Journal of the Royal Society of Western Australia, 79:241–248, 1996

Assessing the conservation reserve system in the Jarrah Forest Bioregion

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Abstract

Recent reviews have assessed the comprehensiveness of the conservation reserve system over the northern part of the Jarrah Forest Bioregion in terms of vegetation complexes. The complexes were distinguished in terms of geomorphology and dominant vegetation. The least reserved complexes are those of the Darling Scarp, Blackwood Plateau, Collie Coalfields and those with agriculturally desirable soils.

Available maps can be used to estimate the reserved area of each of the Bioregion's vegetation complexes or geomorphic units, but there are not enough data on patterns in biodiversity to assess other facets of its adequacy, even in the northern part of the region. A quadrat-based regional survey is necessary if the representativeness of the area's reserve system is to be assessed from an ecosystem perspective. The sampling would need to cover a range of the different components of the biota (perennial floristics, vertebrates and selected invertebrate taxa). Such surveys are time-consuming and expensive. Current studies of rare, restricted and endemic species, of weed, feral animal and pathogen impacts, and of forest management effects, need to continue in parallel.

A recent national assessment of the major gaps in Australia's conservation reserve network suggests that other Western Australian regions have higher priority for regional survey than the Jarrah Forest Bioregion. Seventeen of the State's 26 bioregions have a smaller proportion of their area reserved than the Jarrah Forest, and of these, 11 have a more biased reserve system. Should we commit scarce survey resources to the Jarrah Forest Bioregion?

Introduction

The high rainfall part of south-western Australia is covered by the Darling Botanical District (Beard 1982). This district is made up of the Swan Coastal Plain (Drummond Botanical Sub-district), the northern jarrah forest (Dale Sub-district), the southern jarrah forest (Menzies Sub-district) and the karri forest (Warren Sub-district).

We provide a brief review of the data that are available to assess the coverage of the existing conservation reserve system for the communities indigenous to the Dale and Menzies Sub-districts. Together, these two sub-districts form the Jarrah Forest Bioregion (Thackway and Cresswell 1995). We then describe and discuss previous assessments of the reserve system in this area.

Current knowledge

Beside bioclimatic surface models (Nix & Gillison 1985), various environmental maps at 1:250,000 scale cover all or most of the bioregion;

- surface lithology (Wilde & Low 1978, 1980; Wilde & Walker 1982, 1984),
- landforms and soils (Churchward & McArthur 1980; Churchward *et al*. 1988; Tille & Lantzke 1990; Churchward 1992). The 1:250 000 coverage is 90% complete whereas the 1:100 000 coverage is about 50% complete; R Harper, *pers. comm.*), and
- vegetation structure (Beard 1982; Heddle, Loneragan & Havel 1980).

At such scales, considerable heterogeneity is averaged within each map-unit.

There are also 1:25 000 Aerial Photographic Interpretation (API) maps of tree-canopy floristics, mapped at 1: 15 800 and ground-truthed along tracks and roads (F J Bradshaw *et al*., unpublished). They were produced by the Forests Department during the 1950s and 1960s, and cover virtually all the forested parts of the Bioregion except;

- parts of the far northern end (north of 31º 45' S, although Julimar State Forest was mapped), although the mapping has recently been extended,
- most of the eastern edge between 32º 00' S and 34º 30' S, although some parts, such as Dryandra State Forest, are covered by 1:15 800 scale "Mallet Classification" vegetation maps made during the 1930s, and
- the far south-eastern corner, east of 117º 40' E.

Most of the areas not covered at this scale are reserved for nature conservation and mapped at an equivalent scale, or are private land that is extensively cleared.

