Biodiversity in New Zealand plantations

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ABSTRACT

A common view that New Zealand's plantations are monocultures reflects negatively on forestry as a land use. This paper evaluates components of biodiversity in plantations by addressing two questions: 1) are plantations biological deserts?; and, 2) how does plantation management influence species composition? An ecological perspective is presented showing the relevance of human-induced ecosystems to the maintenance of biological diversity, and illustrating the value of compositional information to other facets of plantation management.

INTRODUCTION

Declining biodiversity has recently emerged as a global environmental issue. Biodiversity may broadly be defined as "the variety and abundance of species, their genetic composition, and the communities, ecosystems, and landscapes in which they occur" (Society of American Foresters 1992). Reasons for conserving biodiversity include its role in providing current and future resources (e.g., genetic), its innate value, and its contribution to overall environmental quality (see Spellerberg and Sawyer 1993). Of a more tangible nature, it has recently been demonstrated, under controlled environmental conditions, that biodiversity influences ecosystem processes, and in particular that increased levels of biodiversity can result in higher plant productivity (Naeem *et al*, 1994).

Pressure for conservation of biodiversity resulted in the 1992 Convention on Biological Diversity, to which the New Zealand Government is a signatory. On a national scale, the Government has demonstrated its concern about such environmental issues by developing new legislation relevant to land use (e.g., Resource Management Act 1991). A result is that impacts of land management on biodiversity may be a consideration in obtaining resource consents. Recognition of this in relation to plantation management is considered by recent articles in this journal (e.g. Perley 1994) and in forest industry association magazines.

One response to the biodiversity issue may be to consider it irrelevant, as plantations have been developed as 'wood factories'. Internationally forestry is, arguably, subjected to closer scrutiny than other forms of land management, and environmental concerns exert pressure on all aspects of forestry, and increasingly trade in forest products. Plantations are a comparatively new component of the New Zealand landscape, and this, coupled with their predicted rapid expansion, will result in increased public interest in their management. For example, increasing plantation area will expand the opportunities for new species assemblages to occur. These assemblages will include as yet unknown combinations and proportions of exotic and indigenous species, and, at least in the view of some, add value to the estate in terms of biodiversity. Although the New Zealand Government rejected multiple-use forestry concepts in the 1980s, environmental issues (e.g., carbon storage, biodiversity, catchment water yields) are resulting in this type of management re-emerging. Multiple-use forestry is now taking a legislative form that will allow it to be applied to the largely privately owned plantations. As a consequence, the 'wood factory' view is unlikely to be tenable in the longer term.

A more acceptable, strategic response to the biodiversity issue may be to evaluate what we know about specific concerns in plantations and how this may guide management. The view that plantations are biological deserts contributes to a negative sentiment about forestry as a land use (e.g. Whitehead 1982; Rosoman 1994). A major concern revolves around the nature of species assemblages found in New Zealand plantations, and suggests two obvious questions: 1) are plantations biological deserts?; and, 2) how does plantation management influence species composition? Informed debate on these questions and the incorporation of biodiversity considerations in land management requires input from a range of disciplines (e.g., taxonomists, ecologists, resource managers). This article presents an ecological perspective on these questions, showing the relevance of human-induced ecosystems to maintaining biological diversity and illustrating the value of compositional information to other facets of plantation management.

ARE PLANTATIONS BIOLOGICAL DESERTS?

In contrast to preconceptions that New Zealand plantations are biological deserts, the few studies undertaken have reported a diverse range of biota (e.g., Henry 1954; McQueen 1961; Clout and Gaze 1984; Norton 1989; Figure 1). This has been noted elsewhere, such as in British plantations, where canopy invertebrates can be both abundant and diverse (Tickell 1994).

One context in which to examine whether New Zealand plantations are really low-diversity systems is to compare quantitative data on biodiversity parameters, such as species richness (number of species at a stand scale), from plantations with data from other ecosystems that represent alternative land uses. Ogle (1976) described greater indigenous plant species richness in Coromandel Peninsula sand dune plantations than in nearby manuka-bracken communities on dunes. Allen *et al* (submitted) have analysed species richness within second and third rotation *Pinus radiata* compartments in Kinleith Forest, where mean numbers of vascular plant species per stand were 35, 23, and 25 in compartments planted one, 13, and 29 years ago respectively. These values are in fact moderately species rich for New Zealand forests. For example, using similar methods, simple mountain beech forest *(Nothofagus solandri)* in the Canterbury mountains may average nine species (R.B. Allen and K.H. Platt, unpubl. data), mixed beech forest may average 10 to 25 species along rainfall and elevation gradients in South Island mountains (Wardle 1984), whereas low-elevation North Island conifer broadleaved-hardwood forests may average 50 species (S. Clegg, unpubl. data).

