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Assessing the Sustainability of Private Native Forestry using Biodiversity Surrogates and Metrics

by Ross J Peacock

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Foreword

Biodiversity surrogates and their compiled metric scoring systems are increasingly used by governments to monitor compliance with environmental standards and certification schemes, and to direct natural resource management investments to on-ground activities. Biodiversity surrogates and related metrics were developed as techniques to rapidly assess vegetation condition and to rank the expected habitat biodiversity value. The metrics include assessment of forest stands relative to regional benchmarks, and the connectivity to nearby remnant vegetation. However metrics such as *Habitat Hectares* and *Biometric* were designed to assess changes in land use, for example vegetation clearing, rather than changes in intensity of land use or forest changes over time. This is a concern when private native forest owners wish to manage their forest for production, while complying with State vegetation management guidelines.

This report uses four case studies in northern NSW, eastern Victoria and southern Tasmania, to examine the applicability of biodiversity metrics to assessing the ecological sustainability of private native forestry under different forest management inputs. The report will be useful to policy makers, private and public forest managers and researchers who are required to test, evaluate or benchmark their forest management activities against sustainability criteria which use biodiversity surrogates or metrics.

The project found that the scoring systems examined had some ability to describe gross changes in habitat following timber harvesting, but lacked the desired sensitivity and parameters to specifically address broader forest management sustainability criteria. It also found that different assessment outcomes can potentially occur using these metrics, depending on the landscape position or regional context of the vegetation being examined, and the metrics may not reflect the actual ecological outcomes which follow timber harvesting. A number of the surrogate measures examined, for example tree hollows, the presence of large trees or large diameter fallen logs, and several of the understorey life forms, were useful in discriminating between sites with different forest management treatments.

Ideally, new biodiversity metrics should be designed for application in a forest management framework. These need to be more inclusive of parameters such as desired stand structures, growth rates, forest product volumes, and tree and habitat feature regeneration. New surrogate variables which are relatively simple to measure, such as an expression of tree diameter distribution or diameter class diversity should now be examined for their sensitivity to forest management inputs. Surrogate measures and their metrics should ideally also incorporate a component of a market-based instrument which recognises and rewards the environmental benefits that flow from sustaining a broader suite of biodiversity components within a productive private native forest.

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This report is an addition to RIRDC's diverse range of over 1700 research publications. It forms part of our Agroforestry and Farm Forestry R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems. The JVAP, under this program, is managed by RIRDC.

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Peter O'Brien

Managing Director,

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Executive Summary

What the report is about

Biodiversity surrogates and related metrics are techniques which have been developed to rapidly assess vegetation structural and compositional status and to score or rank expected habitat biodiversity value. The metrics include assessment of forest stands relative to regional benchmarks, and the connectivity to nearby remnant vegetation. This report examines the applicability of biodiversity surrogates and their compiled metric scoring systems to assessing forest condition, and hence the ecological sustainability, under different forest management inputs. Four private native forest case studies were examined in northern NSW, eastern Victoria and southern Tasmania.

The report provides recommendations for forest managers and regulators of the industry on those elements of the existing metrics which have value in a private native forestry context. It outlines a process for the development of surrogates and metrics which attempts to directly address the sustainability of private native forestry, rather than focusing on vegetation quality or condition as in the existing schemes.

Who is the report targeted at?

The report has direct relevance to private and public forest managers who are required to test, evaluate or benchmark their forest management activities against sustainability criteria which use biodiversity surrogates or metrics. It will also be of interest to researchers, policy makers and policy administrators involved in native forest and natural resource management. The metric scoring systems assessed in this report have intended application through Commonwealth–State natural resource management partnership agreements, and through implementation by regional catchment authorities.

Background

Governments are increasingly using biodiversity surrogates and their compiled metric scoring systems to support national and state-based vegetation management frameworks, to value and monitor market based investments in vegetation rehabilitation or restoration, and to monitor compliance with environmental standards and certification schemes.

Biodiversity surrogates offer a convenient means of assessing a forest stand's structural and compositional status and its inferred ability to provide habitat and resources for local populations of plants and animals. Indices or metrics based on summarising these surrogates also offer a convenient way to rank or compare different stands and then translate those results into monitoring frameworks or on-ground actions. Habitat Hectares and Biometric are the two most widely used measures of vegetation quality or condition in Australia, with both schemes being customised to either formal policy frameworks or legislation. Biometric and Habitat Hectares were designed to implement vegetation policy instruments which seek to apply a 'improve or maintain', 'no net loss' or 'net environmental benefit' test to assessing vegetation change. These systems assess within a property vegetation type, the extent, condition and regional context where a landholder intends to clear native vegetation, to receive incentive management payments, or apply appropriate offset mechanisms for land use change.

The convenience of the above approaches and the tendency to relate index scores to stand management history and by inference a cause and effect relationship is problematic. Private native forests contribute a large component of hardwood supply in Australia as well as regional natural resource values, and are increasingly important as supplies from public native forests diminish – their management is important and occurs over long time periods. The suitability of the metric scoring systems to assess the ecological sustainability of different forest management actions such as clearfelling, thinning or selective harvesting, or measure the recovery of forest condition with time after these actions is debateable, when their primary focus is on the implications for vegetation condition of a change in land use.

Aims/Objectives

This study aimed to:

- undertake comparative analysis of the Habitat Hectares and Biometric data collected as part of three private native forestry projects funded by the Joint Venture Agroforestry Program
- improve understanding of the contribution that biodiversity metrics can make to the assessment of private native forestry sustainability.

The study focuses on the utility of the component biodiversity surrogate measures within each metric for assessing forest vegetation quality and condition.

Methods used

Data from four case studies was used to compare the performance of the site condition component of Habitat Hectares, and the site value component of Biometric, as measures of the sustainability of private native forestry.

The project methods were to:

- Review current knowledge and application of biodiversity metric scores to assessing the sustainability of forest operations, and examine the basis for existing biodiversity metrics within various vegetation policy instruments which seek to apply an ‘improve or maintain’, ‘no net loss’ or ‘net environmental benefit’ test to assessing vegetation change
- Compile all raw field data used to derive metric scores for Biometric and Habitat Hectares from the eastern Victoria, northern NSW and southern Tasmanian studies funded by JVAP
- Derive benchmark values for the variables in the Biometric and Habitat Hectares schemes, using regional data sets from the NSW Department of Environment and Conservation, the Victorian Department of Sustainability and Environment, and the Tasmanian Forest Practices Authority which are aligned with the sampled forest types in each study
- Test individual variables, surrogate scores and metrics with independent variables and indices summarising the condition of the vegetation and ecosystem properties and report using univariate and multivariate analyses
- Develop recommendations on the applicability of existing metric scores for assessing the sustainability of forest operations and recommend alternative scores or approaches.

In the four case studies, the biodiversity surrogates were assessed against the known forest management inputs, with a wide range of independent variables collected from detailed vegetation, ecological, fauna and timber assessments. The assessment of the Biometric and Habitat Hectares systems focussed more on their component biodiversity surrogates (e.g. plant species richness, fallen log volume) and less on their compiled metric scores, which are highly dependent on vegetation landscape context and the form of the additive or multiplicative terms used to derive the summary values. In order to provide a meaningful comparison, the analyses presented are limited to those variables in common across the studies, or those present in at least two of the studies.

Results/Key findings

The Biometric and Habitat Hectare systems differ in the nature of their biodiversity surrogates, and the degree to which the raw values for the biodiversity surrogates are converted into information based on benchmark values or predicted values over time or with a given management type (e.g. cattle grazing, weed control). In Biometric, the biodiversity surrogates are weighted largely upon their ease of replacement (e.g. hollow bearing trees or plant species richness); in Habitat Hectares they are weighted by vegetation quality criteria such as the existing cover and richness of plant life forms, the presence of large trees and site weediness. The Biometric system places more emphasis on vegetation and habitat condition using functional criteria, the Habitat Hectares system places more emphasis on vegetation quality or compositional criteria.

The empirical assessment of individual biodiversity surrogates often produced variable results or was highly context dependent. The majority of the surrogate attributes appeared insensitive to forest management, although their sensitivity was relative to the benchmark values adopted for the particular

ecological community and the systems used to categorise and score the field values. A number of surrogates examined, for example hollow bearing trees, large trees in excess of the benchmark size class, and a small number of late successional faunal groups, were useful in discriminating between sites with different forest management treatments, that is, mature and regrowth forests.

The cumulative site metrics were able to demonstrate compliance with sustainability policy criteria such as the Victorian Native Vegetation Management Framework with relative ease. The implication was that harvesting systems which retain a component of mature forest stand structures, either via variable retention or patch retention systems, will be more likely to score highly in the offsets policy 10 year threshold. However this study does not interpret this as evidence that the forest management regime is sustainable or the policy requirement is appropriate. Too much uncertainty exists in the outcomes of forest management actions for a policy as simple as a site reaching 50% of the pre-harvest site quality score within 10 years to be considered ecological sustainable.

The highly variable results of the ecological surveys conducted in the regrowth and mature forest stands illustrates the difficulty of not only using surrogate attributes to predict species occurrences, but of interpreting complex species-environment relationships using additive or multiplicative biodiversity metric scores. Components of the site condition score of Habitat Hectares and the site value score of Biometric do however have the potential to form part of a reconfigured index or measure of the sustainability of private native forestry, once additional criteria such as stand structural diversity are included and ecologically sustainable forestry is elaborated in a form related directly to the individual surrogate measures and their benchmark values.

Implications for relevant stakeholders

The studies reported here represent some of the first available in eastern Australian to quantitatively assess, using independent data, the value of biodiversity metrics in predicting ecological change. The quantitative field data which was collected serves to illustrate the value of underpinning land management decisions with transparent metrics rather than expert-based systems or qualitative policies or prescriptions that are not amenable to such direct examination. Having documented, transparent and quantitative metrics means that the data can be critically examined, a key feature of any public policy instrument.