The mesic bioregions of south-western Australia are remote from their eastern Australian counterparts, being isolated by 2000 km of the semi-arid and arid environ-

Symposium on the Design of Reserves for
Nature Conservation in South-western Australia

ments that comprise districts such as the Nullarbor and the Great Victoria Desert. They contain many endemic species that are relicts from previously wetter and less seasonal climatic periods. Examples from the Jarrah Forest Bioregion include the frogs *Geocrinia alba* and *G. vitellina,* and the eucalypts Yarri (*Eucalyptus patens*), *E. relictua* and *E. virginia* (Wardell-Johnston *et al.* in press). Their vegetation and floristics have been reviewed by Havel (1975, 1989), Wardell-Johnson *et al.* (1996) and Wardell-Johnson & Horwitz (1996), and the rare flora by Kelly *et al.* (1990), while knowledge of the fauna has been reviewed by Wardell-Johnson & Nichols (1991), Abbott & Christensen (1994) and Wardell-Johnson & Horwitz (1996).

Several factors, including the isolation, the small area and previous climate changes, have lowered diversity in the larger indigenous vertebrates of the south-western forests, but the invertebrates and small vertebrates are rich in species (Wardell-Johnson & Horwitz, 1996). *In situ* speciation is real in the south-west, for the fauna as well as the flora; Havel and others have demonstrated a rich mosaic of landforms, soils and floristic variation in the jarrah forest despite the area's great structural homogeneity in vegetation, and Wardell-Johnson & Roberts (1993) concluded that the rich but fine-scale variation in soil and landscape properties maintains barriers between closely related frog species. A recently discovered frog, endemic to the Bioregion, is the most geographically restricted frog known from mainland Australia (Roberts *et al*., 1997).

It is clear that many scales should be considered in any discussion of conservation in the Jarrah Forest Bioregion. However, coordinated work on the distribution and biology of the naturally rare and of the restricted and endemic flora of the Bioregion has commenced only in the last decade, and most studies have focused on the central and northern parts of the bioregion. Systematically-gathered data are still too fragmentary to reveal their general patterns of occurrence.

Autecological studies of fauna have concentrated on vulnerable species, especially mammals that have become either extinct or rare outside the forests, woodlands and shrublands of the Darling District since European settlement (*e.g. Dasyurus geoffroii, Myrmecobius fasciatus, Bettongia penicillata, Macropus eugenii* and *Pseudocheirus occidentalis;* Burbidge & McKenzie 1989). The numbat study reported by Friend & Thomas (1995) is a good example. The first three species are now the subject of detailed management programs (*e.g.* Orell & Morris 1994; Start *et al.* 1995). Considerable research has also been carried out on *Macropus eugenii, Pseudocheirus occidentalis* and *Isoodon obesulus* (*e.g.* P de Torres, *pers comm.*) Detailed information has also been collected on the distribution and habitat requirements of some rare frogs (*e.g. Geocrinia alba* and *G. vitellina*), reptiles (*e.g. Ctenotus delli*) and birds (*e.g. Atrichornis clamosus*). While the critical requirements of some vulnerable vertebrates are still unknown (*e.g. Macropus irma* and *Setonix brachyurus*), research programs are now in-place. Recovery plans are now being implemented for others such as *Geocrinia alba* (Driscoll *et al.* 1995).

Most research on the disturbance ecology of flora and fauna in the Darling District has been directed to mining and rehabilitation, logging and regeneration, fire, plant disease and the introduced fox *Vulpes vulpes* (Wardell-Johnson & Nichols 1991; George *et al.* 1995, Abbott & Christensen 1996). Rehabilitation following bauxite mining has been studied in considerable detail (*e.g.* Nichols & Bamford 1985; Nichols & Watkins 1984; Majer 1990; Majer & Nichols, unpublished observations), as have the dynamics and management of dieback disease caused by *Phytophthora cinnamomi* in the jarrah forest (Shearer & Tippett 1989). Integrated studies have recently been commenced that will allow predictive-modelling of fauna responses following logging and burning in the jarrah forest (Wardell-Johnson & Nichols 1991; Friend 1993; K Morris, *pers. comm.*). Other studies are being undertaken to examine the occurrence of tree hollows in the forest and to determine the impact of timber harvesting on the availability of these hollows (Faunt 1992; Rhind 1996; K Whitford, *pers. comm.*). Clearing for agriculture (Beard & Sprenger 1984), exotic animals such as foxes (Kinnear 1993; Morris 1993; Friend *et al.* 1994), introduced weeds (Pigott & Gray 1993; Burke unpublished), and plant diseases such as those caused by species of *Phytophthora,* pose the greatest threats to the plant and animal communities of the Jarrah Forest Bioregion.

