) typology addresses rarity as a spatial phenomenon; rarity can also have a temporal component, as when species are associated with particular seral stages of vegetation development.

The present rarity of a species may be contributed to by evolutionary, biological and anthropogenic factors. A species may be rare if it is an old or 'relic' species which has existed for a relatively long evolutionary time, or if it is a developing or 'new' species which has only recently become distinct. In some cases, rarity can be an advantage to a plant species, making it difficult for herbivores and pathogens to find it (Rabinowitz 1981).

A number of factors contribute to the extinction of plant species on large land masses (Muir 1990), however recent attention has focused largely on the anthropogenic threats to plant species. The following factors are generally considered as important human-based threats to the conservation of plant species in NSW: land clearance for agriculture, grazing, forestry, road works, urbanisation, industrial development, altered fire regimes, spread of exotic species, land degradation, pollution, pathogens, and illegal collection (EPA 1995, Leigh et al. 1984, Boyd 1989, Benson 1991a).

Of these, agriculture presents a major threat to many plant species, due primarily to the large land area involved, and the intensive nature of agricultural activities. Species which are restricted to limited vegetation types are most affected when those vegetation types are cleared for purposes such as cropping or improved pasture (Muir 1990). Introduced herbivores also pose significant threats to plant species, as they may not only cause direct damage to plants, but can also create indirect negative effects such as soil degradation (Muir 1990). For example, the European rabbit (*Oryctolagus cuniculus*) was identified by Auld (1990) as the most significant threat to the threatened plant *Acacia carnei*.

Once a species becomes rare, three major stochastic factors can contribute to increasing the probability of its extinction. These are demographic, genetic, and environmental stochasticity (Gilpin & Soule 1986). A small population faces an increasing risk of extinction from these three types of random factors.

Until recently there was little protection for threatened plant species outside conservation reserves in NSW. The *Threatened Species Conservation Act 1995* provides mechanisms to protect threatened species throughout the state, and the Schedules to the Act provide a catalogue (albeit incomplete) of threatened flora. The schedules of the Commonwealth *Endangered Species Protection Act* (and its successor the *Environment Protection and Biodiversity Conservation Act*) as well as the lists of Rare or Threatened Australian Plants (ROTAP) (Briggs & Leigh 1995) also include NSW species, but the lists are not identical, the differences reflecting both the different contexts of the lists and variation in the processes of compilation.

The compilation of the schedules for the *Threatened Species Conservation Act 1995* permits an analysis of the threatened flora of NSW. Are threatened flora uniformly distributed across the state, or are they concentrated in particular regions or habitats? Are some taxonomic groups more likely to contain threatened taxa than others? The result of such an analysis may have relevance to developing strategies for reserve selection, and for prioritising management of threatened species.

The study presented here examines ecological and biogeographical attributes of the threatened flora of NSW as listed in Schedules 1 and 2 of the *Threatened Species Conservation Act 1995*, and compares these attributes to those of the entire indigenous flora of NSW. The attributes examined are the distribution of the threatened flora in the Botanical Divisions of NSW (Anderson 1947), the distribution of the threatened flora among plant communities in NSW, the taxonomic distribution of the threatened flora at genus and family level, and the distribution of the threatened flora with respect to habit or growth form.

Methods

This study examines the flora listed as threatened under the NSW *Threatened Species Conservation Act 1995*, as of November 1998. Under the *Act*, threatened species fall into two categories: Endangered species (in immediate danger of extinction) which are listed in Schedule 1, and Vulnerable species (at risk of becoming endangered) which

are listed in Schedule 2 of the *Act*. Inclusion on the Schedules is based on distribution, abundance, and threats within NSW; in some cases assessment at a national scale differs from that at the state level. Threatened species may be rare in a NSW context by being at the edge of a wider geographic distribution. For example, 44% of the threatened plant taxa in NSW occur in other Australian states. The definition of species for the purposes of the *Threatened Species Conservation Act 1995* is not a strictly taxonomic one, so that some entities listed are currently undescribed, and others are taxa below species rank.

Information regarding the taxonomy, regional distribution, habit, and occurrence within communities was recorded for each of the threatened plant taxa, as well as for all of the indigenous plant species of NSW. These data were taken from the *Flora of New South Wales* (Harden 1990–1993). Where taxa listed as threatened in the schedules of the *Threatened Species Conservation Act 1995* were not described in the Flora of NSW, additional reference material was used (including Cunningham et al. 1981, Jacobs & Pickard 1981, Carolin & Tindale 1993, and NSW Scientific Committee determinations).

Species listed under the *Threatened Species Conservation Act* 1995 as presumed extinct (not recorded for more than 50 years despite directed searches) were also examined with respect to features such as former distribution and habit. Again, this information was obtained largely from the *Flora of New South Wales* (Harden 1990–1993).

The *Flora of New South Wales* (Harden 1990–1993) records species distributions in the botanical divisions established by Anderson (1947) (Fig. 1). The regions used in the analysis are therefore different from the IBRA (Interim Biogeographic Regionalisation of Australia (Thackway & Cresswell 1995)) regions which are formally recognised as regions for the purposes of the *Threatened Species Conservation Act 1995*. The IBRA regions were not used in this study as data on plant distribution within IBRA regions are incomplete. The Botanical Divisions, while large, are variable in size. Unfortunately, data are not consistently available at a finer scale to permit analysis comparable to that of Merren (1999) for the British flora.

An analysis of the distribution of National Parks and Nature Reserves in the Botanical Divisions of NSW was also conducted. The area and proportion of each region covered by National Parks and Nature Reserves within the Botanical Divisions were determined using information on the area of each National Park and Nature Reserve (NSW NPWS 1999).