The results of this study indicate that biodiversity surrogates and to a lesser extent compiled metrics have considerable potential in the assessment and monitoring of private native forestry – such as environmental and operating compliance with standards for vegetation and ecologically sustainable forest management. Components of the metrics and scoring systems were useful in examining the sustainability of private native forestry; however the framework they were developed for (vegetation quality or condition) is not the same framework needed to examine native forests managed for, among other values, a flow of wood products. Critics of these metrics need to be mindful. Both Habitat Hectares and Biometric were developed with a specific suite of policy and operation criteria, and any metric developed for a private native forestry application would need to do the same.

For a new biodiversity metric to be derived to assess the condition of managed private native forests, clear objectives and operational setting are required. An approach could be:

1. Define management or policy objectives and operational constraints.
2. Develop an appropriate conceptual framework for the ecosystems under consideration.
3. Select an appropriate suite of indicators or vegetation attributes.
4. Consider the options available for combining these into an index.
5. Use data collected at broader scales to place the site in a landscape context.

Recommendations

1. Further development is required to define the most appropriate surrogates for forest sustainability in the context of management for harvesting, before certification schemes, regulatory agencies and reporting organisations could adopt them.
2. The regional studies examined in this report indicate that the existing surrogates and metrics have varied applicability across the ecological communities and stand management types examined. Metric scoring must be based on realistic ecological classifications and benchmarks. As part of evaluation, it is important that sites which represent experimental controls and environmental stratification are included; without this control, the assessment of the sensitivity of the surrogates and metrics will be limited.
3. If considered important enough to be applied to private native forestry, biodiversity surrogates and metrics must undergo prior testing against real long term ecological data collected over at least ten years to reflect the time frames and thresholds that current policies are using.
4. There is an opportunity to use several existing long term, replicated and well managed ecological experiments to test how the surrogates reflect ecological changes over time, and to examine options for reconfiguring a metric to assess the sustainability of private native forestry. The experiments are at Cabbage Tree (East Gippsland, Victoria), Tanjil Bren (Central Highlands, Victoria), Warra and upper Florentine (southern Tasmania), Wauchope (mid north coast NSW) and Bago (southern NSW tablelands) and cover the range of forest types managed by private native forest growers. Pre-existing measurements would allow examination of the temporal response of different metric parameters, and importantly a range of independent variables to assess their surrogacy value for other forest values. Specific forest management activities could also be examined, for example fuel reduction burning and thinning, and retention systems which have the potential to be considered as part of the offset calculations.
5. Several alternative approaches to the analysis of the data presented in this report are worthy of consideration. The *a priori* division of plots into management histories such as regrowth and mature in East Gippsland, or the revision of the stratification design used in north eastern NSW to characterise silvicultural treatment along a continuum using an independent measure such as dbh distribution or a size/age class diversity index could improve sensitivity of the analysis. This would aim to detect more subtle continuous variation between plots.
6. In the regional case studies evaluated, the metric scores derived from the managed forest stands were highly dependent on how the metric was compiled, the method of deriving the benchmark threshold or range of values, and how the individual surrogate was measured in the field. Definition of consistent methodologies for assessing sites, benchmarks and forest management inputs is warranted.
7. These metrics have direct applicability in certification audits because they are based on repeatable methods and measurable environmental outcomes, unlike other certification systems based on assessment of management inputs. Any proposed use of biodiversity surrogates and metrics for certification should consider:
 - the costs for the private native forestry industry in adopting metric scoring systems to assess their ecological sustainability
 - consistent monitoring and reporting systems to allow cross-compatibility and statistical power
 - national reporting standards, adopted from one of the existing frameworks such as the Montreal Process, and reconfigured to resemble an offset policy outcome
 - trade offs between dimensionality (how many parameters or surrogates), flexibility (can compromise sensitivity) and representation within environmental indices reconfigured to specific circumstances.

1. Introduction

Approaches to the assessment of biodiversity value and landscape function using surrogates and metrics have developed rapidly in Australia in the last five years, due in part to a demand for such schemes to support national and state based vegetation management frameworks, and for systems to value and monitor market based investments in vegetation rehabilitation or restoration. Recent changes to legislation which seek to regulate broad scale clearing and manage incentive payments have also led to the development of a further suite of tools generally referred to as market based instruments (e.g., BioBanking; Department of Environment and Conservation 2005, Eigenraam *et al.* 2006). Several of these developments are happening in parallel (e.g. Oliver and Parkes 2003), or draw on a similar suite of theories concerning community organisation (e.g. Noss 1990, 1999). With several schemes having been proposed or now operationalised, critical reviews have been published of either the schemes or some of their underlying assumptions (e.g. Burgman *et al.* 2001, McCarthy *et al.* 2003, Gibbons and Freudenberger 2006), or have contrasted the schemes and proposed improvements based on alternate approaches (McElhinny 2005, McElhinny *et al.* 2005).

State based schemes for assessing vegetation quality, condition or function differ in their approaches largely as a result of different legislative requirements and interpretation of policies such as no net loss or the maintain or improve environmental outcomes test. Schemes in Victoria (Parkes *et al.* 2003), NSW (Gibbons *et al.* 2005), Queensland (Eyre *et al.* 2000, 2001), Western Australia (Environmental Protection Authority 2006) have a legislative basis, other schemes developed for specific purposes such as the NSW Environmental Services Scheme (Oliver 2002a,b, 2004, Oliver and Parkes 2003, Oliver *et al.* 2005, Oliver, *et al.* 2007) have been subject to significant iterative research and development without the constraints of a formal legislative framework. Schemes for assessing vegetation condition should meet a minimum set of criteria, for example a demonstrated ecological basis and sensitivity to a range of sites and states under consideration (Gibbons and Freudenberger 2006). Attributes can be combined into a single index or metric using additive or multiplicative scoring systems; their advantage is they are conceptually easy to understand across sites even if the basis for their derivation is not.

Habitat Hectares and Biometric are the two most widely used measures of vegetation quality or condition in Australia, with both schemes being customised to either formal policy frameworks or legislation. The Habitat Hectares approach of Parkes *et al.* (2003) combines site-based attributes (e.g. understorey species richness and cover) with local landscape attributes (e.g. size of patch) to derive a metric of vegetation quality. Each site-based attribute is measured within a stand and given a weighted score based on its relationship to a reference or benchmark value for the relevant Ecological Vegetation Class (EVC). Benchmarks represent the average characteristics for the attribute for mature and apparently long-undisturbed vegetation for the EVC. The landscape context score is based on general principles of landscape configuration and connectivity.

The Biometric approach of Gibbons *et al.* (2005) has many elements in common with Parkes *et al.* (2003) and differs primarily in giving greater value to sites with evidence of long-term viability or functionality at the site scale and secondly being applied by a broad suite of software and decision support tools referred to as the PVP (Property Vegetation Plan) Developer (Native Vegetation Regulation 2005 Environmental Outcomes Assessment Methodology). While Habitat Hectares uses terms such as ‘mature, long undisturbed’ to define its benchmarks, in Biometric the benchmarks aim to ‘describe the range of variation in ecosystems with relatively little evidence of contemporary anthropogenic modification’. Biometric has three main components, the site based habitat surrogates for composition, structure and function, the landscape metrics (cf landscape context score of Habitat Hectares) and the regional surrogates which place the site in a regional context, for example the regional proportion of each vegetation type on the site that is cleared.

Benchmark values are a critical component of the site scoring method in both Habitat Hectares and Biometric, as the values obtained from the field assessment are not used in absolute terms, but in a weighted framework where the values are relativised to a benchmark value representing mature or long undisturbed vegetation. Site Value in Biometric is assessed for each forest stand by measuring the

ten condition variables in plots and comparing the measured values with benchmarks. Each condition variable is allocated a score in BioMetric from 0-3 (0=low, 1=moderate, 2=high, 3=very high) based on the difference between its measured value and its benchmark for the respective vegetation class. The rationale behind the benchmark values in Habitat Hectares and Biometric and the methods used to derived them (Ayers *et al.* 2005, Department of Sustainability and Environment 2005) are broadly similar, although they will vary within and between the schemes on the degree to which they were derived empirically or from expert opinion or a combination of both. Benchmarks also have the important role of standardising site scores across different types of habitat (Keith and Gorrod 2006), theoretically allowing the condition of different habitats to be assessed and ranked simultaneously. Perhaps of greater significance is the vegetation units for which the Habitat Hectares or Biometric schemes apply the benchmarks, Habitat Hectares uses the EVC classification and is spatially explicit, Biometric used the statewide vegetation compilation of Keith (2004). The Keith approach is not based on the provision of a vegetation map and uses a broad typology at the level of vegetation class. Field staff identify vegetation to a finer level or 'type', and then apply the benchmark values for the broader 'class' level. Perhaps in recognition of this incongruence between the two levels of vegetation classification, benchmark values are described as a range, or upper and lower values for each condition variable.