According to Burbidge & McKenzie (1989) faunal changes have not been as dramatic in the Darling Botanical District as in the pastoral and agricultural zones. Seven mammals, fifteen birds, two reptiles and three frogs from this district are currently gazetted as "fauna which is likely to become extinct or is rare"**.** Unfortunately, data on their distribution within the Jarrah Forest Bioregion at the time of European settlement are scant, vague and localised; even the sub-fossil record is fragmentary (A Baynes, *pers. comm.*). While some of these species were apparently rare or had restricted ranges in the bioregion originally, available records indicate that the ranges of most have contracted and / or become fragmented (*e.g. Bettongia penicillata, Setonix brachyuris, Macropus eugenii, Dasyurus geoffroii, Myrmecobius fasciatus, Pseudocheirus occidentalis, Trichosurus vulpecula, Leipoa ocellata, Dupetor flavicollis* and *Ninox connivens*). Wardell-Johnson & Nichols (1991) suggested that species with specialised habitat requirements and low dispersal abilities were the first to decline (*e.g. Macropus eugenii* and *Geocrinia alba*). Other species persist within the bioregion only at Two Peoples Bay (the bioregion's south-eastern margin), although they were recorded elsewhere in its southern parts earlier this century (*Potorous tridactylus*, *Psophodes nigrogularis, Dasyornis longirostris* and *Atrichornis clamosus*). The Western Bristlebird (*Dasyornis longirostris*) and Western Whipbird (*Psophodes nigrogularis*) also occur in the Esperance Plains Bioregion to the east.

The only likely mammalian extinctions have involved species of adjacent bioregions with ranges that extended into the periphery of the Jarrah Forest Bioregion; *Potorous platyops* and *P. tridactylus* on the bioregion's south-eastern periphery, and *Macrotis lagotis* and *Bettongia lesueur* along its eastern periphery. Leeuwin's Rail (*Rallus pectoralis*) is the only bird thought to have vanished from the Bioregion; it was only known from peripheral southern areas.

In explaining why the forested bioregions of the south-west have maintained more of their conservation values than the arid and semi-arid areas of Western Australia, the resilience of the forest is frequently cited (*e.g.* Underwood *et al.* 1991). This should not lead to complacency for there has been a rapid intensification of land-use demands in the Jarrah Forest Bioregion since the 1960s (Havel 1989). The end-results of more intensive use, including extensive clearing and urbanisation, have been documented in the adjacent Swan Coastal Plain (Drummond Sub-district), where 13 bird species declined in abundance in Kings Park between 1927 and 1988 (Recher & Serventy 1991), and at least 8 mammals are known to have become extinct (*Bettongia lesueur, B. penicillata, Macropus eugenii, Rattus tunneyi, Pseudomys fieldi, P. shortridgei* and *Notomys mitchelli*; Kitchener *et al.* 1978, and Western Australian Museum records).

In overview, many specialist projects have been carried out in the Darling Botanical District, but no attempt has yet been made to define the pattern of any group of biota (*e.g.* the plants or the vertebrates) throughout any of its four sub-districts. The most extensive quantitative studies so far have been of the vascular plants in the southern and central Drummond Sub-district (Gibson *et al.* 1994) and in the Tingle Mosaic (which overlaps with parts of the Warren and Jarrah Forest Bioregions; Wardell-Johnson *et al.* 1996), and of the wetland fauna of the Southern Forest Region (Horwitz 1994). Otherwise, current knowledge is summarised by the "Jarrah Book" (Dell *et al.* 1989) for the Dale Sub-district and by Wardell-Johnson & Nichols (1991) for parts of the Menzies and Warren Sub-districts. There is also considerable site-specific data for some localities such as the Worsley alumina leases of the eastern jarrah (Anon 1985) and of the alternative water supply sites (Anon 1987). Existing information is sufficient to demonstrate areas of high mammal richness such as the proposed Perup Nature Reserve (Anon 1987a), and some sites of high endemism, but does not allow an explicit understanding of the overall patterns of the biota across the study area.