Statistical analysis was mainly carried out by chi-squared analyses using contingency tables, comparing the observed attributes of the threatened flora to the values expected from those of the entire indigenous flora of NSW. Linear regressions were conducted using the statistical package MINITAB (1991).

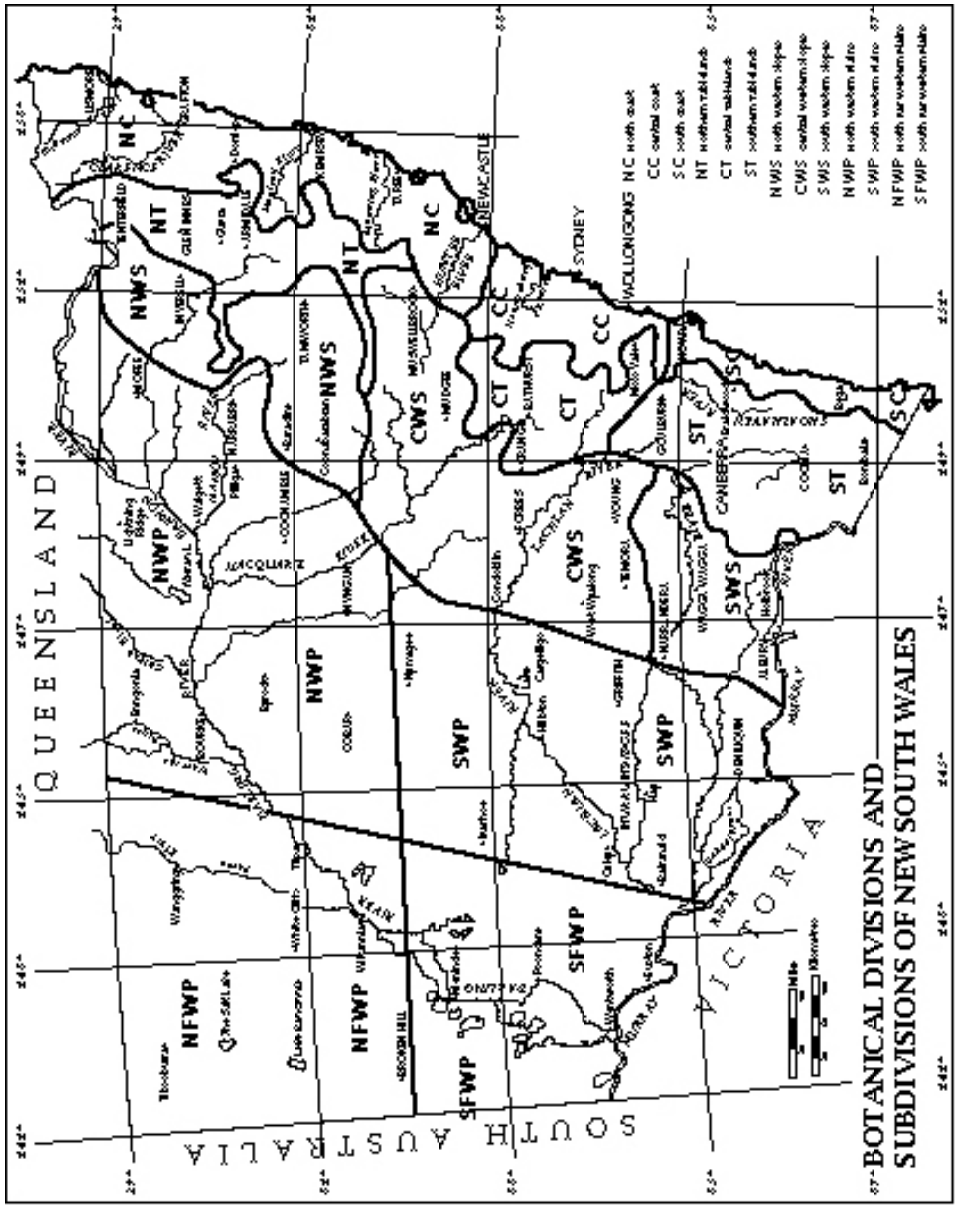

Fig. 1. The Botanical Divisions of New South Wales established by Anderson (1947) and used in the *Flora of New South Wales* (Harden, 1990–1993).

Results

Regional Analysis

Of the 5233 indigenous plant taxa in NSW, 433 (8.3%) were listed as threatened as of November 1998. Of the plant species listed as threatened, 236 were listed as Endangered and 197 as Vulnerable. The North Coast division of NSW contains the highest number of indigenous plant species (2510), as well as the highest number of threatened plant species (140) (Table 1). The Central Coast division also contains a large number of plant species (2098 total with 90 threatened), while the South Western Slopes contain the lowest number of threatened plant species (773 total with 16 threatened). The most striking aspect of this analysis is the greater numbers of both total indigenous and threatened plant species in eastern NSW compared to the west of the state.

Table 1. The number of indigenous plant taxa in each of the Botanical Divisions in NSW, plus the area of each division. Note that a species may occur in several divisions.

Division	All species	Threatened species	Proportion of species threatened (%)	Area of Division (km^2)
SC	1577	33	2.1	11 750
CC	2098	90	4.3	16 575
NC	2510	140	5.6	55 575
ST	1646	56	3.4	40 200
CT	1698	62	3.7	21 800
NT	1560	47	3.0	26 675
SWS	773	16	2.1	28 200
CWS	1428	33	2.3	73 625
NWS	1259	25	2.0	44 381
SWP	1034	23	2.2	112 200
NWP	1326	26	2.1	148 425
SFWP	671	24	3.6	73 475
NFWP	909	31	3.4	119 480

The Central Coast and North Coast divisions were found to have a significantly greater number of threatened species than expected (Fig. 2). Significantly fewer threatened plant species than expected were found in the South Coast, South Western Slopes, Central Western Slopes, North Western Slopes, South Western Plains and North Western Plains.