Differences between the two schemes have the potential to confound their comparison in this study. While the two schemes have broadly similar approaches to deriving their site data ('site condition' score in Habitat Hectares and 'site value' score in Biometric), they differ in their assessment of landscape context and regional value or threat status with reference to further clearing. In Habitat Hectares, the site condition score effectively assesses vegetation quality; in Biometric the site values are weighted by their ease of replacement using functional criteria, i.e. for hollow bearing trees, which take longer to recruit and develop, are given a high weighting. The two methods also differ in their scoring approach, Habitat Hectares adds the site condition and landscape context scores, while in Biometric the site value is initially compiled using a combination of additive and multiplicative terms, with the sum of the ten site attributes being multiplied by the zone area (a distinct patch and type of vegetation) in the equation (in its general form):

$$\sum_{i=1}^n (((a + b + c + d + e + f + g + h + i + j + (a \times g) + (b \times i) + (h \times j) + (c \times d))) \times ZoneArea)_i$$

From this equation, some variables contribute more when they co-occur, the variables with greatest difficulty in recruitment have highest weighting and site value increases linearly with zone area. The comparison of the component weightings in Biometric (Table 1) with those from Habitat Hectares (Table 2) also indicates the greater emphasis on functional attributes in Biometric, and on compositional attributes, for example species richness and cover in understorey life forms, in Habitat Hectares.

Table 1. Components and weightings of the site value score in Biometric (Gibbons *et al.* 2005)

Term	Variable	Weighting
a	Native plant species richness	25
b	Native overstorey cover	10
c	Native mid-storey cover	10
d	Native ground cover (grasses)	2.5
e	Native ground cover (shrubs)	2.5
f	Native ground cover (other)	2.5
g	Lack of exotic plant cover	5
h	Number trees with hollows	20
i	Proportion of overstorey species regenerating	12.5
j	Length of fallen logs	10
	Total	100

Table 2. Components and weightings of the site condition and landscape context scores of Habitat Hectares (Parkes *et al.* 2003).

	Component	Maximum value (%)
Site condition	Large trees	10
	Tree (canopy) cover	5
	Understorey (non-tree) strata	25
	Lack of weeds	15
	Recruitment	10
	Organic litter	5
	Logs	5
	Site total	75
Landscape context	Patch size	10
	Neighbourhood	10
	Distance to core area	5
	Total	100

The characteristics of these schemes have a direct bearing on the extent to which they can be used to test the sustainability of private native forestry. Both schemes aim to assess site vegetation condition, a concept with its own pervasive ambiguity and under-specificity (Keith and Gorrod 2006). Condition scores are compared with a defined suite of benchmark values to produce weighted output measures of relative condition. The types of production values of concern to a private forest manager are not necessarily the same values measured by a condition score with an emphasis on assessing biodiversity and its likely response to clearing or an investment in restoration. Nonetheless biodiversity and condition scoring systems do have the potential to assess the sustainability of private native forestry, at least for those attributes of concern to regulators of ecological sustainability. The most direct application of these scoring systems in a private native forestry context is *Victoria's Native Vegetation Management - A Framework for Action* (Natural Resources and Environment 2002), and the offset criteria for timber harvesting. Using the net gain approach, offset requirements for clearfall harvesting of naturally established native forest on private land are deemed to have been met through effective regeneration as described by Table 7, Appendix 5 of the Framework. The quantity and quality of gains and losses from clearfall harvesting are combined using Habitat Hectares assessments, where the policy aims to achieve a target within 10 years of 50% of the quality (Habitat Hectares final score) of the vegetation that was harvested. The difficulty in achieving the Habitat Hectares large tree score (or

50% of it) within 10 years was recognised by the policy and provision made for mitigation of the impacts on large trees on a case-by-case basis. The policy also considers landscape context impacts of clearfall operations on private land, with a higher level of mitigation being required as specified in Regional Native Vegetation Plans. For selective harvesting, different criteria apply, with the reduction in habitat quality on a site not to exceed the percentage specified in the Regional Native Vegetation Plan. The 50% target is based on an assessment at the commencement of the clearfall harvesting, and in this way the target is a comparative one matched to the site, not one based on ‘mature, long undisturbed’ vegetation which is the rationale for the EVC benchmarks. The Victorian timber harvesting offset criteria are used in this study as a working definition of sustainability for private native forestry, although the limitations of this approach for the broader interpretation of sustainability criteria are recognised.

1.1 Aims and methods

Aims

This study aimed to:

- undertake comparative analysis of the Habitat Hectares and Biometric data collected as part of the eastern Victoria (Vaughan *et al.* 2006, Peacock 2006), northern New South Wales (Jay 2006) and Tasmanian (Peacock 2006) studies conducted in private native forests and funded by the Joint Venture Agroforestry Program (JVAP)
- improve understanding of the contribution that biodiversity metrics can make to the assessment of private native forestry sustainability.

The focus of the analyses is an evaluation of the utility of the component biodiversity surrogate measures within each metric for assessing forest vegetation quality and condition and by implication the sustainability of private native forestry.

Methods used

Two metric scoring systems are examined: Biometric and Habitat Hectares. Data from four studies are used to compare the performance of the site condition component of Habitat Hectares and the site value component of Biometric as measures of the sustainability of private native forestry (Figure 1). One study is based in northern NSW (Jay 2006), two are from eastern Victoria (Vaughan *et al.* 2006, Peacock 2005) and one is from southern Tasmania (Peacock 2005).

The project methods were to:

- Review current knowledge and application of biodiversity metric scores to assessing the sustainability of forest operations, and examine the basis for existing biodiversity metrics within various vegetation policy instruments which seek to apply an ‘improve or maintain’, ‘no net loss’ or ‘net environmental benefit’ test to assessing vegetation change
- Compile all raw field data used to derive metric scores for Biometric and Habitat Hectares from the eastern Victoria (Vaughan *et al.* 2006, Peacock 2006), northern New South Wales (Jay 2006) and Tasmanian (Peacock 2006) studies undertaken for JVAP
- Derive benchmark values for the variables in the Biometric and Habitat Hectares schemes, using regional data sets from the NSW Department of Environment and Conservation, the Victorian Department of Sustainability and Environment, and the Tasmanian Forest Practices Authority which are aligned with the sampled forest types in each study
- Test individual variables, surrogate scores and metrics with independent variables and indices summarising the condition of the vegetation and ecosystem properties and report using univariate and multivariate analyses
- Develop recommendations on the applicability of existing metric scores for assessing the sustainability of forest operations and recommend alternative scores or approaches.

The indices are assessed against known forest management inputs, with a wide range of independent variables collected at the same sites from detailed vegetation, ecological, fauna and timber assessments. The landscape context score of Habitat Hectares and the regional and landscape value of

Biometric are not included in this assessment, which focuses on site based attributes only. To do so would have confounded the analysis, as two of the studies (Vaughan 2006, Jay 2006) have sampled across regions where the regional and landscape values will vary independently of the site condition or value scores. To facilitate the comparison of the two site scores (in the absence of the regional and landscape values) the site scores are re-scaled to a value of 100. The four studies all differ in the variables studied and their methods of collection, calculation and weighting. In order to provide a meaningful comparison, the analyses presented are limited to those variables in common across the studies, or those present in at least two of the studies.

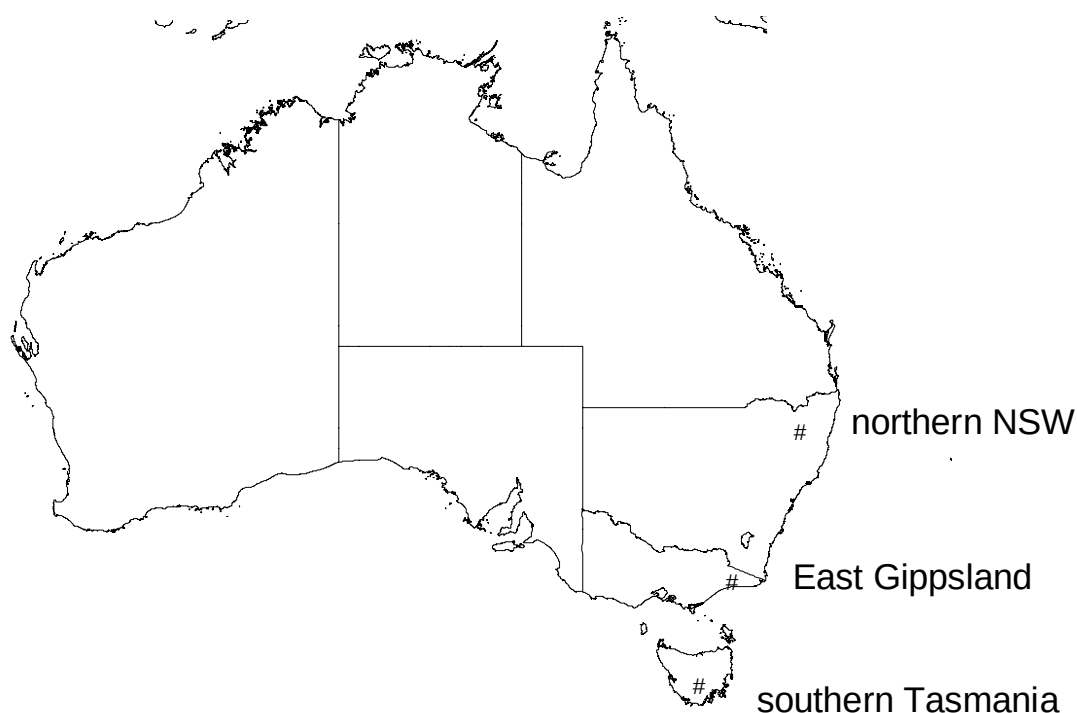


Figure 1 Location of regional studies examined in this report.

The four studies all encompass different forest types and management histories which are characteristic of the private native forest estates. The first two regional studies (northern NSW and East Gippsland) were conducted in 2005, and encompass a broad range of ecological surveys in addition to the site condition and site value scores required for Habitat Hectares and Biometric. In northern NSW, four localities in north eastern NSW were examined: Drake, Rappville, Whiporie and Nymboida. All were composed predominantly of Clarence Lowlands Spotted Gum, and up to six sites of varying management history in this forest type on each property were sampled (Jay 2006).