Reserve system assessments

Existing network. The existing conservation reserve system, developed through the work of Havel (1975), is described by Anon (1987b) and Heddle *et al*. (1980). It comprises National Parks, Nature Reserves and "conservation parks". In previous reviews of the forest reserve system, some of the "conservation parks" were Management Priority Areas (MPAs), but were treated as conservation reserves because the relevant lands are to be

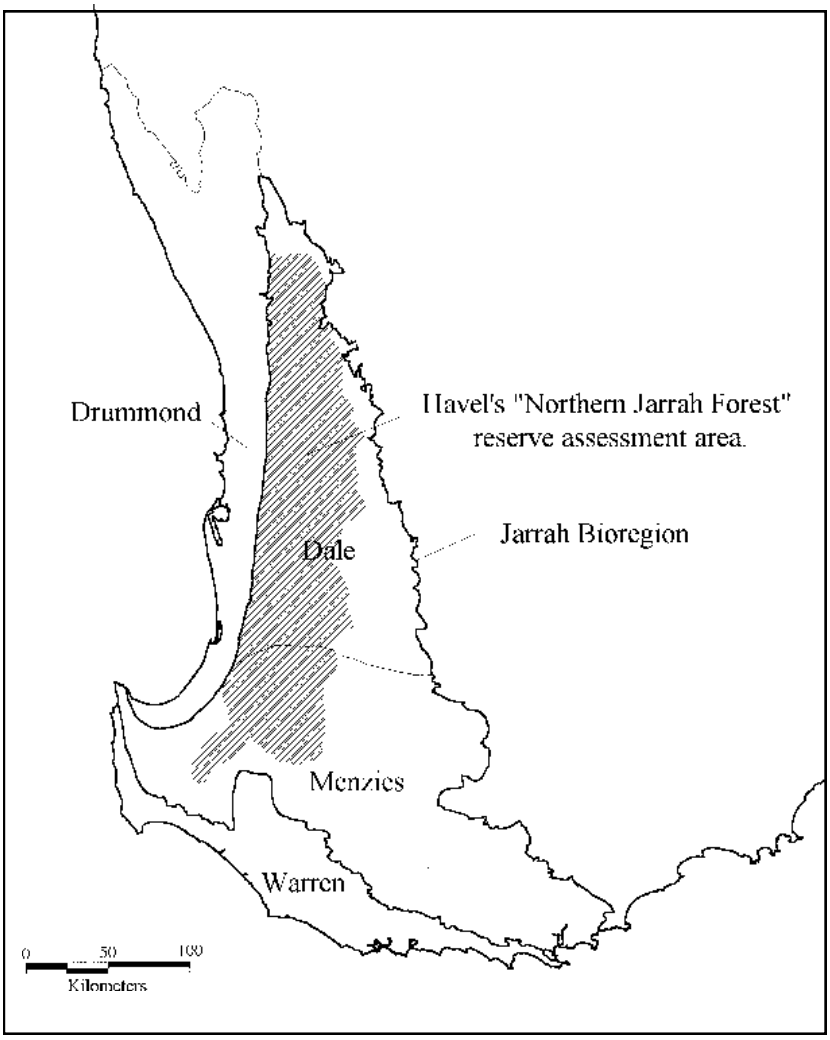

Figure 1. The Jarrah Forest Bioregion showing subdistrict boundaries and Havel's "northern jarrah forest".

vested in the National Parks and Nature Conservation Authority. Subsequently, these MPAs were enlarged and inter-connected as a series of "proposed Conservation Parks".

The formal "Conservation Park" legislation is now in place, so the proposals that have been gazetted (virtually all) are conservation reserves for the purposes of this review. We have also included Lane Poole Reserve, which was declared in 1987 under Section 5g of the *Conservation and Land Management Act*. It should be noted that both the Conservation Parks and "5g" reserves in this region retain the optional purpose of bauxite mining.