A markedly different trend is evident in the distribution of plant species presumed extinct (Fig. 2). Equal numbers of species presumed extinct occurred in the South Far Western Plains and the North Far Western Plains as also occurred in the Central Coast

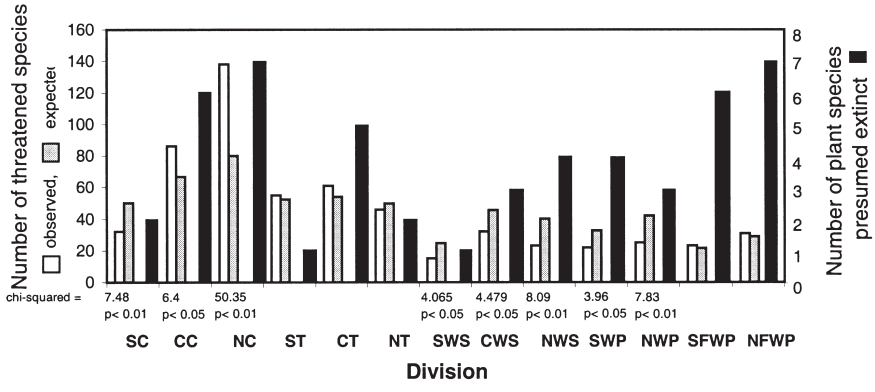

Fig. 2. The occurrence of threatened plant taxa and the former occurrence of plant taxa presumed extinct within NSW. For threatened plant taxa, the expected distribution is also shown with the χ^2 values and the p-values given for those divisions which show a significant difference between the observed and expected occurrence.

and the North Coast. A large number of plant species presumed extinct occurred in the Western divisions, with the least number of plant species presumed extinct having occurred in the Southern Tablelands and South Western Slopes.

Threatened plant species in NSW were found to be restricted in their geographical distribution (Fig. 3a). A significantly greater proportion of threatened species occur in only one division than for all species in NSW. Although there were similar proportions of plant species occurring in two divisions, the proportion of plant species occurring in more than two divisions was significantly smaller for threatened plant species than for all the indigenous plant species in NSW.

In comparing the distribution of the Endangered flora to that of the Vulnerable flora (Fig. 3b), a significantly larger proportion of Endangered plant species was found to occur in only one division, while a significantly smaller proportion of Endangered species occurs in two divisions. There are also some differences in the distribution of Endangered and Vulnerable plant species throughout the Botanical Divisions of NSW. However, it is misleading to compare the numbers of Vulnerable and Endangered plant species occurring in each division separately, as a greater proportion of Vulnerable plant species occur in more than one division (Fig. 3b).

National Parks and Nature Reserves within NSW were distributed unevenly between divisions (Fig. 4). The Central Coast has the largest proportion of its area protected in National Parks and Nature Reserves (over 45%). The western divisions of NSW have smaller proportions of their areas protected in National Parks and Nature Reserves than do those in the east. (Note that these data are subject to change as new protected areas are declared — Fig. 4 does not include new areas of parks and reserves very recently proclaimed in the east of the state as a result of the Regional Forest Agreements).

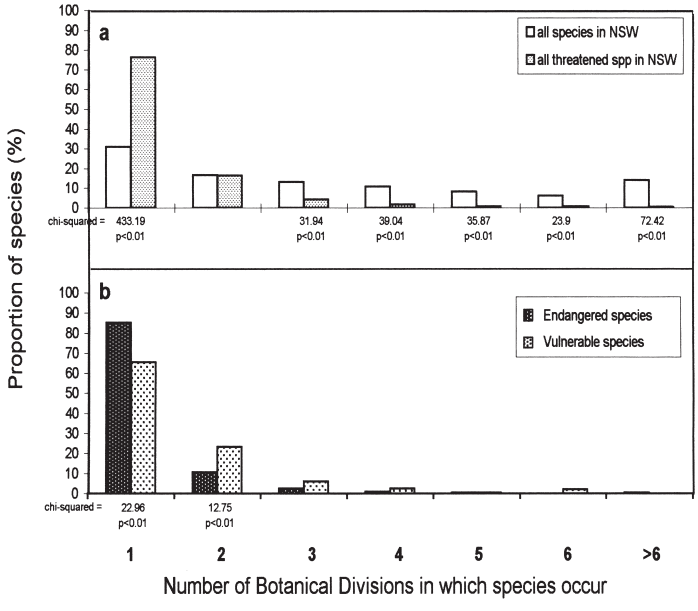

Fig. 3. The proportion of species that occur in a given number of Botanical Divisions for: (**a**) all indigenous plant species in NSW and all threatened plant species in NSW, and (**b**) all Endangered plant species and all Vulnerable plant species in NSW. The χ^2 values and the p-values are given where there is a significant difference between: (**a**) the proportion of all indigenous plant species in NSW and all threatened plant species in NSW, (**b**) the proportion of Endangered plant species and Vulnerable plant species in NSW.