In East Gippsland the Department of Primary Industries/Department of Sustainability and Environment study established a series of paired plots (mature forest versus regrowth forest) in the following districts: Wangarabell, Cann River, Noorinbee North, Combienbar, Waygara (Orbost) and Mt Taylor (Bairnsdale). A total of 13 pairs (26 sites) were sampled predominantly in East Gippsland Lowlands bioregion Lowland Forest (EVC 16). This ecological vegetation class is dominated by *Eucalyptus sieberi* (Silvertop Ash), *Eucalyptus globoidea* (White Stringybark) and *Eucalyptus consideriana* (Yertchuk). Mature plots were long undisturbed and regrowth plots were logged 11-23 years prior to sampling.

In addition to these two regional scale studies, two further studies were examined which were restricted to a single location but have been monitored since their establishment in 1988 and 1991. The aim of these studies was to address the extent to which temporal vegetation changes since thinning can

be described by the composite site condition and site value scores required for Habitat Hectares and Biometric. The study conducted in East Gippsland at West Bemm (between Cann River and Orbost townships) was established in 1988 in East Gippsland Lowlands bioregion Lowland Forest (EVC 16) and has continued to 2005. Plots established in 1988 prior to thinning were subsequently re-measured in 1989 (year 1), 1999 (year 10) and 2005 (year 17). The study conducted in southern Tasmania in the Florentine Valley consists of even-aged *Eucalyptus regnans* silvicultural regrowth originating from logging in 1961. Thinning and pre-treatment inventory was conducted in 1991, and the vegetation re-measured in 1992 and 2005 (Peacock 2006).

Any explicit examination of the utility of biodiversity metrics in assessing the sustainability of private native forestry will require a definition of sustainable forestry. A range of definitions of sustainable forestry exist, including those which debate whether ecological should be in the title, or whether the concept has different a meaning in a public or private forest context. In view of the difficulties of defining sustainable forestry, the preferred definition of ecologically sustainable forestry (from Lindenmayer *et al.* 2006) is one that is also accompanied by a set of guiding principles or checklist:

“...perpetuating ecosystem integrity while continuing to provide wood and non-wood values; where ecosystem integrity means the maintenance of forest structure, species composition, and the rate of ecological processes and functions within the bounds of normal disturbance regimes.”

The above definition can provide a context to assess the sustainability of private native forestry in the current study, however sustainability is more of an overall direction in conservation and forest management (Lindenmayer and Franklin 2003) and not an endpoint to measure the outputs of a private forest management regime.

2. Comparison of mature and regrowth forest, East Gippsland

2.1 Objectives

The objectives of this study were to examine the relationship between biodiversity surrogates and metrics and environmental changes following clearfell logging in East Gippsland, Victoria. The specific objective was to quantify changes in Habitat Hectares and Biometric scores following clearfell logging through a comparison of environmentally similar mature and logged forest stands which were sampled for a wide range of vegetation, timber and ecological attributes. These attributes are used to quantify changes in forests subject to logging and are compared to changes in the Habitat Hectares final score between the mature and regrowth stands. The policy which quantifies the extent of change in Habitat Hectares scores is *Victoria's Native Vegetation Management - A Framework for Action* (Natural Resources and Environment 2002), and the offset criteria for timber harvesting. As part of this policy, a net gain approach is applied to assessing the effects of timber harvesting and subsequent habitat modification. Changes in habitat condition are required to be offset through effective stand regeneration. The policy threshold is to achieve a target within 10 years of 50% of the quality (Habitat Hectares final score) of the vegetation that was harvested.

2.2 Methods

2.2.1 Study Area

The study area is centred on six localities in lowland East Gippsland, Victoria; Wangarabell, Cann River, Noorinbee North, Combienbar, Waygara (Orbost) and Mt Taylor (Bairnsdale). Forest stands are sampled predominantly from private land typically subject to private native forestry in this region. The characteristics of the study area are detailed in Vaughan *et al.* (2007).

2.2.2 Experimental Design

The experiment contrasts thirteen pairs of forest stands, one consisting of mature forest, the other regrowth forest harvested 11-23 years prior to sampling. There is an assumption that only two treatments exist, that is regrowth forest originating from harvesting, and mature un-harvested stands. The twenty-six stands were stratified for Ecological Vegetation Class (EVC) and other environmental variables, and were sampled predominantly on private land typical of the estate managed for private native forestry and related enterprises such as cattle production in lowland East Gippsland.

The aim of the survey design was to limit sampling to a single environment, and the Ecological Vegetation Class is used a convenient environmental classification scheme. Of the thirteen paired plots sampled, ten were classified from ground truthing as East Gippsland Lowlands Bioregion EVC 16 Lowland Forest, two as EVC 21 Shrubby Dry Forest and one as EVC 29 Damp Forest. Each of these EVC's are widespread in lowland East Gippsland on moderately infertile soils and share many species in common in both the *Eucalyptus* dominated overstorey and low shrubby understorey. For the purposes of this analysis, all samples were pooled and are generically referred to as EVC 16 Lowland Forest.

2.2.3 Vegetation, Tree and Fauna Sampling

A range of vegetation, stand, ecological and species field sampling protocols were applied in this study. Fixed area plots were used to record the stand level characteristics of tree, vegetation, strata, weed and cut stumps. A variable radius plot was used to record individual tree level attributes. Floristic survey plots were sampled to record vegetation life form and stratum attributes and evidence of mammal activity. Coarse woody debris was sampled using a line transect method. In addition to these sampling regimes, fauna was sampled using a combination of call playback, spotlight surveys, diurnal bird census, scat analysis and general habitat searches and observations. Fixed area plot based surveys, or stand level sampling for fauna was designed to sample a common portion of the stand. A full description of the sampling approaches followed for trees, stands, vegetation, fauna and other habitat attributes is available in Vaughan et al. (2007).

2.2.4 Data Analysis

Benchmarks are quantitative measures which attempt to describe the range of variability in a plant community's key biodiversity surrogates or measures of condition. Benchmarks are described at the scale of a stand or patch of vegetation using prescribed plot-based field sampling protocols. Benchmark values for Habitat Hectares attributes were those published by Department of Sustainability and Environment for EVC 16.

Biometric adopts a range of values (upper and lower) for its benchmarks, recognising the range of alternate states a plant community can occur in. In NSW, upper and lower range values are derived for the relevant Keith (2004) class or vegetation type and it is assumed a complementary approach is applicable to the EVC level of classification in Victoria. When deriving benchmarks from pre-existing floristic plot data, two approaches are available: if the plots have been stratified into those from good condition or least disturbed sites the 10th to 90th percentiles are used to define the lower and upper range values; if the plots are from a range of condition states the 50th to 90th percentiles are used. A refinement of this technique is currently being trialled for Biometric in NSW using the 95% confidence intervals around the mean.

Benchmark values for Biometric site value scores were derived for EVC 16 Lowland Forest using a sample of 1138 floristic quadrats from this vegetation class in lowland East Gippsland. The data set was the same sample used to build the Habitat Hectares site condition scores by the Department of Sustainability and Environment. The approach followed to derive the benchmark values empirically follows Ayers *et al.* (2005) and adopted the 50th to 90th percentiles. The mid-storey and ground cover values were calculated from individual species cover-abundance values converted to the mid-point of their class ranges and from a classification of species life forms into grasses, shrubs and other following the criteria for these ground cover groups in Gibbons *et al.* (2005). The Biometric benchmark values derived for EVC 16 Lowland Forest were then validated against benchmark values for broadly similar lowland forests in south eastern NSW.

To provide a broader context to the site condition variables measured in the field trials in East Gippsland, and to assess the variability around the median values of the Habitat Hectares life forms, the same data set of 1138 floristic quadrats was annotated for life form and the results presented graphically as box plot diagrams. Each of the 1138 quadrats had its component species annotated with the appropriate life form and a cumulative cover values calculated from individual species cover-abundance values converted to the mid-point of their seven point class ranges. The limitation of using non-continuous ordinal scale cover class estimates to derived continuous cover estimates is recognised. Each species also was limited to a single life form per plot, although some species will occur in more than one life form, for example an overstorey *Eucalyptus* species will occur in both the tree canopy and shrub layer when it occurs in both the canopy and tree sapling layers. Species richness was calculated per quadrat as the cumulative number of species in each life form category. The upper adjacent value, upper quartile (75th), median, lower quartile (25th) and lower adjacent values are provided. The adjacent values are 1.5 times the inter-quartile range.

Based on the field trial data, site condition (Habitat Hectares) and site value (Biometric) scores were calculated following the procedures outlined in Department of Sustainability and Environment (2004) and Gibbons et al. (2005). For Biometric, the site value score was calculated using the visual basic software procedures in Biometric Version 1.8 for the NSW Property Vegetation Plan Developer April 2005.

Ordinations were performed on the 26 plots using two approaches. Floristic data collected from 9 sub-plots nested within the Fixed Area Plot were compiled into a single plot of 100m² and the field percentage cover foliage scores average across the 9 sub-plots. In the second example, foliage cover scores for each of the 12 Habitat Hectares understorey life forms (Table 3) present were derived to create a matrix of 26 objects by 12 attributes, and this data subject to ordination. The foliage cover scores were derived from the 9 sub-plots by attributing the individual plant species by their respective understorey life forms and summing the values across the 9 sub-plots. A Bray-Curtis association matrix was calculated between all pair wise object combinations. The ordination technique was non-metric multidimensional scaling (NMS). NMS ordinations in the global form were derived from 50 multiple runs, using 10 different random starting configurations, with a maximum of 100 iterations. Ordinations were performed in 1-3 dimensions, and the minimum stress solutions for each dimension examined. Stress is “a measure of departure from monotonicity in the relationship between the dissimilarity (distance) in the original p-dimensional space and distance in the reduced k-dimensional ordination space” (McCune and Mefford 1999). The appropriate number of dimensions (axes) was chosen through an examination of the final stress versus the number of dimensions. The stability criterion for terminating successive iterations was 0.001. The axis scores from the 1-3 dimensional solutions were saved and examined graphically using 3-dimensional plots rotated on the x-axis and through graphical overlays. NMS ordinations were implemented in PC-ORD v. 4.41 (McCune and Mefford 1999).