Figure 1 shows the Jarrah Forest Bioregion, with the "northern jarrah forest" cross-hatched to show the area that Havel assessed (modified from Havel 1989, and as mapped on page 394 of Dell *et al.* 1989).

Land-classes. Heddle *et al.* (1980) integrated available climatic, floristic, geomorphic and vegetation structural data to produce a set of three maps showing vegetation complexes at a scale of 1:250 000. Havel (1989) concluded that maps such as these "*... are, in fact, the only basis on which adequacy of coverage* [by the conservation reserve system in the forested regions of south-western Australia] *can be assessed at present*". Wardell-Johnson & Nichols (1991) reached a similar conclusion.

Given this basis, the comprehensiveness of the reserve system was assessed as early as 1980 (Heddle *et al.* 1980). Havel (1989) reviewed and updated this analysis (Table 1), concluding that there was no representation of those vegetation complexes in the northern jarrah forest that are centred in the adjacent regions and have been desirable aquisitions for agriculture since European settlement (Helena, Williams River). The Forrestfield vegetation complex, which straddles the western edge of the Jarrah Forest Bioregion, and Cardiff (on the Collie Coal measures) were also unrepresented.

Table 1

Percent of the total area of the northern jarrah forest's vegetation complexes that are within reserves (from Havel 1989 and Anon 1994)[1]. Neither list of percentages corresponds exactly to the Jarrah Forest Bioregion (see Fig 1)[2].

Vegetation Complex	% Representation in reserves (Havel 1989)	% Representation including new reserve proposals (Anon 1994)
Helena (L/M)	–	25.5
Williams	–	0.9
Lowden	0.2	5.8
Darling Scarp	1.5	3.8
Michibin	3.5	9.0
Wilga	3.8	13.4
Muja	4.3	3.0
Cardiff	–	–
Coolakin (L)	7.5	17.4
Dwellingup (H)	6.0	6.5
Yarragil (M/S)	5.7	6.7
Murray (L/M)	8.7	10.6
Murray (M/H)	8.9	18.1

[1] In the National Forest Policy terminology (NFPS 1992), this assessment relates to the reserve system's "comprehensiveness" and, in part, its "adequacy" rather than to its "representativeness"; [2] The figures in column 1 are based on mapped vegetation complexes within the System Six boundary (see Anon. 1993). The figures in column 2 are based on the total area of vegetation complexes depicted in maps published by the former Department of Conservation and the Environment (Heddle *et al.* 1980). The issue of conservation reserves in the Collie Coal Basin is being addressed by a detailed "Structure Plan". Complexes in the Drummond Botanical Sub-district (Swan Coastal Plain Bioregion) are excluded because they are outside the scope of this review.

Havel's analysis also showed that the agriculturally-desirable complexes centred in the northern jarrah forest had less than 5% representation (Wilga, Lowden, Michibin and Darling Scarp), as did the Muja vegetation complex of the Collie Coal Basin. Furthermore, Collie (the third complex of the Collie Coal Basin) was 5-10% reserved, as were the remaining complexes listed in Table 1, from:

- the lateritic uplands and shallow valleys in the western high rainfall zone — Dwellingup and Yarragul respectively.
- rocky valleys in the eastern low rainfall zone; Coolakin, and
- deep major river valleys; Murray (L/M) and Murray (M/H).

Havel (1989, pp 387-89) showed that the rest of the vegetation complexes had higher percentages reserved. These included the complexes;

- on lateritic uplands of the low to medium rainfall zone, and in the shallow valleys and depressions in the high to moderate rainfall zone (10 - 15%);
- on uplands and in the shallow valleys of the eastern low rainfall zone, and
- on infertile sands, steep rocky slopes of the monadnocks and swampy headwaters of the streams, as well as certain complexes of eastern dry lateritic uplands and of the deep valleys in the medium to high rainfall zone (20%+).

Generally, the coverage by conservation reserves within the forested landscape was found to be greater in the east than in the west of the region, and better on the extreme and less productive parts of the landscape than on the more productive ones. Historically, alienation for agriculture preceded both conservation and forestry, thereby limiting the opportunities for subsequent reservation.