Moderate species richness in Kinleith Forest stands may be maintained by the proximity of a range of seed sources (e.g. indigenous forest, agricultural lands) and frequent disturbance by forestry operations resulting in a diverse range of habitats. Greatest species richness was found in the youngest Kinleith Forest

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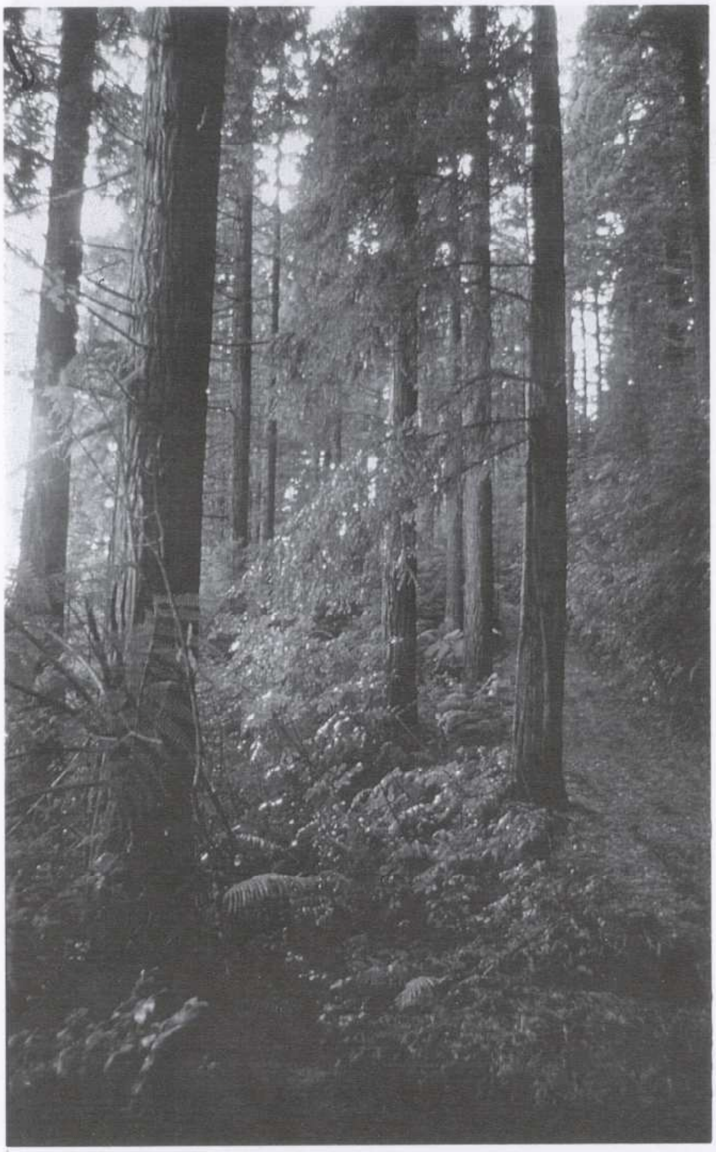

Figure 1. A well developed redwood understorey near Green Lake, Bay of Plenty. The dominant vascular plant species present are indigenous shrubs and tree ferns. (Manaaki Whenua – Landcare Research photo-library)

compartment and supports a view that even extreme disturbances, such as harvesting and site preparation, can create opportunities for many species to establish (Figure 2). Such data are consistent with the emerging view of ecologists that principal factors contributing to high local diversity include disturbance frequency and spatial heterogeneity (e.g., Connell 1978; Attiwill 1994). This contrasts with earlier ecological ideas (e.g. Odum 1969), and a common misconception, that ecosystem stability usually leads to high diversity.

