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Priority setting and the conservation of Western Australia's diverse and highly endemic flora

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Abstract

A fundamental role of government conservation agencies is to set priorities for the conservation and management of biodiversity. This is particulary important in an area such as Western Australia which has a rich and highly endemic flora with over 11,000 listed native vascular plants. Legislation provides an initial focus for priority setting through the listing and protection of threatened flora, although this excludes over 1900 Western Australian plant taxa which are poorly known but may be of conservation significance. The priority setting process for the conservation of this flora, discussed herein, focuses on single taxa, groups of taxa within geographic regions, populations and threatening processes. This process is particularly applicable to the highly diverse and endemic flora of the south-west Botanical Province. Within this region there has been extensive habitat loss and degradation over the last 100 years. Currently the prioritisation process has identified 95 critically endangered taxa in the southwest which require immediate remedial action to prevent extinction. Actions such as translocations are already showing promise, but with this number of critically endangered taxa and limited resources there may also need to be some ranking of taxa for immediate translocation. Although the priority setting process outlined here relates primarily to taxa, we emphasise that the conservation of this flora is also addressed at ecosystem and ecological community levels, and that each approach has its merits depending upon land tenure, location within the State and, in particular, the level of land degradation. Crown Copyright © 2000 Published by Elsevier Science Ltd. All rights reserved.

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1. Introduction

Setting priorities for the allocation of limited resources to conservation actions is a basic function of conservation organisations, particularly government agencies which have the direct responsibility for the conservation and management of biodiversity. This is often a difficult task, especially in areas of high biodiversity and where the biota is poorly known. Lack of detailed biological and census information can severely restrict priority setting and the assessment of the relative conservation importance of populations, taxa and ecosystems. Yet even when this information is available for a species or ecosystem, assessing conservation status and setting the subsequent priorities for action can be contentious. Risk of extinction involves the evaluation of concepts such as threat, rarity and endangerment and their relative importance in assessing conservation status (Given, 1994; Burgman and Lindenmayer, 1998). For example, the classification of rarity is frequently used in setting priorities for conservation and wildlife management (Burgman and Lindenmayer, 1998). Yet rarity in plants may be due to a whole range of factors from the evolutionary history of the species through to human intervention and issues such as land — use policies and taxonomic classification (Fiedler and Ahouse, 1992). Different forms of rarity will inevitably require different management actions and may result in different conservation priorities.

The process of setting priorities for conservation particularly at the species level has largely focussed on the listing and ranking of species based on their level of threat and likelihood of extinction. The International Union for the Conservation of Nature and Natural Resources (IUCN) has developed a range of categories for assigning species in relation to the degree of threat including: extinct, critically endangered, endangered, and vulnerable (IUCN, 1994). These categories have been widely accepted throughout the world and form the basis for the IUCN Red List of Threatened Plants (Walter and Gillet, 1998). Within Australia, constitutional arrangements between the Commonwealth and State Governments means that management responsibilities

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for rare and threatened flora reside largely with the States. At both State and Commonwealth levels the listing of threatened flora is based primarily on the qualitative IUCN criteria. However, in some States quantitative approaches are also used to assist in the clarification of conservation status as part of assigning IUCN categories.

Over the last decade a broad range of issues associated with setting priorities for conservation have been considered in relation to the Western Australia flora with a particular focus on the rich and highly endemic flora of the south-west Botanical Province (see Hopper et al., 1990; Burbidge et al., 1997; Coates and Atkins, 1997; Brown et al., 1998). The database of plant names for Western Australia lists 11,885 taxa (Western Australian Herbarium, 1998) with the total likely to exceed 13,000 once botanists have completed surveying, searching and describing the flora. This is nearly half of the Australian total, and represents some 4–5% of the estimated world vascular flora. Nearly 46% of Australia's rare and threatened flora are found in Western Australia (Atkins, 1998), while Leigh and Briggs (1992) estimate that Australia has 17.6% of the worlds threatened, rare and poorly known flora. Based on these figs. nearly 8% of the world's threatened, rare and poorly known flora occur in Western Australia (Atkins, 1998).

A significant proportion of the Western Australian flora is concentrated in the south-west of the State, with nearly 75% of the 8000 taxa endemic to this region. The majority of these endemic taxa occur in the heathlands and shrublands (kwongan) which originally covered some 27% of the south-west. Many of the areas where kwongan predominates occur in the cereal growing areas where there has been extensive land clearing and habitat degradation. Only 25% of the agricultural region is now covered in vegetation (Beeston et al., 1996)

The high level of species diversity and endemism in the south-west has been attributed to a number of factors. The region is characterised by an extremely ancient landform which has largely weathered in situ. Unlike many other floras, the south-west flora has persisted for an extremely long period without any large scale extinction episodes associated with glaciation, volcanism or mountain uplifting. The flora has also evolved in isolation from eastern Australia, over a considerable period of time and in association with increased aridity and climatic instability since the late Tertiary. As a consequence, the south-west flora shows a diverse array of evolutionary patterns across the landscape, combining refugial species in higher rainfall areas with fragmented relictual species and suites of newly derived taxa in the more arid areas (see Hopper, 1979, 1992).

A significant outcome of these landscape and climatic changes is the high number of taxa with extremely localised and disjunct distributions. This, combined with the extensive land clearing, has resulted in the large number of rare and threatened taxa now recorded from the region. In addition, 72% of threatened flora populations occur outside the conservation reserve system (Coates and Atkins, 1997) focussing attention on vegetation remnants on private land, road reserves and other Crown land.

Apart from those flora which are under immediate threat of extinction, loss of genetic diversity is also an issue concerning many more common taxa. Of these a number have genetic resources of considerable commercial value in the timber industry, cut flower and horticulture trades, while many others are considered to be of potential value in the pharmaceutical industry (Armstrong and Abbott, 1996).