Hierarchical clustering was performed on percent cover floristic data using the unweighted pair-group method (UPGMA) method (Sokal and Michener 1958). The distance measure was Bray-Curtis (Bray and 1957). Dendrograms were generated from the cluster analysis as a visual representation of the binary tree structure. Species fidelity with treatments and years was assessed using indicator species analysis (Dufrene and Legendre 1997). Relative abundance was defined as the average abundance of a given species in a treatment group divided by the average abundance of that species across all treatment groups, expressed as a percentage. It was implemented in PC-ORD v. 4.41 (McCune and Mefford 1999).

Fauna analyses followed the multivariate approaches described above or relied upon tabular or graphical summaries. For the bird count data, each species was classified according to the scheme developed by Loyn (1997, 1998) and Loyn *et al.* (2002) and detailed in Appendix 1. The actual classification of bird species into feeding guilds in particular is based on local knowledge and will vary across regions.

2.3 Results

Benchmarks for understorey life forms published by the Department of Sustainability and Environment for EVC 16 Lowland Forest (Table 3) had median values resembling those derived empirically from a large sample of regional floristic plot data. Understorey life forms exhibiting the greatest degree of variability around their median values were medium shrubs, medium tufted graminoids and medium herbs (Figure 2). Benchmark values for foliage cover (Table 3) were generally higher than those derived empirically (Figure 3), with the variability greatest for the shrub and herb components of the understorey. Values of plant species richness, derived for the Biometric benchmark, were normally distributed around a median value of 42 species per plot (Figure 4).

Table 3 Habitat Hectares site benchmark values for EVC 16 Lowland Forest following the Department of Sustainability and Environment.

		weighting
Large trees	70 cm	20/ha
Tree canopy cover		30%
Understorey: Life Form	Species richness	% cover
Immature Canopy Tree	na	5
Understorey Tree or Large Shrub	2	10
Medium Shrub	10	30
Small Shrub	6	15
Prostrate Shrub	2	5
Large Herb	1	1
Medium herb	6	10
Large Tufted Graminoid	2	10
Medium to Small Tufted Graminoid	6	10
Large Non-tufted Graminoid	2	5
Medium to Tiny Non-tufted Graminoid	2	5
Ground Fern	3	10
Scrambler or Climber	3	5
Bryophytes and lichens	na	10
Recruitment	Continuous	10
Organic Litter	40% cover	5
Logs	20 m/0.1 ha	5
Weediness	No consistent	15

Table 4 Biometric site benchmark values for EVC 16 Lowland Forest

	lower	upper	weighting
Native over-storey cover (%)	13	37	10
Native mid-storey cover (%)	24	55	20
Native ground cover (%) - grasses	5	13	10
Native ground cover (%) - shrubs	16	37	2.5
Native ground cover (%) - other	42	80	2.5
Exotic plant cover (%)			2.5
Native plant species richness count	na	42	25
Number of trees with hollows (>5cm)/0.1 ha		2	12.5
Overstorey regeneration (<5cm DBH) spp%		100	10
Total length of logs>10cm	20/0.1 ha		5

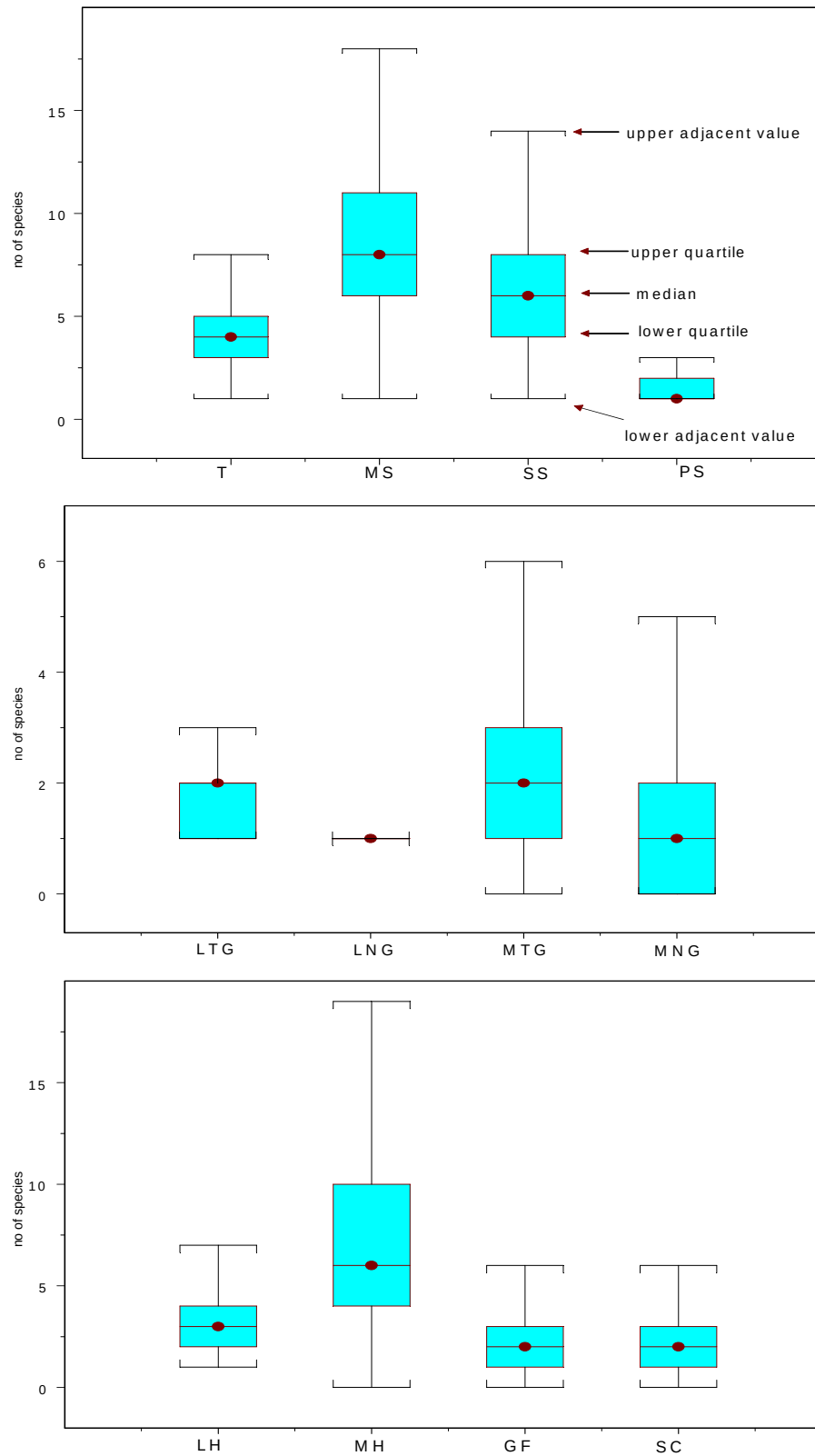


Figure 2 Variability in median values of species richness of understorey tree and shrub life forms for EVC 16 Lowland Forest, derived from a sample of 1138 mature quadrats. T= Understorey Tree or Large Shrub, MS= Medium Shrub, SS= Small Shrub, PS= Prostrate Shrub. LTG = Large Tufted Graminoid, LNG = Large Non-tufted Graminoid, MTG = Medium to Small Tufted Graminoid, MNG = Medium to Tiny Non-tufted Graminoid. LH = Large Herb, MH = Medium Herb, GF = Ground Fern, SC = Scrambler or Climber.