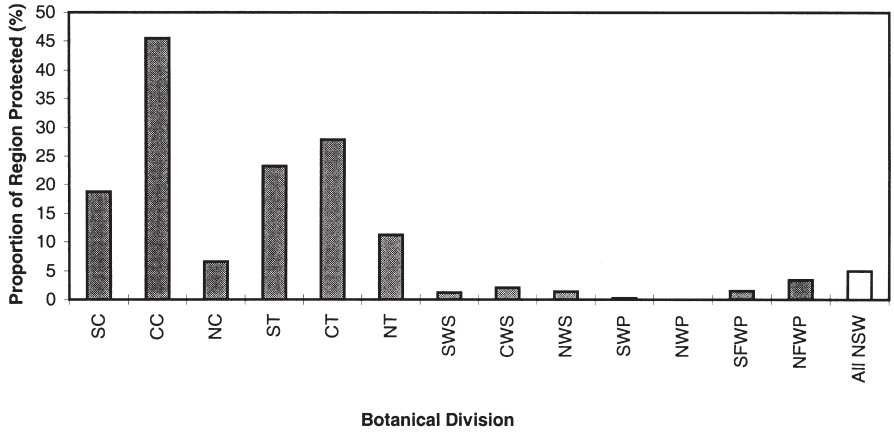

Fig. 4. The proportion of each Botanical Division in NSW protected as National Parks and Nature Reserves (from NPWS 1999). Also shown is the total proportion of NSW which is protected by National Parks and Nature Reserves.

Community Analysis

The analysis of the distribution of plant species in NSW with respect to the community they occur in was limited by a lack of detailed information. The community types listed in the Flora of NSW (Harden 1990–1993) are few in number, and it is uncertain whether there was consistency between authors of different sections. In the case of species in western NSW no community information was provided in many instances. Accepting these limitations, the greatest numbers of threatened plant species are found in sclerophyll woodland, subtropical rainforest, all types of sclerophyll forest, and heath (Fig. 5). When comparing the observed distribution of threatened plant species to that expected, *Nothofagus* rainforest, sclerophyll woodland, dry sclerophyll woodland, wet heath, and arid zone communities all had significantly greater numbers of threatened plant species than expected while temperate rainforest, swamp, and coastal communities had significantly fewer.

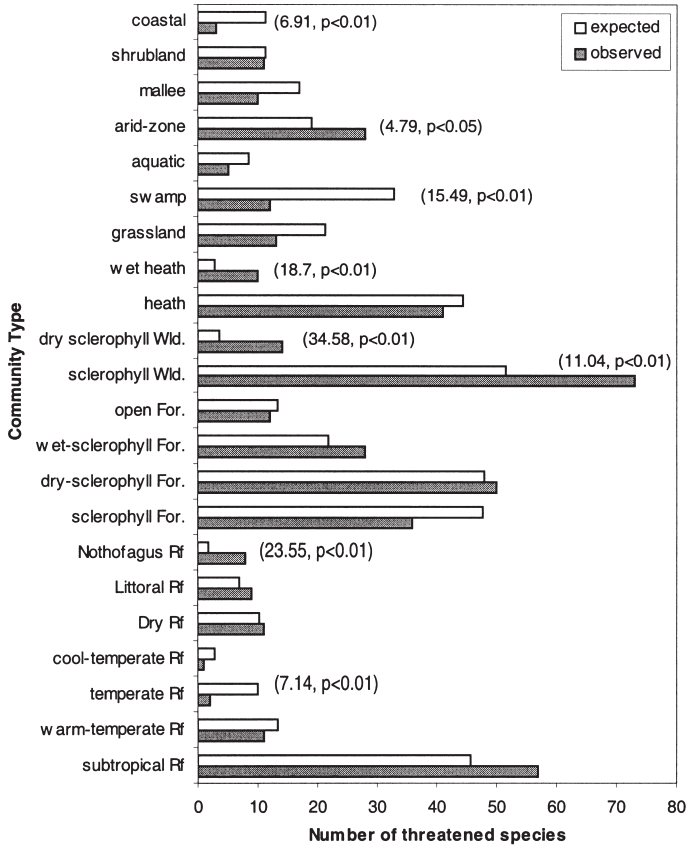

Fig. 5. The occurrence of threatened plant species in NSW in different ecological communities using the terminology of Harden (1990–1993) (note: For. = forest, Rf = rainforest, Wld = woodland). The expected distribution of threatened plants in regards to community type is also shown, with the χ^2-values and p-values for those communities which show a significant difference between the observed and expected distributions of threatened plant species.

Taxonomic Analysis

Most families which contain threatened flora possess only one threatened plant species (Fig. 6), with decreasing numbers of families containing increasing numbers of threatened plant species. In total, 41% of the 215 plant families in NSW contain threatened plant species. However, 53% of the 433 threatened plant species in NSW occur in only six families; Fabaceae, Myrtaceae, Proteaceae, Orchidaceae, Rutaceae and Asteraceae (Table 2). Significantly more threatened plant species than expected occur in the families Myrtaceae, Proteaceae, Rutaceae, Lamiaceae and Casuarinaceae. In contrast, the Asteraceae, Poaceae and Cyperaceae contain significantly fewer threatened plant species than expected.

The distribution of threatened plant species by genera shows a similar trend to that of the family distribution, but an even greater proportion of genera containing threatened plant species possess only one threatened species (Fig. 7). Threatened plant species occur in 18% of the 1132 genera in NSW, while 20% of the threatened plant species in NSW occur in just four genera (*Eucalyptus* (sensu lato), *Acacia*, *Grevillea*, and *Zieria*) (Table 3). Of these, *Eucalyptus*, *Grevillea* and *Zieria* were found to contain significantly more threatened species than expected.