With only 94 species presumed extinct at that time, Hopper et al. (1990) indicated that the State had the opportunity to conserve some 99% of the native plant species. This is perhaps an optimistic viewpoint, given the increasing number of critically endangered taxa and the ongoing destruction of the flora through threatening processes such as salinisation and root rot disease (dieback) caused by *Phytophthora* species. However, significant achievements are possible through careful prioritisation and allocation of resources. This involves targeting populations, taxa, groups of taxa or ecological communities under immediate threat, and the strategic longer term research and management of threatening processes and ecosystems.

Although Western Australia has recently commenced the identification and prioritisation of threatened ecological communities (English and Blyth, 1999) the primary focus of this paper will be on the range of procedures used to prioritise plant taxa and populations. These procedures account for both the nature of threatening processes and the relative risks of extinction of different taxa. We stress the need for a multifaceted approach to the issue of prioritisation which not only considers loss of biodiversity, but also limited resources, cultural, scientific and commercial values, and legislative requirements.

2. Legislation and priority setting

A key factor in flora conservation and the priority setting process in Western Australia is legislation for the protection of the flora, which defines the responsibilities of the State Government nature conservation agency, the Department of Conservation and Land Management. It is important to recognise the limitations legislation may have in relation to setting priorities for managing and conserving a large number of taxa, of which around 20% (2309, Table 1) are currently listed as threatened, rare or poorly known.

Western Australia's native flora is protected under the *Wildlife Conservation Act 1950–1979*. The Department of Conservation and Land Management has the statutory responsibility of administering that Act, and thus

Table 1
Definitions for the grouping of rare and poorly known flora in Western Australia

Priority one—poorly known taxa Taxa which are known from one or a few (generally < 5) populations which are under threat, either due to small population size, or being on lands under immediate threat, e.g. road verges, urban areas, farmland, active mineral leases, etc., or the plants are under threat, e.g. from disease, grazing by feral animals, etc. May include taxa with threatened populations on protected lands. Such taxa are under consideration for declaration as 'rare flora' (threatened flora), but are in urgent need of further survey[a]
Priority two — poorly known taxa Taxa which are known from one or a few (generally < 5) populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered). Such taxa are under consideration for declaration as 'rare flora' (threatened flora), but are in urgent need of further survey[a]
Priority three — poorly known taxa Taxa which are known from several populations, and the taxa are not believed to be under immediate threat (i.e. not currently endangered), either due to the number of known populations (generally > 5), or known populations being large, and either widespread or protected. Such taxa are under consideration for declaration as 'rare flora' (threatened flora), but are in need of further survey[a]
Priority four — rare taxa Taxa which are considered to have been adequately surveyed and which, whilst being rare (in Australia), are not currently threatened by any identifiable factors. These taxa require monitoring every 5–10 years

[a] The need for further survey of poorly known taxa is prioritised into the three categories depending on the perceived urgency for determining the conservation status of those taxa. This urgency is determined by the apparent degree of threat to the taxa based on the current information regarding number and land status of populations.

conserving the State's flora, through the provisions of the *Conservation and Land Management Act 1984*. Under the Wildlife Conservation Act, all classes of native flora are protected including algae, fungi, mosses, lichens, ferns, gymnosperms and flowering plants. Licences are required to take (pick or disturb) any protected flora on Crown lands, and a licence is required to sell protected flora taken from private lands. Special protection is provided to flora that the State Minister for the Environment declares to be 'rare flora'. These flora are protected on all lands throughout the State.

Flora may be declared 'rare' if:

- it is a distinguishable taxon, whether formally named or not;
- it has been searched for thoroughly in the wild according to guidelines approved by the Executive Director of the Department of Conservation and Land Management; and
- the searches have established that the plant in the wild is either:
  (a) rare; *or*
  (b) in danger of extinction (including presumed to be extinct), *or*
  (c) deemed to be otherwise in need of special protection.

While the term 'rare flora' may apply to rare, threatened or specially protected flora, currently only those flora that are considered to be threatened as a consequence of either few populations and small population size (rare) or a threatening process are listed. Thus the list may be regarded, under international terminology, as 'threatened' flora.

Although Western Australia's threatened flora are protected under the Wildlife Conservation Act, there are two aspects of the legislation which have very important implications for setting conservation priorities. Firstly, taxa have to be listed under government notice to be afforded the special protection given under the Act. The process of listing must satisfy the conditions listed above which require a sound understanding of the conservation status of the taxon. This ensures credibility of the listing, but excludes the 1708 poorly known taxa until their conservation status is adequately understood (see below). A proportion of these are likely to be rare and some possibly critically endangered, while others are likely to be more common once adequate surveys have been undertaken. The dilemma here is to detect those apparently rare but poorly known taxa which are in fact critically endangered, and provide them with appropriate protection before they become extinct whilst such surveys are being carried out. Resources for survey are the critical limiting factor.

Secondly, the entity to be listed has to be a distinguishable taxon. This usually means described by a genus name and any other name or description (i.e. species, subspecies, variety). This does not necessarily exclude genetically distinct populations or phylogenetic groups which may be defined using molecular or chromosome markers, providing they are defined and recognised as distinct taxa. However, if the ultimate goal of conservation is to conserve genetic diversity and evolutionary processes, then it places unnecessary emphasis on the recognition of taxa rather than populations and population-based ecological and genetic variation. This concern does not apply to Australian Government Federal legislation and legislation in a number of other Australian States, where genetically distinct populations and ecological communities considered to be under threat can be listed for protection.

3. The priority setting process

The priority setting process for the conservation of Western Australia's flora has developed rapidly over the last 10 years, particularly with improvements in biogeographical databasing and a better understanding of the biology of threatened plants (see Hopper et al., 1990; Brown et al., 1998). Despite this, at least some priorities will no doubt change given continuing developments in taxonomic knowledge and further field survey work, coupled with the remarkable richness of the flora and the range and complexities of life histories and specialized genetic systems (see James and Hopper, 1981; James, 1996). It is incumbent on conservation agencies to accommodate such changes in priority by ensuring that flora conservation resources are appropriately targeted.