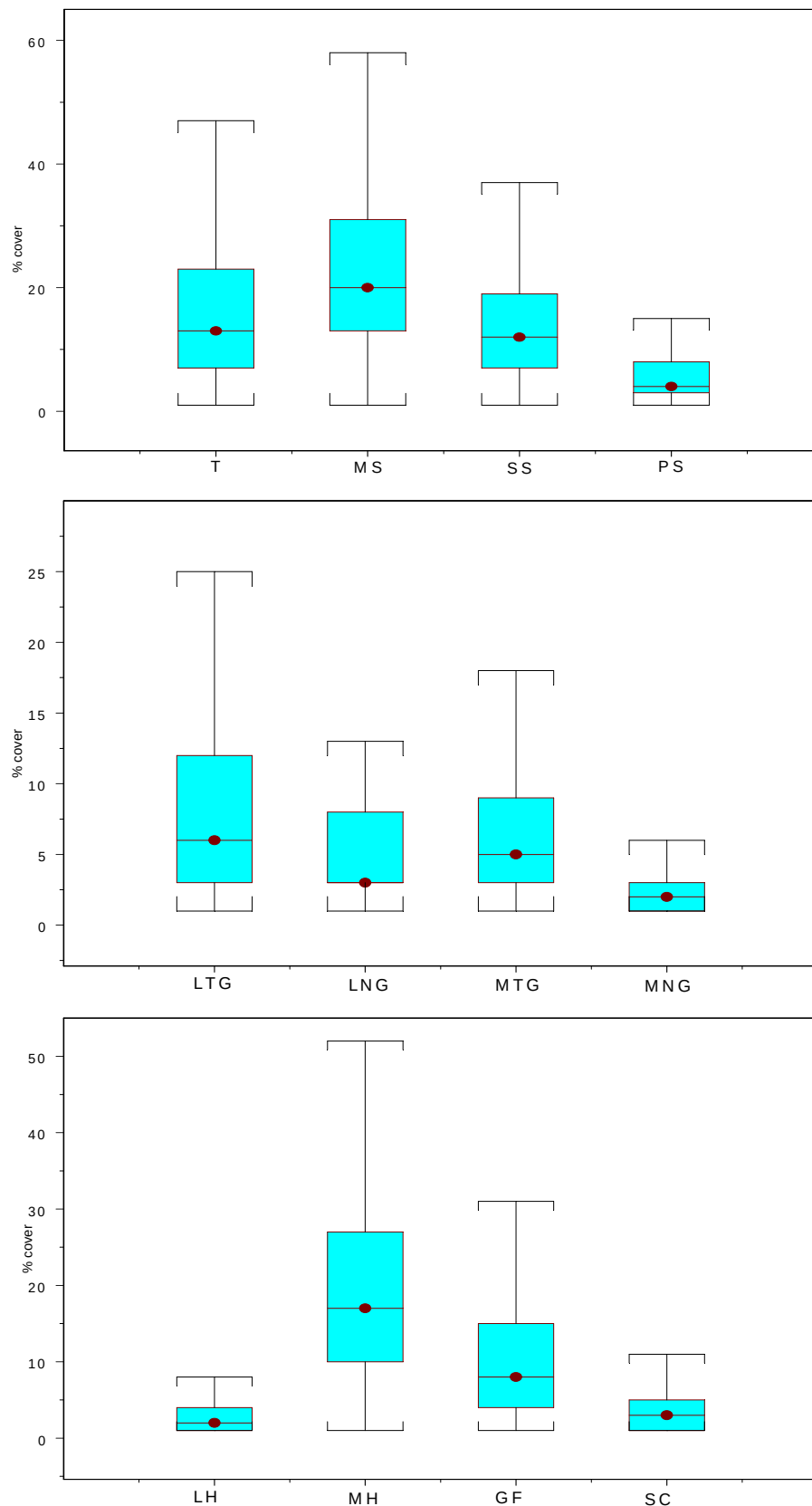


Figure 3 Variability in median values of % cover of understorey tree and shrub life forms for EVC 16 Lowland Forest, derived from a sample of 1138 mature quadrats. T= Understorey Tree or Large Shrub, MS= Medium Shrub, SS= Small Shrub, PS= Prostrate Shrub. LTG = Large Tufted Graminoid, LNG = Large Non-tufted Graminoid, MTG = Medium to Small Tufted Graminoid, MNG = Medium to Tiny Non-tufted Graminoid. LH = Large Herb, MH = Medium Herb, GF = Ground Fern, SC = Scrambler or Climber.

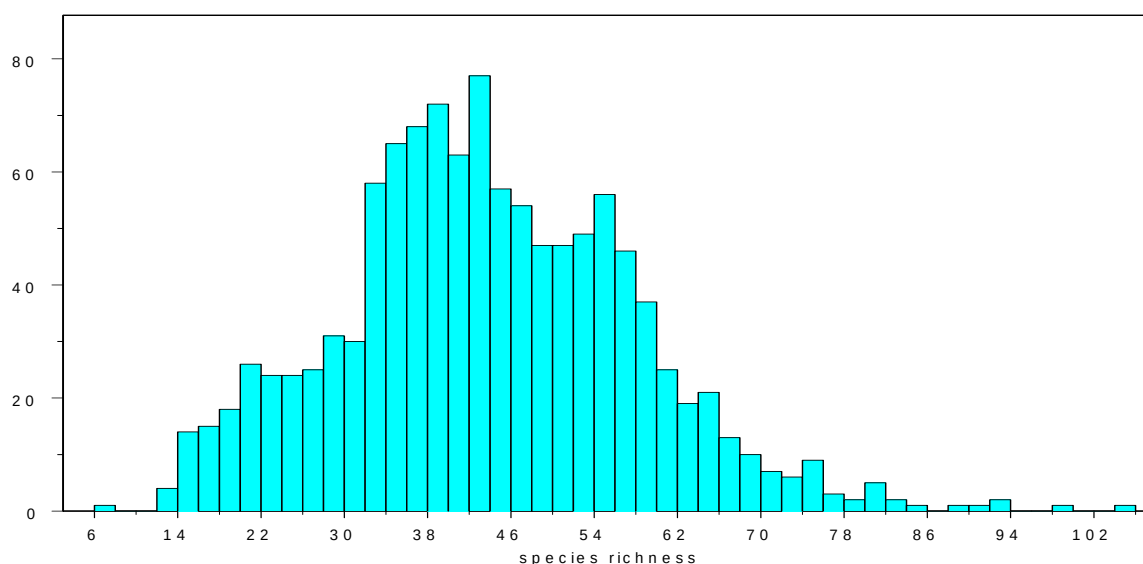


Figure 4 Distribution of values for plant species richness in a sample of 1138 floristic plots from EVC 16 Lowland Forest East Gippsland. Plot size is 0.09 ha. Following the methods used to derive benchmarks for Biometric, the benchmark range is the 50-90th percentile (42-60 species), with only the lower benchmark (median value is 42) required for the calculation of site value.

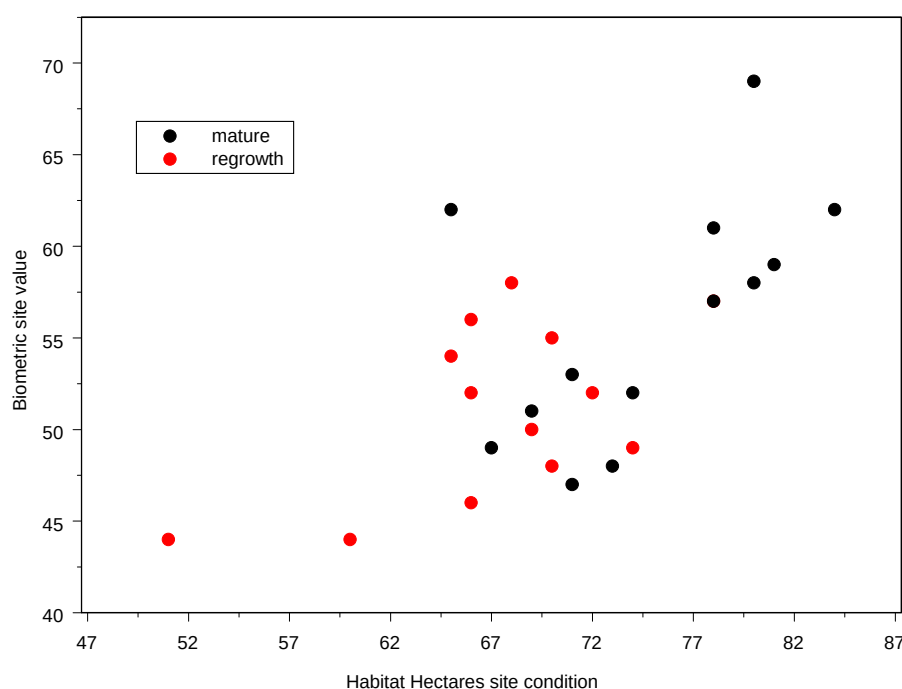


Figure 5 Site condition (Habitat Hectares) and value (Biometric) scores for 13 regrowth and 13 mature forest stands in East Gippsland. Pearson's product-moment correlation coefficient, $r=0.638$.

Site condition and value scores for the 13 paired regrowth and mature lowland forests in East Gippsland (Figure 5) had a modest to strong correlation (cf. Fowler *et al.* 1998). The scores for Habitat Hectares had more discriminatory power for the same sites than Biometric did. Regrowth forests were discriminated from mature forests by both scoring systems, although again Habitat Hectares provided greater separation of the two types.

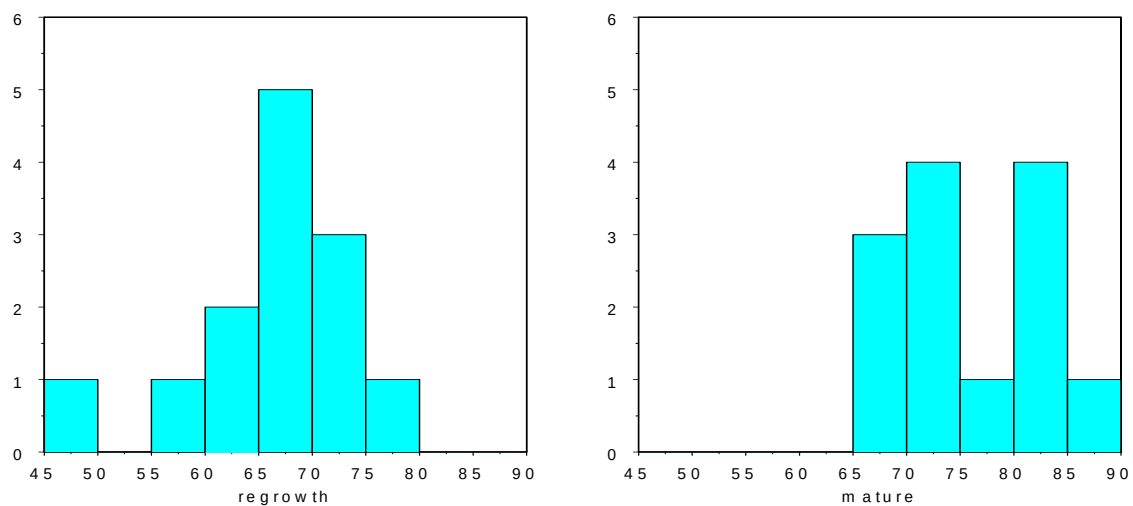


Figure 6 Site condition scores of the Habitat Hectares index for 13 regrowth and 13 mature forest stands in East Gippsland.