Linear regression showed that the proportion of threatened species in a family was not significantly related to the size of the family (F-value = 0.04, p = 0.85). The lack of a linear trend can be attributed to the large variation in the proportion of threatened species in the smaller families. In contrast, the proportion of threatened species in the larger families remained around 8%, the average proportion of threatened species in all families in NSW. There was also no significant relationship between size of genus and proportion of threatened species (F-value = 0.70 , p = 0.403).

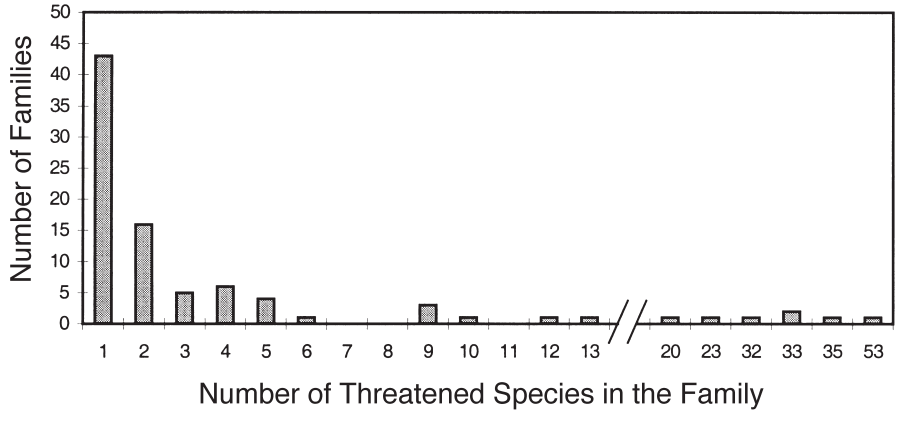

Fig. 6. The distribution of threatened plant species in NSW by family. Note that the *x*-axis is not continuous.

Table 2. The families with 5 or more threatened plant species in NSW. Also shown are the size of the family, the proportion of the family which is threatened, and whether that family has significantly more or fewer threatened plant species than expected.

FAMILY	Number of threatened species	Total number of species	Proportion of species threatened (%)	Significance	χ^2	P-value
Fabaceae	56	547	10.2	n.s.	3.168	> 0.05
Myrtaceae	53	443	12.0	sig. more	8.675	< 0.01
Proteaceae	35	181	19.3	sig. more	30.215	< 0.01
Orchidaceae	33	333	9.9	n.s.	1.255	> 0.1
Rutaceae	33	156	21.2	sig. more	35.130	< 0.01
Asteraceae	20	413	4.8	sig. fewer	6.949	< 0.01
Lamiaceae	13	86	15.1	sig. more	5.383	< 0.01
Euphorbiaceae	12	103	11.7	n.s.	1.581	> 0.1
Poaceae	10	411	2.4	sig. fewer	20.055	< 0.01
Epacridaceae	9	96	9.4	n.s.	0.157	> 0.1
Rhamnaceae	9	62	14.5	n.s.	3.247	> 0.05
Chenopodiaceae	9	180	5.0	n.s.	2.608	> 0.1
Brassicaceae	6	52	11.5	n.s.	0.747	> 0.1
Casuarinaceae	5	24	20.8	sig. more	5.036	< 0.05
Cyperaceae	5	243	2.1	sig. fewer	12.971	< 0.01
Thymeleaceae	5	45	11.1	n.s.	0.489	> 0.1

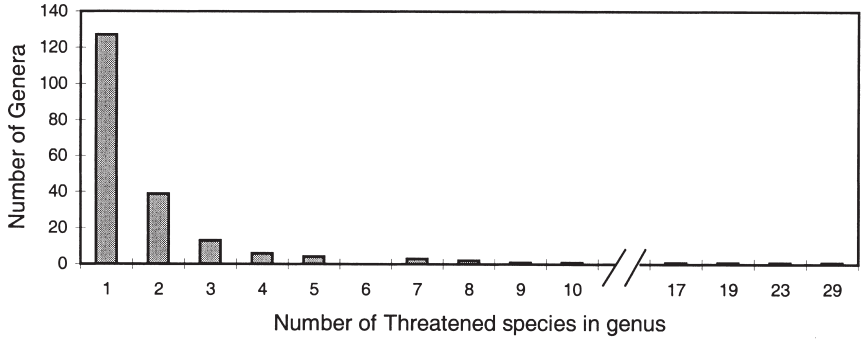

Fig. 7. The distribution of threatened plant species in NSW by genus. Note that the *x*-axis is not continuous.

Table 3. The genera with the greatest number of threatened plant species in NSW.

	Number of threatened spp	Total number of species	Proportion of species threatened	Significance	χ^2	P-value
Eucalyptus	29	235	12.3%	sig. more	5.366	< 0.025
Acacia	23	217	10.6%	n.s.	1.609	> 0.1
Grevillea	19	53	35.8%	sig. more	53.556	< 0.01
Zieria	17	33	51.5%	sig more	81.834	< 0.01

Growth Form

The analysis of the growth form (or habit) of threatened plants in NSW shows that the largest number of threatened plant species are trees or shrubs, with herbs being next most abundant, and only a small number of threatened plant species being ferns or climbers (Fig. 8). Significantly more threatened plant species than expected were trees/shrubs, while significantly fewer threatened plant species were herbaceous. However, there were many more herbaceous plants presumed extinct than either trees or shrubs (Fig. 8).