The current priority setting process for taxa is outlined in Fig. 1. Risk of extinction at population, taxon and ecological community levels is the primary determinant for setting priorities. However, if conservation resources became severely limited it might be necessary to consider more extreme prioritisation procedures which could take into consideration other factors such as taxonomic (phylogenetic) distinctness and the potential for recovery.

Given the high level of diversity in the Western Australian flora and the large number of rare and threatened species there is perhaps some merit in considering phylogenetic distinctness and utilising procedures that tend to maximise the conservation of genetic diversity to set priorities. Phylogenetic trees and genetic distances between taxa encompass various approaches which have been proposed (see May, 1990; Vane-Wright et al., 1991; Faith, 1992; Crozier and Kusmierski, 1994). These approaches are discussed in relation to the prioritisation of populations and intra-specific genetic variation in a following section. The limitation to these approaches in Western Australian is the lack of detailed taxonomic knowledge for many plant groups and the lack of phylogenetic data for most species and genera.

The potential for recovery may be considered in particular situations where the only remaining known population consists of one or two plants, or perhaps a single clone. In these "basket cases" ex situ conservation may be the only solution and limited resources might be better allocated to those species where in situ recovery is at least possible. However, it is noteworthy that all government agencies concerned with conservation must consider the overriding political, public and in some cases legal consequences of extinction. Even if the

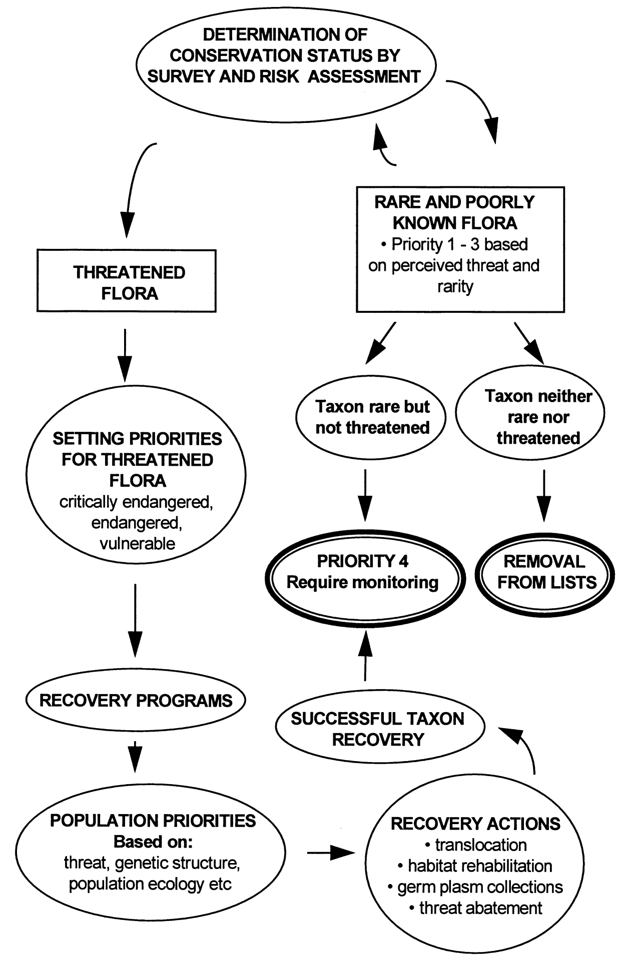

Fig. 1. Process for setting conservation priorities in Western Australian vascular plant taxa and populations.

potential to recover a taxon in the wild is low, resources will usually be allocated to those taxa under most serious threat.

3.1. Single taxon strategies

To date the process of setting priorities in the Department of Conservation and Land Management has largely focussed on taxa, which is a reflection of the legislation. Over the last 20 years there has been considerable effort by a number of botanists to develop lists of rare and threatened flora in Western Australia (see Marchant and Keighery, 1979; Rye and Hopper, 1981; Hopper et al., 1990). The initial source of information for these lists was herbarium collections with more recent listings assisted by extensive field surveys to gain a better understanding of conservation status. Burgman et al. (in press) emphasise the value of herbarium collections in assessing conservation status and assigning initial conservation priorities. Currently, the Western Australian Herbarium databases (Western Australian Herbarium, 1998) provide much of the baseline data for

Western Australia's conservation flora list, in a readily accessible format.

The present listing provides six categories of flora; threatened, presumed extinct, and four priority flora groups referred to in Table 1. The priority flora can be broadly defined as:

- those taxa which may be rare or threatened but for which there is insufficient survey data available to accurately determine their true status (those which may be categorised as 'data deficient' or 'poorly known' in international terminology); and
- those taxa which have been determined as being rare, but are currently not threatened (categorised as 'rare' in international terminology).

More than 1900 taxa are currently listed as priority flora, with 1708 being poorly known. There has been a substantial increase in listed conservation taxa since threatened flora were first listed in 1980, and priority flora in 1987 (Fig. 2). This increase represents the improvement in knowledge of the State's flora through survey, taxonomic study, and the databasing of the Western Australian Herbarium collections. Even so, there is a clear need for further taxonomic research to resolve the many issues of synonymy and identification within the Priority Flora. More importantly, there is a critical need for further survey to determine their true conservation status.

Because of the large number of taxa on the list, the priority flora are ordered according to the perceived urgency for further survey. The priority flora list assigns top priority for survey to those taxa whose known populations are few and on land under threat (Priority 1). The lowest priority is for those rare taxa that require monitoring to ensure that their conservation status does not decline (Priority 4) (see Table 1).