Figure 2. A diverse assemblage of vascular plant species found in a Kinleith Forest compartment one year after site preparation and planting; a high proportion of which are indigenous (e.g., *Pomaderris philicifolia* var. *ericifolia* and *Deyeuxia avenoides*).

Another perspective on whether plantations are biological deserts is the degree to which they support indigenous species. In New Zealand plantations a high proportion of vascular plant and bird species can be indigenous. Clout and Gaze (1984) recorded between 38% and 53% of bird species as indigenous in northern South Island exotic plantation stands, whereas 58% to 65% of species were indigenous in nearby native forests. Allen *et al* (submitted) found a high proportion of indigenous plant species (67%, 73%, and 82% in the Kinleith Forest one, 13, and 29 years old compartments respectively) in plantations. This does not necessarily mean, however, that vascular plant species assemblages will be close analogues of indigenous forests on nearby sites. Even if indigenous plantations were to be developed this might be a stringent expectation, as some ecologists question the existence of species association principles that dictate a specific composition (Wilson 1991).

Much of the interest in indigenous species also focuses on the presence or absence of specific taxa. A well-known example is the attention given rare orchids that are found in plantation forests (Johns and Molloy 1983; Wilson and Given 1989). Interestingly, Rooney (1989) has described rare naturalised plant species as occurring in plantations. Presumably this is because plantations have increased the limited range of sites with environmental conditions appropriate for the growth of such species. In some instances plantations clearly do not provide suitable conditions for particular groups of species. Clout and Gaze (1984) considered birds that were frugivores, nectar feeders, and hole-nesters did not find suitable habitat in plantations. Possibly the only way to incorporate such guilds within plantations is through specific management practices that provide appropriate habitats.

HOW DOES PLANTATION MANAGEMENT INFLUENCE SPECIES COMPOSITION?

Within a single rotation, changes in species composition on any site reflect general processes operating during forest development (e.g., Peet 1992), as well as the impacts of silvicultural manipulations (e.g., Spellerberg and Sawyer 1993). Forest ecologists have devoted considerable energy to determining developmental processes occurring in unmanaged forests following disturbance. On favourable sites compositional development can be described in a four-stage model (Oliver 1980; Peet 1992). The first stage is one of extensive establishment by species and little competition between trees. Species richness is often high and composition is unpredictable. During the second stage there is intense competition and thinning amongst the established trees, competitive sorting results in fewer species and a more predictable composition as species are confined to habitats suitable for their growth. In the third stage, mortality exceeds the ability of established trees to fill canopy gaps and further recruitment is possible. The fourth stage is a form of steady state in which mortality is balanced by recruitment, and this can be associated with increasing species richness.

Silvicultural manipulations within a rotation modify these developmental processes and influence species composition, including the weedy component. Harvesting and site preparation represent an extreme disturbance, with crop felling followed by the application of non-selective herbicides. As indicated above, vascular plant species richness was high one year after such treatment in a Kinleith Forest compartment (Allen *et al,* submitted), and primarily due to the establishment of many weedy species. The Kinleith Forest study also suggested that the predictability of composition was low in the early stage of forest development:

this has important implications for our ability to develop models of weed distributions. Thinning of crop trees alters the second stage outlined above by reducing tree competition and maintaining high light levels in the understorey environment. This may reduce the influence of the competitive stage in lowering species richness, including that of weedy species. McQueen (1973) showed that late thinning of *Pinus radiata* in Kinleith Forest allowed the re-establishment of vascular plants including *Coriaria arborea*, an indigenous N-fixing species, in the understorey. Rotation lengths used in plantation management as practised in New Zealand are shorter than the time to reach the third and fourth stages outlined above. This does not allow time for immigration of species that are slow to disperse, nor for certain habitats to develop (for example large dead snags) that are necessary for some species to establish.

Species compositional changes within a rotation also vary spatially, in part because developmental processes and the influence of silvicultural manipulations differ with site conditions. The range of possibilities within a compartment can be described by underlying compositional gradients. Within Kinleith Forest compartments, the dominant gradient in vascular plant species was strongly related to topographic position (i.e., from riparian areas to ridge crests), which also correlates with mineral soil total phosphorus (Allen *et al,* submitted). Few species were in common between sites found at gradient extremes, supporting a view that protecting specific habitats (riparian areas) maintains only part of the biodiversity. These compositional gradients, and their relationships to site differences, provide a framework to understand biodiversity patterns, including weed distributions. For example, *Rubus fruticosus* (blackberry) and *Buddleja davidii* were more frequent on ridge crests than on sheltered sites in the youngest Kinleith Forest compartment studied, whereas *Pteridium esculentum* (bracken) is bimodally distributed, being less common on mid-slope positions (Figure 3). This bimodality may be a consequence of competition with other species (Økland 1990). If so, removing the competitor could increase the importance of bracken.