Discussion

Regional Analysis

Currently listed threatened plant species in NSW are markedly restricted in their range when compared to all plant species in NSW, with more than 75% of threatened species occurring in only one Botanical Division. Within the 'threatened' category, Endangered species are more restricted in their distribution than Vulnerable species. Thus most species listed as threatened in NSW display the rarity types identified by

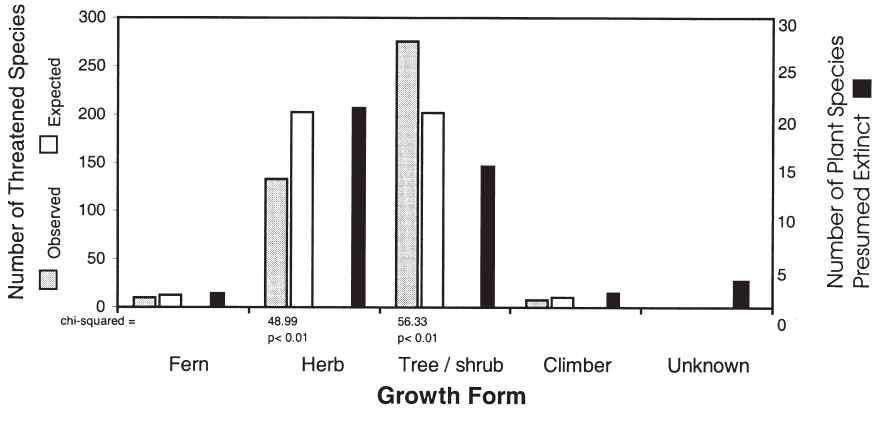

Fig. 8. The occurrence of threatened plant species and plant species presumed extinct in NSW, with respect to growth form.

Rabinowitz (1981) involving small geographic ranges and narrow habitat specificity, typical of local endemics. This may indicate that either locally endemic species are the most prevalent type of rare plant and that they experience the greatest degree of threat, or that there is a predisposition to list species which show the most obvious signs of being geographically restricted or threatened.

The schedules of the *Threatened Species Conservation Act 1995* do appear to be deficient in their listing of Vulnerable plant taxa in comparison to Endangered taxa. Most states and countries list about twice as many Vulnerable species than Endangered species, whereas in NSW there are 39 more Endangered species listed than Vulnerable species. The ROTAP list has 301 Endangered species and 708 Vulnerable species (6% and 14% of the national vascular flora respectively) (Briggs & Leigh 1995). The process by which the initial schedules of the *Threatened Species Conservation Act 1995* were created favoured identification of Endangered species, and nominations since the proclamation of the *Act* have not redressed the balance.

On a regional basis, the North Coast and Central Coast contain the most threatened plant species, while the South Western Slopes contains the fewest. A larger number of species and threatened species occur in the eastern divisions (the Coast and Tablelands) than occur in the western divisions (the Western Slopes, Plains, and Far Western Plains) (Fig. 2). Taking into account the different size of each division by examining the regional distribution on a species per area basis, the eastern divisions, such as the Central Coast and the Central Tablelands, contain much higher threatened species densities than the western divisions. Lunney et al. (1997) found that the North Coast region of NSW also contained the highest number of threatened vertebrate species. However, the western region of NSW was found to contain the largest number of threatened mammals in total (Lunney et al. 1997) and the largest number of threatened rodents (Dickman et al. 2000).

Not only do the North Coast and the Central Coast support the most threatened plant species, they also contain more threatened plant species than expected. In contrast, the South Coast, South Western Slopes, Central Western Slopes, North Western Slopes, South Western Plains and the North Western Plains all contain significantly fewer threatened plant species than expected. The trend for there to be significantly more than expected threatened plant species in the eastern divisions and significantly fewer than expected in the western divisions may be due to a number of factors. These include the level of botanical study conducted in each division, the sizes of the geographic ranges of species, the level of threats present in each division, and the degree of environmental heterogeneity in each division.

The larger number of species (threatened and non-threatened) in the eastern divisions may reflect the greater environmental complexity and, in general, more favourable climatic conditions for plant growth compared to the inland. The eastern divisions include habitat from sea level to high peaks (by Australian standards), and high rainfall and locally high nutrient conditions provide habitats for sclerophyll forest and rainforest communities which are absent further west (Adam 1987). The absence of a relationship between the size of the regional flora and regional area (Fig. 9) supports the hypothesis that habitat diversity is important in determining patterns of species

richness. The high species richness of the South Coast and Central Coast divisions in a national context was emphasised by Keith, Miles and Mackenzie (1999).

While environmental factors may explain the distribution of species richness, how might the greater proportion of threatened taxa in the east of the state be explained? One possible explanation is that there is a greater degree of threat (real or perceived) in the east of the state. Both the North and Central Coasts have experienced significant impacts since European settlement. The Central Coast faces continued pressure associated with the growth of the greater Sydney metropolitan area, while the North Coast lowlands were extensively cleared for agriculture and face continued pressure from coastal development. However, the divisions which have been most extensively affected by human land use are the flatter areas of the Western Slopes and the eastern portion of the Western Plains (Benson 1991b). Benson (1991b) regards the major threats to plant species in NSW as grazing and cropping, which are primarily carried out in the mid west (cropping) and the far west (grazing) of the state.

The NSW wheat belt occupies approximately 22.5% of the state (Sivertsen 1994) (the Western Slopes and the Western Plains) of which roughly 90% has been cleared of native vegetation (Biodiversity Unit 1995). This clearing may be reflected in the number of plant species presumed extinct from the Western Slopes and Plains. Sivertsen (1994) showed that significant levels of clearing of native vegetation is continuing to occur in the wheat belt of NSW, maintaining a level of threat to the remaining native flora.

The Western Plains of NSW have been grazed extensively since the 1830s (Benson 1991b). Benson (1989) reported that grazing has affected more than 60% of NSW, and has resulted in major reductions in the abundance of plant species and has been implicated in a number of extinctions. Grazing may therefore have contributed to the relatively high number of plant species presumed extinct in the Far Western Plains region, and as the onset of grazing preceded full botanical documentation, a number of species may have become extinct without ever having been recorded.