Clearly with 350 threatened flora currently listed, and inevitable additions as the list is updated each year as further survey work is undertaken, it is difficult with current resources to prepare and implement individual recovery programs for all taxa. Thus a more detailed prioritisation process is applied to the threatened flora through the Western Australian Threatened Species and Communities Unit (WATSCU), Department of Conservation and Land Management, utilising the greater knowledge base available for these taxa.

A range of methodologies has been developed to rank and prioritise threatened species (see Given and Norton, 1994; Chalson and Keith, 1995; Burgman and Lindenmayer 1998). These methodologies can be broadly assigned to three different categories: qualitative descriptions, point scoring procedures and rule sets (Burgman and Lindenmayer, 1998). As pointed out by Burgman and Lindenmayer (1998) no single method is likely to give the best result in all situations.

Until relatively recently the classification of rare and threatened plant species in Australia has been largely based on IUCN terms and their associated qualitative descriptions (see Briggs and Leigh, 1988, 1996). Currently, the national list of threatened plants and animals under Schedule One of the Australian Endangered Species Act 1992 provides for listing of species under three categories based broadly on qualitative IUCN criteria. Significant shortcomings of the qualitative approach include the lack of clear guidelines for assigning taxa to categories, reliance on expert opinion, potential inconsistency among different workers using the same scheme, and the inability to resolve conflicting opinions (see Chalson and Keith, 1995).

Point scoring methodologies usually based on linear ranking (Molloy and Davis, 1992) have some merit because they result in a more definitive ranking of

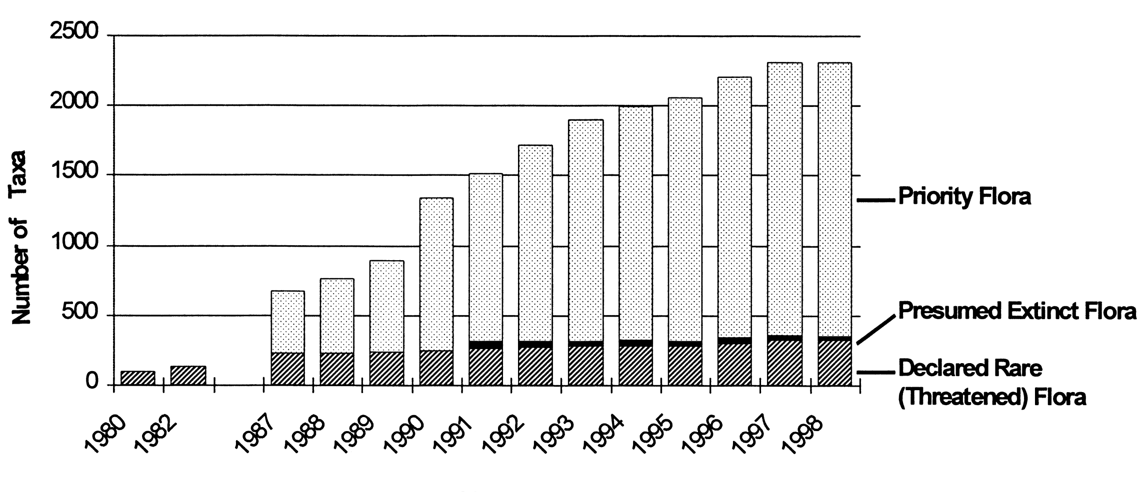

Fig. 2. Number of listed "conservation flora" from 1980 to 1998.

individual taxa or grouping of taxa. However, as pointed out by Burgman and Lindenmayer (1998) and Given (1994) there are limitations with these approaches particularly in relation to the weighting of variables and the biologically unjustified use of the same weighting across all taxa. They also indicate that the variables are often not independent of one another and that correlations between variables will differ substantially between taxa. Both factors can significantly influence the scores assigned to different species and their relative rankings.

The grouping of taxa into distinct categories based on rule sets for classifying threat has developed directly from the previous qualitative IUCN criteria (Mace and Lande, 1991; IUCN, 1994). The IUCN rules are based on information relating to population size, distribution of individuals, fluctuations in abundance and risk of extinctions. Again, as with the other approaches, there can be limitations in assigning taxa based on rule sets to the IUCN categories (Burgman and Lindenmayer, 1998). Perhaps the most significant concerns relate to the thresholds that delimit the categories of threat.

The prioritisation of threatened flora in Western Australia was initially based on a point scoring system developed by Burbidge and Brown (1993). This system used a linear ranking procedure modified from Molloy and Davis (1992) based on 12 criteria, with three major criteria types reflecting population features, threat of extinction and ex situ propagation. Subsequently in 1994 taxa were also evaluated against the IUCN criteria and the categories critically endangered, endangered and vulnerable (see Burbidge et al., 1997). WATSCU now prioritises threatened taxa based on the IUCN categories and associated rule sets. However, the point scoring system is also used in some cases to help clarify the allocation of a taxon to the IUCN categories, particularly where the current quantitative thresholds used in the rule sets are considered inappropriate for the particular taxon. Long lived mallee eucalypts are a good example. Currently of the 327 taxa listed as threatened (Table 2), 95 are ranked as critically endangered, 128 endangered and 104 vulnerable.

Whether ranking poorly known taxa or threatened taxa, it was recognised that there will be some risk in allocating a taxon using empirical criteria to a particular group for prioritisation of resources. Final ranking will depend on the subjective assessment of the practitioners in the field, in either setting nominal rankings or interpreting linear ranking schemes. Lack of information, particularly for the poorly known taxa, may lead to an incorrect assessment of conservation status, but this is an inevitable consequence of dealing with a flora that is both diverse and poorly researched. Hence, the conservation status of populations may change dramatically in a short period of time as information is gained, so there needs to be flexibility in adding or deleting a taxon from a particular group.