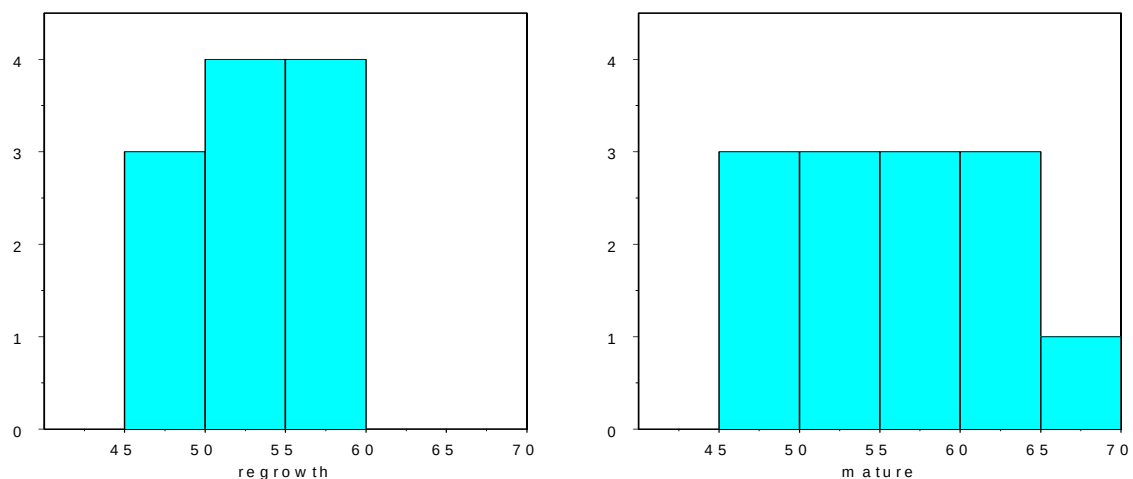


Figure 7 Site value scores of the Biometric index for 13 regrowth and 13 mature forest stands in East Gippsland.

The scores for Habitat Hectares and Biometric differed in their distribution, with scores > 65 characterising mature forest for Habitat Hectares, while regrowth forest scores were more asymmetric. Biometric scores offered less insight into the differences between the regrowth and mature forests sampled. The magnitude of the difference for the median scores per treatment (regrowth and mature) was greatest for Habitat Hectares, although both median scores were significantly different (Figure 8). The policy threshold of achieving within 10 years 50% of the quality (Habitat Hectares final score) of the vegetation that was harvested was exceeded by both scoring systems, although a small number of sites were borderline to it (e.g. Waygara, west of Orbost Figure 9).

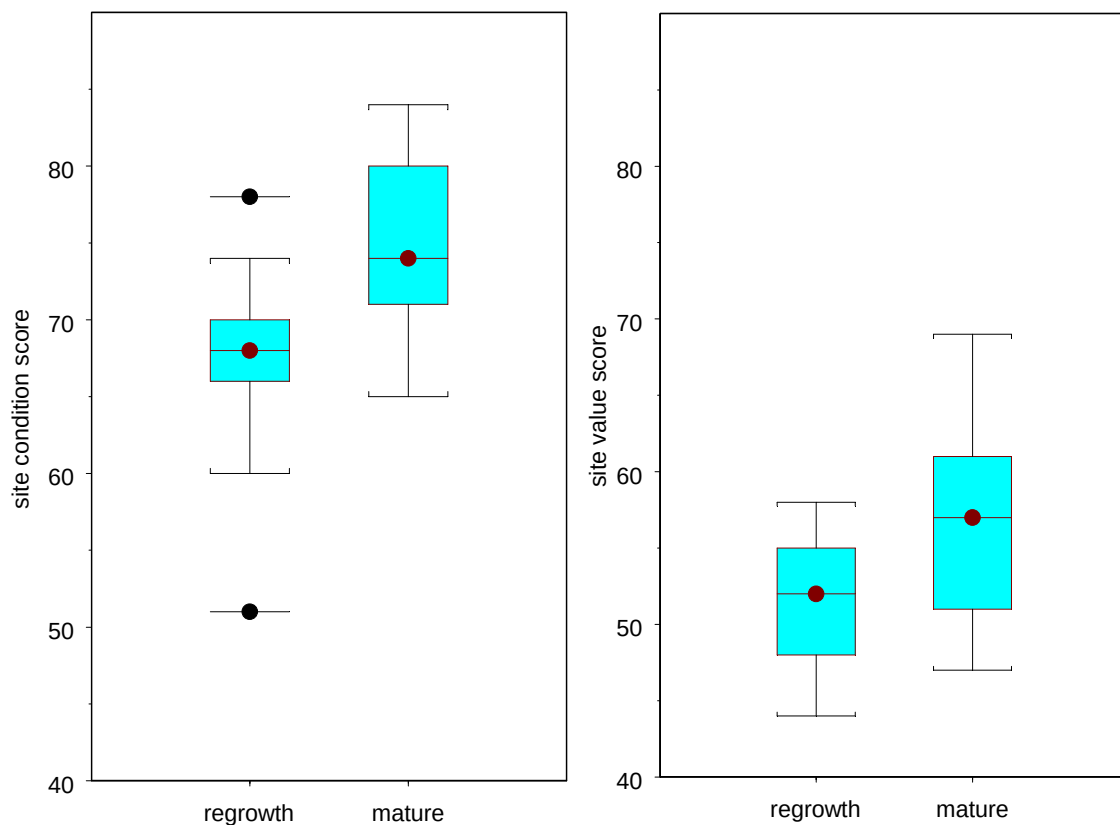


Figure 8 Site condition scores (Habitat Hectares) and site value scores (Biometric) for 13 regrowth and 13 mature forest stands in East Gippsland. The site value scores (two-sample t-test, $p < 0.05$) and site condition scores are significantly different (two-sample t-test, $p < 0.01$).



Figure 9 Regrowth forest of EVC 16 Lowland Forest, regenerated in 1988 and subject to on-going cattle grazing at Waygara, west of Orbost (site 13). This site received the lowest site score for both Habitat Hectares and Biometric of any in the study.



Figure 10 Regrowth forest of EVC 16 Lowland Forest, regenerated 1985 at Waygara, west of Orbost (site 12).



Figure 11 Mature forest of EVC 16 Lowland Forest at Waygara, west of Orbost (site 27).

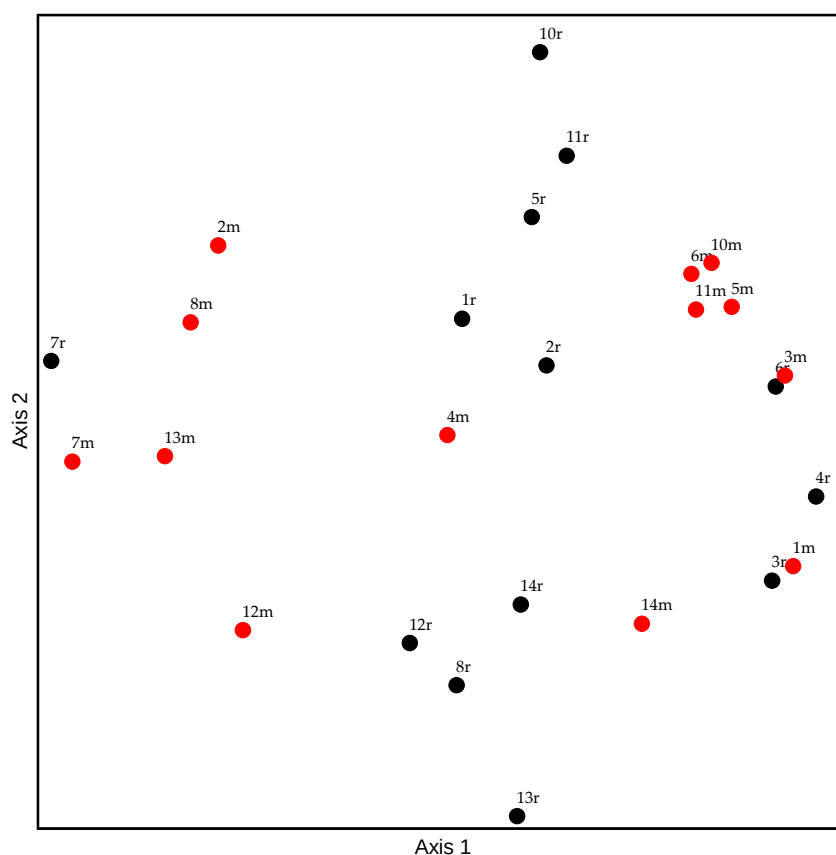


Figure 12 Ordination of floristic cover data for 13 pairs of regrowth and mature lowland forest, East Gippsland. The sites are labelled as red (mature) and black (regrowth) with their corresponding paired plot numbers.

Table 5 Model fitting statistics for the ordination of floristic cover data in 1 to 3 dimensions and coefficients of determination for the correlations between ordination distances and distances in the original n-dimensional space. Increment and cumulative R-squared were adjusted for any lack of orthogonality of axes.

Axis	r-squared		Minimum stress in real data	r-squared and % orthogonality with	
	increment	cumulative		axis 1	axis2
1	0.193	0.193	43.2	-	0.027, 99.9%
2	0.216	0.409	23.9	-	-
3	0.280	0.689	13.4	0.002, 100%	-0.035, 99.9%

Floristic compositional differences between the regrowth and lowland forests sampled were poorly expressed in the data collected, with only a weak separation of sites by treatment, and a further pattern where paired plots were not necessarily contiguous in the multivariate space (Figure 12). The classification process revealed a similar result (Figure 13); despite the imposition of a cluster derived structure through the association measures, little was revealed in terms of treatment effects, although paired plots frequently revealed the potential for spatial autocorrelation. Total plant species richness was similarly uninformative as a descriptor of logging treatment effects, and was unrelated to the site condition or site value scores (Figure 14).