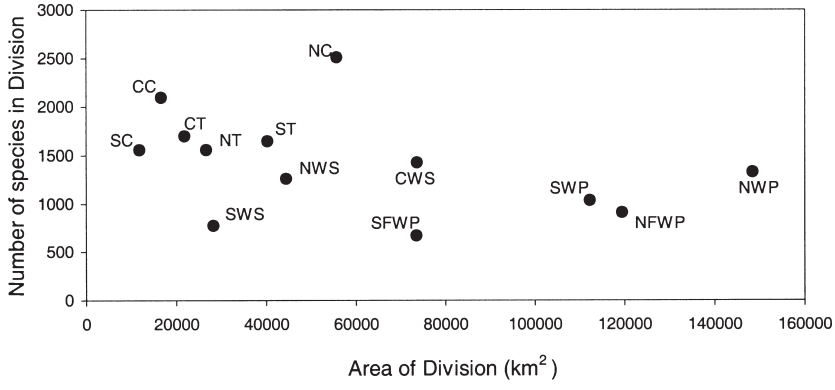

Fig. 9. The relationship between the size of each division and the number of species.

Hence it would appear that, although difficult to quantify, the levels of threat faced by plant taxa are unlikely to be greater in the east than in the west of NSW. Nevertheless, the more intense, localised threats in the east of the state, and their visibility to a much larger number of people, might tend to support a perception of greater and more immediate threat.

A further possible explanation of the skewed distribution of threatened species is that plants on the North and Central Coasts may possess an innate degree of rarity, by virtue of limited geographical distributions and/or small populations. The distinctiveness of north eastern NSW with its representation of northern and southern elements of the flora was recognised by Burbidge (1960) as the Macpherson/Macleay overlap. The high incidence of local endemism, associated with distinctive areas of geology, topography and local climate has been stressed by Adam (1987) and Benson (1991b). Species with geographically restricted distributions may be at greater threat from wide spread disturbance than widespread species. In comparison, the lower levels of local endemism in the west may reflect the more homogenous environment. Burrows (1998) has pointed out that most threatened plant species in the South Western Slopes region are not local endemics, but have a reasonably wide distribution.

A final possibility is that the currently recorded distribution of threatened flora is at least in part an artefact of the intensity of botanical exploration and survey. It is possible that large numbers of plant species have become extinct in the western regions before being taxonomically documented. Certainly there has been much more study in the east of the state, but even in what are regarded as the better explored regions, major finds can still be made (as for example the recent discovery of the Wollemi Pine (*Wollemia nobilis*)). It is difficult to assess the extent to which under-recording or lack of appropriate data have influenced the present composition of the schedules. In the future, as the schedules are subject to amendment, it will be interesting to see whether the proportional representation of western plant species increases.

The distribution of protected areas in the National Parks and Wildlife Service estate also shows a marked bias to the east of the state (Fig. 4). It is known that many species and communities are not represented in the limited reserve areas of the western regions (Pressey 1990, Benson 1999), but it is less clear how adequately the reserve system in the east conserves the threatened flora of these regions. In 1992, Leigh and Briggs estimated that nationally only 48.8% of threatened plant species had some part of their population protected in conservation reserves, and that only 13.7% of these were 'adequately conserved' (it must be noted however that population data for most threatened species are inadequate to properly assess conservation status). Comparable data for the species on the Schedules of the *Threatened Species Conservation Act 1995* are not readily available, however it is notable that many of the species from eastern NSW added to the Schedules since the *Act* came into effect are either inadequately conserved, or not conserved at all.

Community Analysis

Sclerophyll woodland was found to be the community containing the most threatened plant species and possessing many more threatened plant species than expected. This

supports the findings of Leigh and Briggs (1992) who also showed that woodland communities contained the largest number of endangered plant species in NSW. This prevalence of threatened plant species in woodland communities may simply reflect the large area of NSW originally covered by woodland vegetation. Most woodland in NSW has been either cleared or modified under European settlement (Leigh et al. 1984). Where the understory of woodland is composed of herbs and grasses, sheep and cattle have been allowed to graze, often preventing the regeneration of woodland plant species. Alternatively, woodland has been cleared to allow for more vigorous growth of native grasses, or the establishment of crops and improved pasture. For both the vertebrate fauna in general and rodents in particular, woodland also supports the greatest number of threatened species (Lunney et al. 1997, Dickman et al. 2000).

Subtropical rainforest was the community with the next largest number of threatened plant species, and if all rainforest types were grouped together then rainforest would have the largest number of threatened plant species. This agrees with the findings of Leigh and Briggs (1992), and the commonly held view that rainforests possess high species diversity and many threatened species. Rainforest distribution is very fragmented in eastern NSW (Adam 1987), and many rainforest species have very restricted distributions. Rainforests in NSW have been seriously depleted since European settlement, and continue to face significant threats. Approximately 75% of rainforest in NSW has been cleared or disturbed by logging since European settlement, leaving only small remnants of 'virgin' subtropical rainforest in northern NSW (Floyd 1990). Adam (1987) estimated that half of the 250 000 ha of rainforest remaining in NSW is in some way degraded.

Both wetland and coastal communities contain significantly fewer threatened species than expected, despite these communities showing spatially disjunct distributions, being subject to significant threats, and being regarded as of high conservation value. There is a low degree of local endemism in both wetland and coastal communities, and many species have very wide geographic ranges. It is important to recognise that while consideration of threatened species is necessarily an important component of conservation strategies, it cannot be the only one, and that communities of high conservation value (which may satisfy the criteria for listing as Endangered Ecological Communities) need not necessarily provide habitat for threatened species. The widespread distribution of species in habitats such as wetlands does, however, lead to complacency as to their status, and declines may be under-recorded.