Table 2
Summary of plant taxa with priority for conservation by Department of Conservation and Land Management administrative regions as at 15 July 1998

	Declared rare (threatened) flora		Priority codes				Total no. of taxa
Region	R[a]	X[b]	1[c]	2[d]	3[e]	4[f]	
Kimberley	3	0	36	36	25	4	104
Pilbara	2	0	33	35	35	6	111
Goldfields	8	0	72	37	34	17	168
Midwest	97	3	207	169	153	57	686
Swan	52	1	43	54	70	61	281
Central forest	41	0	28	35	54	43	201
Southern forest	18	0	20	55	38	28	159
Wheatbelt	97	10	101	139	126	71	544
South coast	82	6	113	206	144	96	647
Unknown	–	4	4	–	–	–	8
Western Australia[g]	327	23	591	640	477	251	2309

[a] R: Declared rare flora — extant taxa.
[b] X: Declared rare flora — presumed extinct taxa.
[c] 1: Priority one — poorly known taxa.
[d] 2: Priority two — poorly known taxa.
[e] 3: Priority three — poorly known taxa.
[f] 4: Priority four — rare taxa.
[g] Species may occur in more than one region.

3.2. Multiple taxon area-based strategies

An alternative approach to prioritising individual taxa is to consider geographical areas and rank such areas for conservation action based on the number of rare and threatened taxa they contain, and the level of threat posed by various threatening processes. A hierarchical approach has been used in area-based management focussing initially on the south-west Botanical Province because of its floristic richness, high level of endemism and widespread land clearing (See Brown et al., 1997). By assessing the distribution of rare and threatened flora and level of floristic richness within this region, area-based management programs were prepared and resources allocated to the highest priority areas.

Rare and threatened flora are concentrated in the south-west Botanical Province in the northern and southern sand heath plant communities, and in the shrublands and heathlands of the inland areas (Wheatbelt) (Fig. 3). In contrast the higher rainfall forest areas of the extreme south-west have far fewer rare and threatened taxa. Therefore, preparation of area-based flora management programs initially focussed on areas outside the forests. These programs considered all rare and threatened taxa within the specified geographical area. For convenience, the geographical areas chosen for this approach were the Department of Conservation and Land Management's administrative regions or districts (Fig. 3) which tend to represent areas of similar biogeography and land use. Each program prioritises

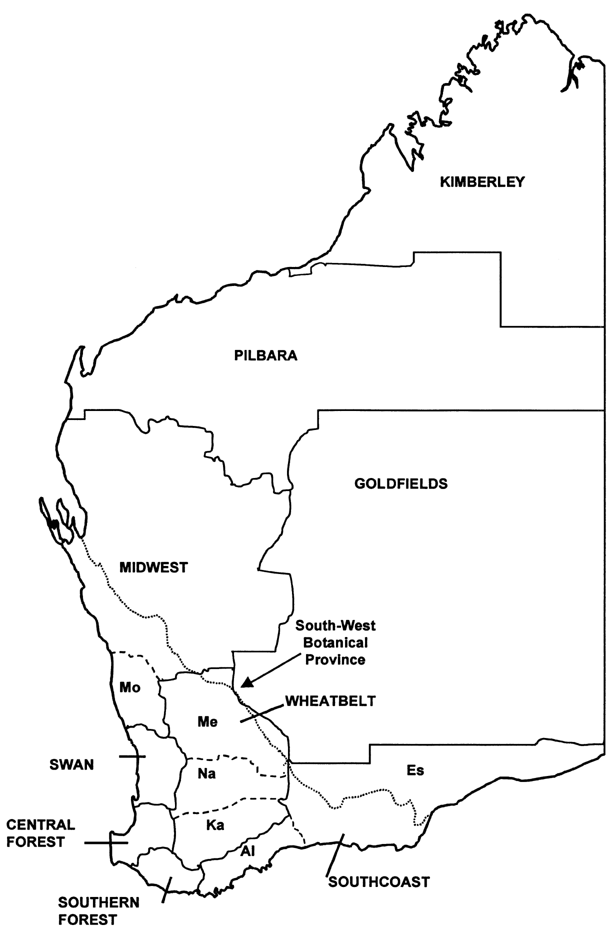

Fig. 3. Department of Conservation and Land Management Administrative Districts: Mo (Moora; northern sand heaths); Me, Na, Ka (Merredin, Narrogin, Katanning; wheatbelt); Al, Es (Albany, Esperance; southern sand heaths) for which area — based flora recovery programs have been developed in Western Australia. Department Administrative Regions and the boundary for the south-west Botanical Province are also shown.

individual threatened taxa and threatening processes for conservation action. To date, eight such management programs have been completed covering parts of the northern sand heaths (Kelly et al., 1990, 1993; Patrick and Brown, in press) the wheatbelt (Mollemans et al., 1993; Durell and Buehrig, in press; Graham and Mitchell, in press) and the southern sand heaths (Robinson and Coates, 1995; Craig and Coates, in press).

These area-based management programs can cover large geographic areas and include many Local Government Authorities and community groups. For example, the Merredin District (Fig. 3) where the first of these plans was implemented, covers an area of 77 000 km^2 of which 80% is used for agricultural purposes (Mollemans et al., 1993). In some shires, up to 97% of the original vegetation has been removed. When implemented, there were 33 threatened species targeted for management.

This area-based approach has some advantages in providing broader options for management in relation to threatening processes, although less detailed attention can be provided to any single taxon in the area the plan covers. Conversely, the joint management of clusters of threatened flora populations enables more effective, integrated management, and efficient use of resources. There is also a potential difficulty of ensuring liaison between different area-based plans in relation to the same taxon. However, this is generally a minor problem given the localised distribution of most taxa and the need to conserve each taxon over its entire range. In addition, species-specific recovery plans may still be produced for taxa identified in area-based plans where more specific recovery actions are required.