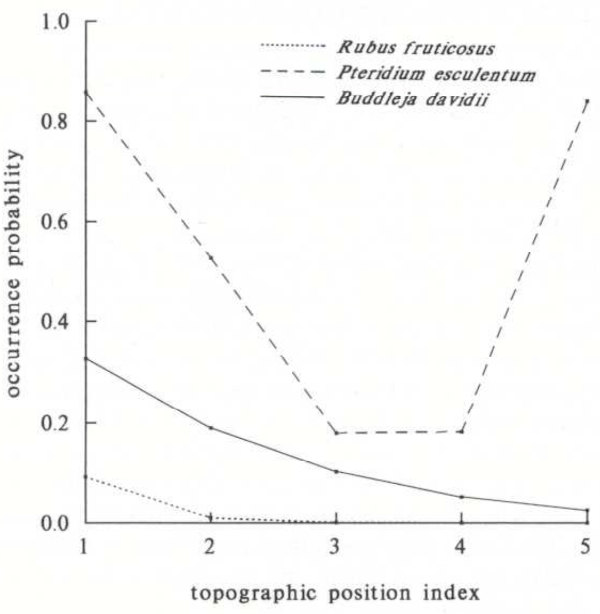

Figure 3. Probability of blackberry (P<0.001), bracken fern (P<0.05), and *Buddleja davidii* (P<0.05) occurrence along a topographic gradient, based on data from 38 vegetation plots located in a *Pinus radiata* compartment in Kinleith Forest one year after site preparation and planting. Topographic position ranges from ridges (1), through convex, flat, and concave slopes, to valley bottoms (5). Probability of occurrence fitted using generalised additive models, which do not require parametrically defined relationships between predicted variables and fitted values (Yee and Mitchell 1991).

Figure 4. Aerial view of Kaingaroa Forest as a mosaic of compartments varying in silvicultural history and site conditions. Such a system forms a useful framework for studying land management impacts on biodiversity and concepts about plant succession. (Manaaki Whenua – Landcare Research photo-library).

Compositional patterns may also be considered at larger spatial scales than compartments, and longer temporal scales than within a rotation. Plantations are complex landscapes with a mosaic of stands that make up compartments differing in distance and connectivity (by riparian areas or road verges) to other types of ecosystems (e.g., indigenous forest or plantings of various ages). Species life history attributes, such as dispersal abilities and length of time plant seed remains viable, will influence composition at the landscape scale and must be taken into account in any attempt to model overall biodiversity patterns. In Kinleith Forest, some of the indigenous plant species that characterised the pre-planting shrubland (70 years ago) now exist only in recently harvested areas (e.g., *Moreolotia affinis*). This includes compartments at the beginning of the third rotation, and results in questioning how similar is species composition during forest development between successive rotations. Interestingly, vascular plant species composition in Kinleith Forest towards the end of the first rotation was similar to that towards the end of the second rotation (McQueen 1961; Allen *et al,* submitted).

CONCLUSIONS

- The limited quantitative information available suggests that plantations sometimes contain diverse species assemblages, including a high indigenous component. However, a fuller evaluation requires sampling of a wider range of organisms and ecosystems. Plantations are now mostly being established on marginal farmland, and it would be useful to compare their species composition with plantations on similar sites, as well as with indigenous forests.
- The issue of biodiversity in plantations is complex, and its understanding requires more sophisticated approaches than have usually been applied. In fact, plantations provide a very useful system for such research because they contain a network of compartments, with a known age and silvicultural treatment, that form a useful sampling framework (Figure 4).
- Compositional patterns provide information relevant to other facets of forest management. For example, weed distributions in plantations may be understood by using community ecology approaches to study their habitat requirements.
- More robust guidelines on the biodiversity issue are required for forest managers and regulatory agencies (see Spellerberg and Sawyer, this issue).

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