Taxonomic Analysis

Most families and genera which contain threatened taxa possess only one or two threatened plant species. However, there are several taxonomic groups which contain a large proportion of the threatened flora. These genera and families were notably the larger ones, and several of the larger genera/families contain significantly more threatened plant species than expected. Of these, the families Proteaceae and Rutaceae and the genera *Zieria* and *Grevillea* contained markedly high proportions of threatened plant species. *Zieria* is an interesting case as many of the taxa acknowledged to be threatened have yet to be formally described. In both *Zieria* and *Grevillea* many of the

threatened taxa are local endemics, suggesting that restricted distribution may be a major threat, or contribute to a perception of threat.

It will surprise many botanists that the number of threatened species in the Orchidaceae is not significantly greater than expected. A large proportion of orchids grow in very specific habitats, such as on particular rock types or as epiphytes on particular tree species. Orchids also require the presence of specific fungi for successful germination and establishment. However, the common notion that orchids are innately rare may simply reflect the views of the large number of orchid enthusiasts.

Asteraceae, Poaceae and Cyperaceae are three large families in which relatively few species have been recognised as threatened. These families are largely herbaceous and are regarded as 'difficult' by many field botanists. Accordingly, under-recording and lack of data may contribute to the apparent paucity of threatened grasses, daisies and sedges. In a study of the threatened flora of the Cape Peninsula in South Africa, Trinder-Smith et al. (1996) also found that the Proteaceae were over-represented and the Asteraceae under-represented. They related this to the different degree of endemism in the families, with the Proteaceae having a high degree of endemism and more threatened species. Local endemism is not a feature of Asteraceae in NSW, so this may also contribute to it possessing a low proportion of threatened species. In the mainland United States, however, the Asteraceae contains a very large number of threatened species (Morse 1996).

Growth Form Analysis

The most noteworthy feature of the growth form analysis was the over-representation of trees/shrubs in the threatened flora, and the under-representation of herbaceous species. An important difference between these two growth forms is the ability for herbaceous species to reach higher densities of individuals compared to shrubs or trees. Despite this, the more palatable plants (e.g. the herbs) are likely to have suffered the most damage from activities such as large-scale grazing. The larger number of herbaceous species presumed extinct (20) compared to trees or shrubs (14) tends to support this hypothesis. However, herbaceous species tend to be under-recorded, so that low overall representation of herbs amongst threatened species may reflect inadequate documentation (as was suggested by McIntyre (1992) for Northern NSW), while a number of the apparently extinct herbs may simply have not been refound.

Conclusions

Both the *Flora of New South Wales* and the Schedules of the *Threatened Species Conservation Act 1995* are works in progress, so the statistics reported in this paper should not be regarded as absolute. The known composition of the flora is likely to change more slowly than the Schedules of the *Act*, although at this stage in our knowledge, newly described taxa will most likely be rare and therefore candidates for recognition as being threatened. Our knowledge of the distribution of taxa improves with collection and survey, so that the distributional data recorded in the flora is being continually updated. Changes to the Schedules of the *Act* will be limited by the

availability of data sufficient for the NSW Scientific Committee to make an assessment, and the nomination process.

Early experience with nominations has been that they reinforce the existing distribution patterns, with a very strong predominance of nominations being from eastern NSW, and particularly the Central and North Coasts (Dickman 1997). The successful nominations satisfy the criteria of the *Act*, so that even in regions which already have a high proportion of threatened taxa, more are still being added. However, it is not clear as yet whether the relatively few additions from west of the Divide are a true reflection of the distribution of threatened taxa, or of the concentration of nominees in the Central and North Coasts. The proportion of the flora which is threatened, currently nearly 9%, is an indication of the magnitude of the conservation challenge facing NSW. The indication from the number of successful nominations for addition to the Schedules is that the 'real' proportion of threatened plant species in NSW will be much higher. If the flora of NSW is similar to those of other states and countries then a very substantial increase in the number of Vulnerable species would be expected (Briggs & Leigh 1995, Groombridge 1994).

The distribution of the threatened flora of NSW shows similarities to that of the threatened vertebrate fauna (Lunney et al. 1997), with both threatened plant and vertebrate species occurring in their greatest numbers in the north-east, and in woodland communities. Adequate conservation reserves in these areas could therefore act to protect large numbers of both threatened flora and fauna. However, differences in regional distribution were noted between the threatened flora and sub-groups of the vertebrate fauna, with more threatened mammals (and amongst mammals, the rodents) occurring in the west of the state. The larger number of presumed extinct taxa in the west of the state is also paralleled amongst vertebrates.

It is important to note that this study deals only with the vascular plants of NSW. Information on the cryptogamic flora is very limited and, as yet, no non-vascular plant species has been listed in the Schedules of the *Threatened Species Conservation Act 1995* (although an Endangered Ecological Community defined by fungi has been listed). This is unlikely to represent the degree of threat to cryptogams, but it is likely to be considerable time before data appropriate to assess the non-vascular flora are available.

Our analysis was limited by the availability of data. Testing for relationships between threat status and ecological attributes of the flora might permit better prediction of categories of species at risk. Ecological attributes which would be interesting to examine include post-fire regeneration strategy, breeding system, pollination mechanisms, seed bank dynamics, mycorrhizal status and soil preferences. A more detailed community classification and more consistent recording of community information would also permit more detailed analysis.

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