3.3. Population genetic structure and phylogeny

The ranking and prioritising systems described for taxa in the preceding section clearly rely on the accurate delimitation of taxa by botanists and assume that such taxa are appropriate units for conservation. Yet, in many cases population genetic and phylogenetic studies reveal additional levels of structuring within well defined taxa.

This indicates that conservation units or more specifically management units may exist below the taxon level as clusters of populations or individual populations (see Moritz, 1994).

The application of population genetic and phylogenetic studies to conservation can be both useful and informative in defining units for conservation and setting priorities for genetic resource management (Hopper and Coates, 1990; Avise, 1994; Moritz, 1994; Vogler and DeSalle, 1994; Coates, 2000). This is particularly evident in recent studies where there has been a far more rigorous approach to the practical application of genetic markers in conservation issues (see Moritz and Faith, 1998).

Recent population genetic and genetic system studies, specifically targeting endangered Western Australian flora, have provided critical information for the implementation of recovery programs. This information has been of particular value in the development of in situ and ex situ genetic resource management strategies (Sampson et al., 1990; Kelly and Coates, 1995; Stace and Coates, 1995), and in prioritising other management and research activities. These studies have highlighted both the natural disjunct pattern of many rare and threatened plant taxa in the south-west and the significant levels of genetic divergence which may be found between their populations (see Coates, 2000).

For example, rare and threatened eucalypt species with disjunct population systems such as *E. caesia* (Moran and Hopper, 1983) and *E. crucis* (Sampson et al., 1988) show substantial genetic differentiation between populations and population groups.

Similarly, *Acacia anomala* (Coates, 1988), *Stylidium coroniforme* (Coates, 1992), *Banksia cuneata* (Coates and Sokolowski, 1992) and *Lambertia orbifolia* (Coates and Hamley, 1999) all have geographically disjunct, genetically distinct population groups (Fig. 4). In these cases prolonged isolation and genetic drift readily explain the significant genetic differences observed between populations. For each of these species there are distinct population clusters which are considered separate management units for conservation.

The pattern of differentiation between populations is one of a number of aspects of the population genetic structure of a species which can be considered when assessing conservation priorities (Petit et al., 1998). Frequently, conservation genetic studies use reduction in genetic diversity and inbreeding to help identify populations at risk of extinction (see Avise, 1994). More specifically this information can be used to assess the population viability and recovery potential of small populations and to prioritise populations for enhancement programs or habitat re-habilitation (see Sampson et al., 1996; Young et al., 1997).