Anon (1994) updated Havel's analysis, although somewhat different study area boundaries were used (Table 1). Since these assessments, the coverage of suitable environmental maps has been extended across the Blackwood Plateau and Manjimup areas in the south-west of the Jarrah Forest Bioregion (Tille & Lantzke 1990 and Churchward 1992, respectively), and through south coastal areas from Northcliffe to Manypeaks (Churchward *et al.* 1988) which includes the south-eastern corner of the Jarrah Forest Bioregion. In broad geographical terms, the currently recognised forest, woodland and shrubland communities that are least conserved by reserves are those:

- on the western margin of the Dale Sub-district (=Darling Scarp),
- agriculturally desirable surfaces throughout,
- the Collie Coalfields, and

- the north-western 30% of the Menzies Sub-district (=Blackwood Plateau) (Havel 1989 p 387; Keighery 1990).

Discussion

Gradients in community species composition

The problems of "land-class" approaches to reserve assessment mainly derive from assumptions of homogeneity and determinism, and have been reviewed by McKenzie *et al.* (1989). Intuitive regionalisations (land-classes such as land-systems, land-units and structurally based vegetation complexes) allow large areas to be surveyed quickly and are objective (Pressey & Nicholls 1991), but are insufficient from a biodiversity perspective because they usually reflect some mixture of vegetation patterns, topography, lithology and/or climate. This does not necessarily reflect the pattern of the entire biota (or even an "averaged" pattern), and does not quantify or map internal heterogeneity (McKenzie 1984; Margules *et al.* 1991; Pressey & Bedward 1991; McKenzie *et al.* 1992). In fact, land-classes are unlikely to be internally homogeneous and their boundaries may not be meaningful for many of the species in the region. The approach lacks spatial resolution because the relationships between the four layers (vegetation, topography, lithology and climate) are usually undefined in quantitative ways, and attributes such as species are not necessarily present at any point at any one time. This means that the generated data-base is intractable for more detailed analyses of ecological patterns. At fine scales, intuitive regionalisations also assume that compositional patterns are static, which they certainly aren't for mobile vertebrates.

Thus, land-class approaches provide only a first approximation of biological diversity patterns, and the reserve network should be subsequently refined using the ecological realism offered by quadrat strategies of data acquisition (McKenzie & Sattler 1994). Point data-sets derived from quadrat sampling strategies provide the spatial resolution that is needed to address the continuous gradients underlying ecological patterns, and allow us to compare sites quantitatively (Margules & Austin 1994). These data allow species with similar responses to environmental attributes to be clustered so that patterns in species composition across landscapes can be modelled for reserve design, and the predictions can be tested (Margules & Nicholls 1994; McKenzie *et al.* 1989 1991). Although quadrat sampling strategies are slow and expensive, significant cost-savings are offered by "gradsec" approaches to quadrat stratification (Gillison & Brewer 1985; Austin & Heyligers 1989) that systematically sample regions along major environmental gradients.

Quadrat data from surveys in different study areas (*e.g.* districts) can be combined into a geographically more extensive data-base without loss of spatial resolution, and quadrat-data also provide a basis for monitoring future changes (McKenzie *et al.* 1991a).

Jarrah forest context

The recent reviews of the conservation reserve system in the northern jarrah forest have concluded that a thorough assessment of this reserve system's coverage in terms of the study area's biodiversity was not possible with available data (Havel 1989; Wardell-Johnson & Nicholls 1991). Havel (1989, p. 389) pointed out;

> *The already barely adequate representation of Yarragil (M/S) becomes even more critical when it is recognised that some of the component site-vegetation types, such as W and D, occur in topographical positions which render them susceptible to dieback infection, and contain a number of species which are highly vulnerable. This is also true of the Muja and Collie vegetation complexes.*

According to the National Forest Policy Statement (NFPS 1992, p. 49) forest reserve systems should be assessed using three criteria;

1. comprehensiveness: include the array of community-types,
2. adequacy: ecologically viable and maintain integrity of populations, species and communities, and
3. representativeness: reasonably reflect the biotic diversity of each community.