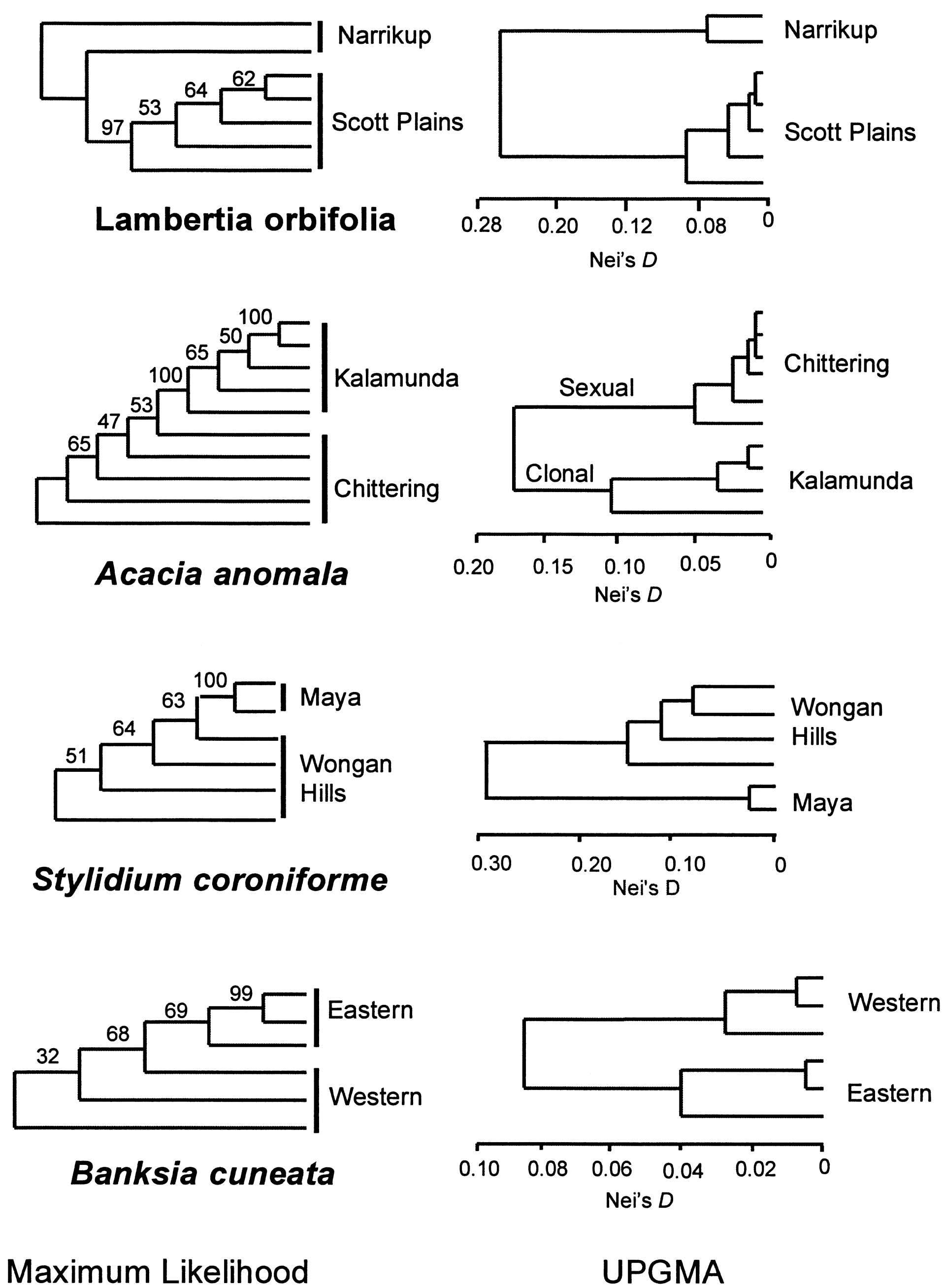

Fig. 4. UPGMA and continuous character Maximum Likelihood clustering of populations of the endangered species *Lambertia orbifolia, Acacia anomala, Stylidium coroniforme*, *Banksia cuneata*. Both methods result in the same clustering of geographically discrete groups of populations which are considered separate conservation units.

A feature of many rare and threatened plant populations in Western Australia is a substantial reduction in size due to habitat destruction and degradation. This would generally be expected to be associated with reduced levels of genetic variation (Karron, 1987; Barrett and Kohn, 1991; Young et al., 1997). Yet in a significant proportion of Western Australian flora this reduction has not been observed (Moran and Hopper, 1987; Coates, 1988, 1992; Coates and Hamley, 1999). There are a number of possible explanations. The decrease in population size in these species may not be great enough to affect the level of genetic variation, or there may have been insufficient time since recent fragmentation for genetic drift and increased isolation to lead to a detectable reduction in genetic variation. Alternatively, populations of many of these rare species may have always been relatively small and isolated, with the capacity to maintain high levels of genetic variability in association with extensive balanced polymorphisms (see James, 1996). Under these conditions James (1996) suggests that the evolutionary potential of these population systems may be severely diminished irrespective of their genetic diversity levels. Thus genetic diversity levels within populations alone may not necessarily be useful in prioritising populations for conservation in the flora of south-west Australia. A sound understanding of the genetic system and ecological dynamics of population systems may be far more critical.

Other factors associated with reduced population size and the prioritisation of populations are increased inbreeding, reduced fecundity and reduced progeny viability. For example, in the threatened species *Banksia goodii,* no seed production was observed, over a 10 year period, in the nine smallest populations which occur largely on narrow road verges (Lamont et al., 1993). It was suggested that the conservation of these small populations may be of far less value than a single large population of equivalent total population size. Field observations have shown that many other small roadside populations are also in decline, indicating that current recruitment regimes are not sufficient to maintain these populations.

In some cases reduced population size and habitat degradation is also associated with a change in pollinator abundance and behaviour apparently leading to increased inbreeding. Thus in the rose mallee (*Eucalyptus rhodantha),* a large increase in inbreeding, mainly due to increased self-fertilization, was found in a small remnant on cleared farm land (Sampson et al., 1989). The change in the mating system was attributed to the loss of potential mates and lower pollinator numbers. Pollinators were less likely to visit the remnant because the habitat destruction had removed other species which were sources of food and shelter. In addition, lack of corridors would be expected to restrict most pollinator movement between remnants.

Similarly, in *Banksia cuneata,* a highly disturbed remnant road verge population showed a significant increase in inbreeding compared with populations on relatively undisturbed sites. Coates and Sokolowski (1992) suggested that disruption of selection regimes, due to increased water availability from road runoff, had led to significant numbers of inbred progeny surviving to maturity and that mating between related plants was more likely. It was also proposed that a change in pollinator syndrome from birds to insects may have contributed to the increased inbreeding levels. In both theses cases, population management needs not only to consider genetic structure and the number of plants, but also the availability and abundance of pollinators, which in turn rely on the associated flora as a food resource outside the flowering season of the threatened species.

3.4. Threatening processes

Another approach to prioritising taxa and populations for conservation actions is to consider threatening processes, and focus resources on those processes considered to require immediate attention. Current major threats to threatened flora populations in Western Australia are shown in Fig. 5. The largest number of populations appear to be under threat because they are already thought to be critically small. It seems likely that short term catastrophic events, such as habitat destruction and degradation are likely to be more critical for initially setting conservation priorities than the medium term genetic and ecological consequences of small population size. However, given adequate protection from abiotic effects, there is still the need for a much better understanding of the ecological and genetic processes important for long term population survival.

Apart from those threats relating to small population size, three other major threatening processes are evident. These are, introduced weeds (particularly grasses), grazing by introduced domesticated and feral animals, and root rot (dieback) disease caused by *Phytophthora* species, particularly *P. cinnamomi*. Long term control of either weeds or *Phytophthora* in most affected populations is at present problematical, and both threats require major research and management resources. The increasing epidemic of destructive root rot disease caused by *Phytophthora cinnamomi* presents an ongoing and extremely serious threat to a significant portion of the flora and fauna of the south-west part of Western Australia. The epidemic is already well developed across extensive regions of the higher rainfall zone and in some areas has lead to the collapse of entire ecological communities. Although this presents a bleak outlook for a number of critical ecosystems and rare plant populations in this region, research over the last 6 years has provided some hope and optimism for the control of this disease. In particular, the use of phosphite in

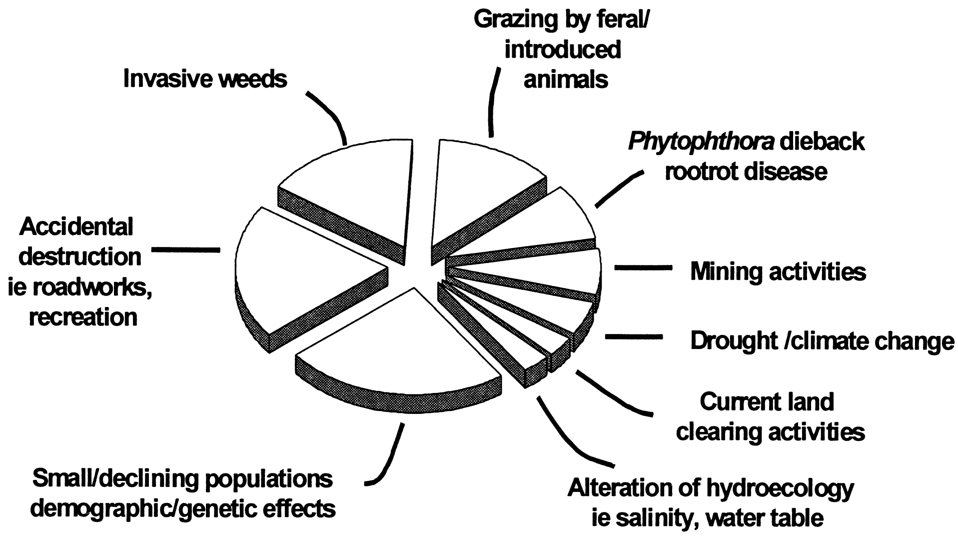

Fig. 5. Number of threatened plant populations in Western Australia considered to be at risk from nine major threatening processes.

reducing the rate of spread and protecting threatened ecological communities shows considerable potential (see Podger et al., 1996; Komorek and Shearer, 1998).

Other major threatening processes such as land clearing and subsequent altered hydroecology are currently considered to be lesser direct threats to rare and threatened plant populations. Yet the alteration to regional hydroecology, in particular, through rising water tables and increased salinity of water, is no doubt a major threatening process in relation to ecological communities in the agriculture areas of the south west (George et al., 1996). Although relatively low priority in the current conservation and management of rare and threatened flora, its overwhelming impact on native vegetation systems, and agricultural production, makes it one of the highest priorities for conservation action in the Western Australian wheatbelt. Furthermore, if remedial action is not implemented and stabilisation, or reversal, of hydrological trends achieved, many rare and threatened flora will eventually be affected. This example clearly demonstrates the importance of a multifaceted approach to setting conservation priorities. No single approach whether it be based on populations, taxa, ecological communities or threatening processes is likely to achieve the satisfactory conservation of Western Australia's flora.

4. Conclusions

The immense diversity within the Western Australian flora above and below the species level highlights the need for a rigorous approach to prioritising populations, species and ecological communities for conservation. There are many factors which influence flora conservation priorities in Western Australia. In particular lack of knowledge concerning location, population biology, life history and genetic systems often frustrates attempts to set priorities and long term goals. Clearly, a key to the prioritisation process must be flexibility as knowledge of the flora improves, new populations and taxa are discovered, and as individual threatened taxa are recovered.

Although there is some dependence on legal protection, conservation and management of the flora generally goes well beyond that required under the current legislation. Many issues of protection are currently being achieved through consultation, liaison and collaboration with other government agencies, private land managers, land owners and community groups. There is an increasingly positive response by all these groups to threatened and priority flora conservation with the majority of area-based management plan and recovery plan teams having representation from all groups particularly community groups.

We have reviewed four broad approaches to prioritising the flora for conservation. These considered individual taxa, groups of rare and threatened taxa, populations and threatening processes. The focus on single taxa, or small groups of taxa, and their populations has provided a major impetus for conservation of Western Australia's flora. Their use as "umbrella" species (Blyth et al., 1996; Coates and Atkins, 1997) in the conservation of associated ecological communities has been significant, particularly in the management of threatening processes and liaison with the many landholders and land managers. The issue of single threatened species conservation is readily grasped by the public and continues to provide a very important focal point for flora conservation in Western Australia. However, some suggest that such a focus may result in a disproportionate allocation of limited resources to rare and threatened species conservation, rather than protecting ecosystems and ecological communities (McIntyre et al, 1992; Bowman and Whitehead, 1990). Yet conservation is most effectively achieved at a number of different levels (see English and Blyth, 1999) and it is broadly accepted that threatened flora conservation is an essential component of biodiversity conservation (Blyth et al., 1996). Furthermore, we believe that there has not been a disproportionate allocation of resources to threatened flora conservation in Western Australia. It has also been addressed at both ecosystem and ecological community levels. For example, broad scale strategic biogeographic surveys over the last 15 years have provided the basis for the acquisition of large areas of land for conservation reserves in the largely undisturbed arid interior and parts of the semi-tropical north (see McKenzie et al., 1989; McKenzie and Belbin, 1991). More recently, flora conservation has been addressed in Western Australia through the development of a process of listing and prioritisation of threatened ecological communities (English and Blyth, 1999).

The current prioritisation process provides the framework for a strategic approach to the conservation of this flora and one of the highest priorities is the recovery of critically endangered flora. Yet the current listing of 95 critically endangered taxa involves the allocation of significant resources which will also require some prioritisation. Although recovery plans are in preparation or targeted for all critically endangered taxa in Western Australia, many are likely to go extinct without immediate remedial action. One action which shows considerable potential is translocation or re-introduction. It is becoming increasingly clear both in Western Australia (Rosetto, 1995; Monks and Coates, 1999) and in other parts of the world (see Falk et al., 1996) that translocations have a key role to play in averting the extinction of plant species. Over the next few years a major flora conservation challenge in Western Australia will be to determine which taxa should be the immediate target for translocations and how effectively translocations can be implemented.

The conservation of Western Australia's flora currently involves a range of approaches based on populations, taxa, ecological communities and biogeographic regions. Each approach has its merits depending upon land tenure, location within the State and in particular the level of land degradation. Broadscale reserve design and acquisition is an obvious approach to flora conservation in the largely undisturbed arid interior and parts of the semi-tropical north. In contrast, taxon and population based approaches provide a practical focus for flora conservation in many parts of south-Western Australia where extensive habitat loss has occurred.

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