While contemporary reserve selection algorithms can use land-class data to address "comprehensiveness" (Pressey & Nicholls 1989, 1991), data with more spatial and biological resolution are required to address "adequacy" and "representativeness" (Margules *et al.* 1991; Woinarski & Norton 1993; McKenzie & Sattler 1994).

Detailed knowledge of species biology and community dynamics and regional context are required to assess adequacy. Standardised, point-based data-sets that encompass a wide variety of organisms are required to assess representativeness. Wardell-Johnson & Nichols (1991) discuss this subject in a south-western forest context. While such data sets have been collected in parts of the forest (*e.g.* at Boddington, Worsley 1985), the problem is that they are too localised, and/or limited to a particular sort of organism (*e.g.* endangered plants, Kelly *et al.* 1990; birds, Wykes 1983; ants, Majer 1980).

Havel (1975) collected the most geographically extensive point-based data set, but his sampling concentrated on uplands and was confined to a selection of perennial plants. Granite outcrop, alluvial flat and heathland communities were under-represented, while annuals, perennials such as orchids, vertebrates, invertebrates, and the rarer components of the flora were all ignored (Havel 1989, p. 384).

Conclusion

We concur with previous reviews - the reserve system has already been assessed in terms of its comprehensiveness over most of the Jarrah Forest Bioregion. As yet there is no quantitative basis for assessing the reserve system's representativeness in terms of the jarrah forest's biodiversity at a level equivalent to that now possible in remote areas such as the Nullarbor (McKenzie *et al.* 1989), Western Australia's Eastern Goldfields (*e.g.* How *et al.* 1988; Burbidge *et al.* 1995) and Kimberley rainforests (McKenzie & Belbin 1991), and South Australia's Gawler Ranges (Robinson *et al.* 1985).

A quantitative biogeographical survey would provide a model of the area's biological patterns from an ecosystem perspective. Such a survey would be quadrat-based and cover the major geological and geographical gradients in the area. At each quadrat, detailed sampling would need to cover different components of the biota that could be reasonably expected to be responding to different scalars. Typically such a survey would include vascular flora, small mammals, birds, reptiles and amphibians and selected invertebrate and cryptogram groups for which a good taxonomic basis exists.

Such data allow the development of regional models of gradients in the species composition of communities (quantified regional contexts) and allow decisions concerning land-use and management to be more explicit (McKenzie 1988). Such an approach would allow a more representative regional conservation network to be designed, one that could be expected to better represent the genetic resources of the widespread elements of the biota. It would not achieve adequate representation of the rare or restricted elements of the biota, for which the program of specific studies will need to continue in parallel.

Regional priorities have to be considered in proposals for major biogeographical surveys. There are 25 other biogeographical regions in Western Australia, and large-scale biogeographic surveys are expensive in terms of time, and in human and financial resources (Burbidge 1991). In the last 15 years it has not been practical to conduct more than one such survey at a time. Each survey requires up to 15 people during the fieldwork, and five people during the analysis and write-up phase for a period of 3 to 5 years. Recent analysis of the reservation status within the 26 bioregions recognised in Western Australia (Thackway & Creswell 1995) showed that 17 have a smaller proportion of their area reserved than the Jarrah Forest Bioregion, and 11 of these have a more biased reserve system (this means that entire sub-regions, or many of the extensive ecosystems that characterise a region, are missed). All of these regions can be considered much less resilient than the Jarrah Forest Bioregion.

From a biodiversity perspective at a state-wide scale, the Jarrah Forest Bioregion does not have a high priority for ecological survey. Nevertheless, the appraisals reviewed in this paper have identified gaps in the existing reserve system, even at the level of its comprehensiveness. These gaps relate to certain vegetation complexes on the Darling Scarp, the Blackwood Plateau, the Collie coalfields, and on agriculturally desirable soils. They should be addressed as a priority during the implementation of the National Forest Policy Statement (NFPS 1992).

Acknowledgements: We thank I Abbott, A Burbidge, A Hopkins, N Marchant and G Stoneman for their helpful comments on the draft. This review was updated from notes compiled in 1991 by N L McKenzie, S D Hopper and G Wardell-Johnson.

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