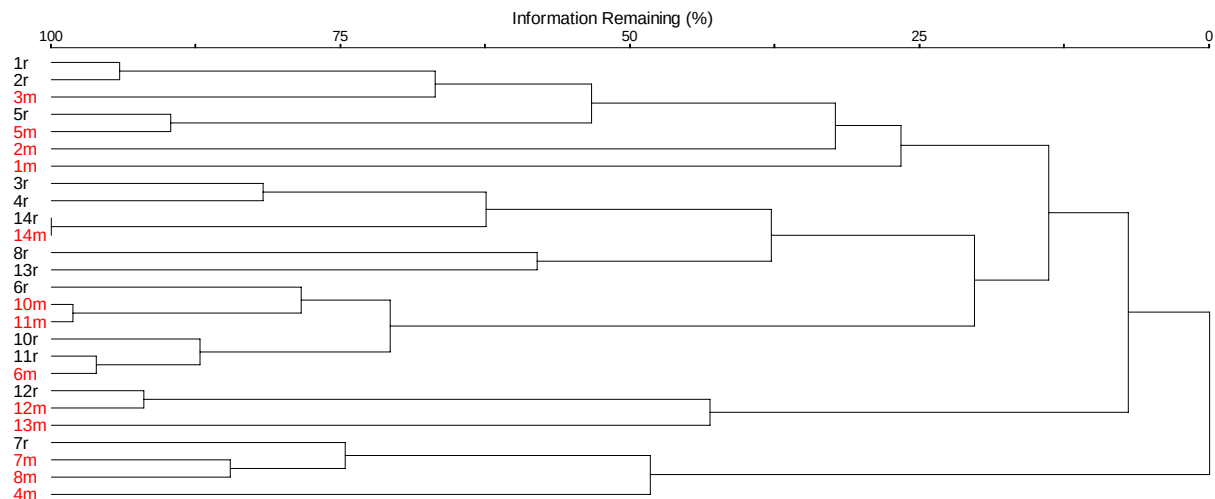


Figure 13 UPGMA cluster dendrogram of floristic cover data for 13 pairs of regrowth and mature lowland forest, East Gippsland. The sites are labelled as red (mature) and black (regrowth) with their corresponding paired plot numbers.

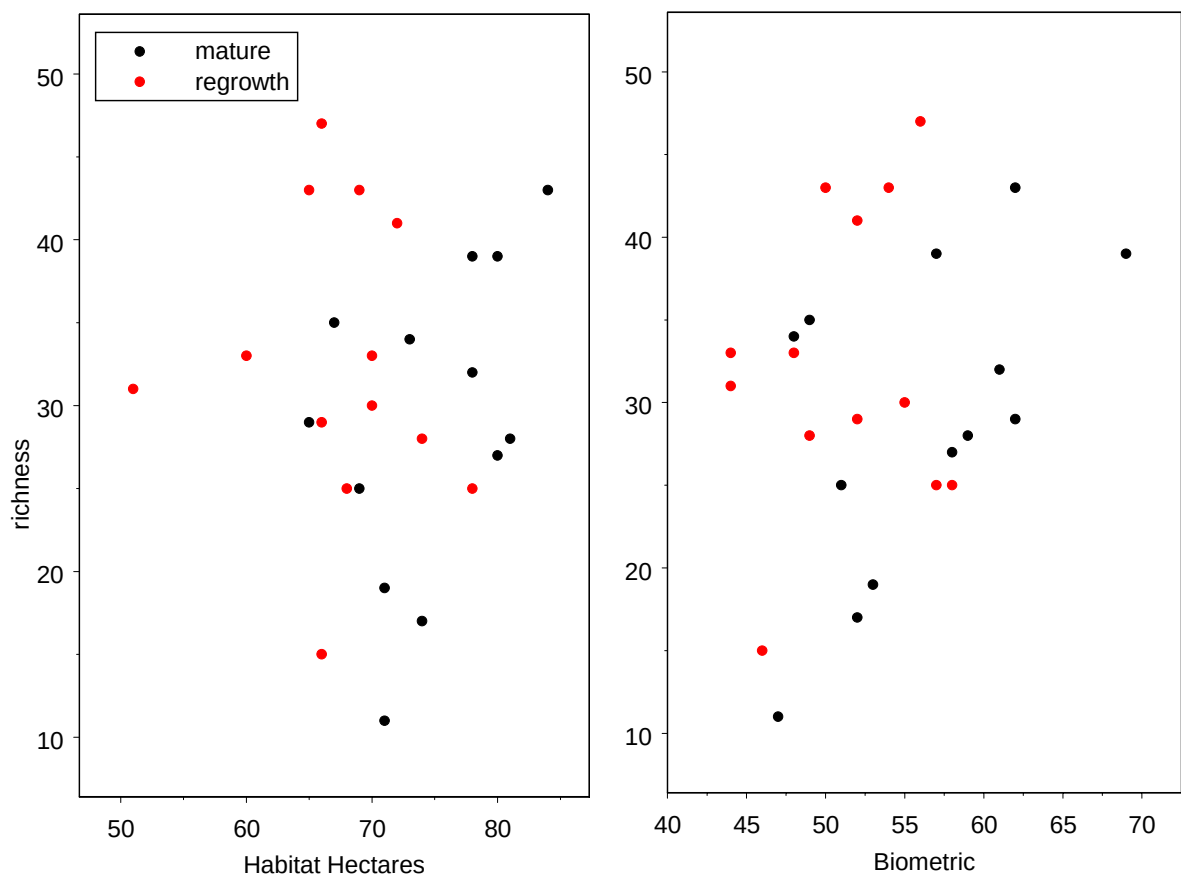


Figure 14 Plant species richness was weakly correlated with the Biometric score ($r=0.279$) and not correlated with the Habitat Hectares score ($r=0.039$). Neither scores were able to distinguish regrowth from mature lowland forest in terms of plot plant species richness.

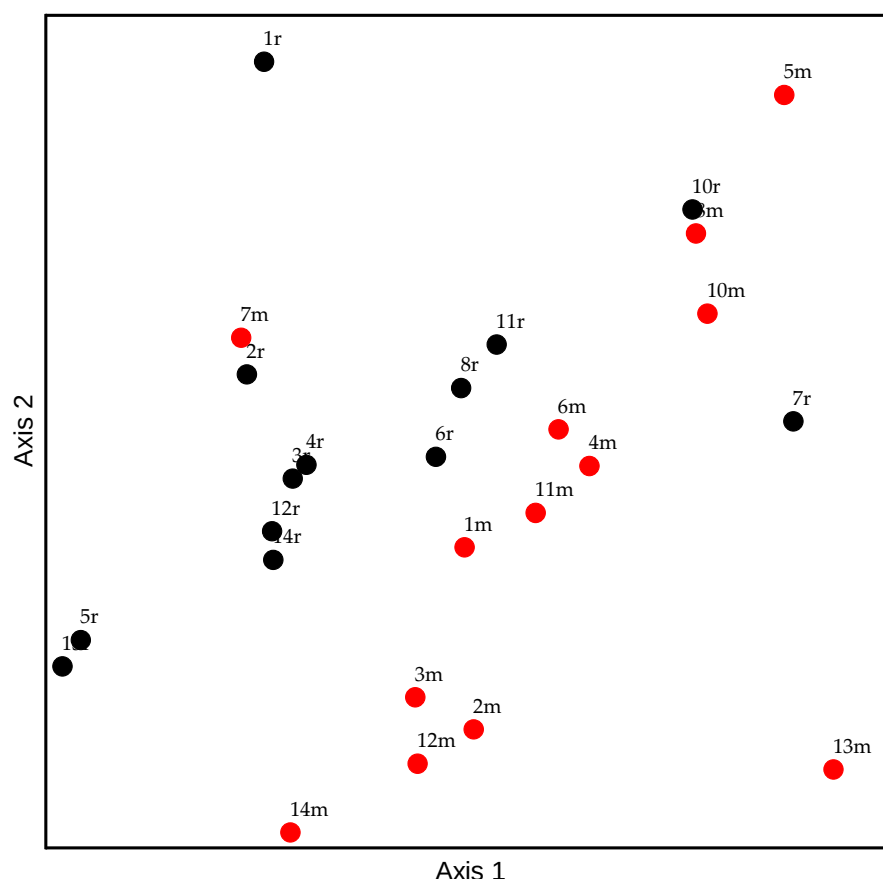


Figure 15 Ordination of understorey life form cover data for 13 pairs of regrowth and mature lowland forest, East Gippsland. The sites are labelled as red (mature) and black (regrowth) with their corresponding paired plot numbers.

Table 6 Model fitting statistics for the ordination of understorey life form cover data in 1 to 3 dimensions and coefficients of determination for the correlations between ordination distances and distances in the original n-dimensional space.

Axis	r-squared		Minimum stress in real data	r-squared and % orthogonality with	
	increment	cumulative		axis 1	axis2
1	0.251	0.251	30.3	-	0.285, 91.9%
2	0.297	0.548	18.5	-	-
3	0.285	0.833	12.0	0.121, 98.5%	0.386, 85.1%

Floristic compositional differences between the regrowth and lowland forests sampled were expressed in a more definitive manner by the analysis restricted to the twelve understorey life forms (Table 3, excluding bryophytes and lichens). In this analysis, the 213 individual vascular plant species recorded during the survey are replaced by their cumulative percent cover scores for their respective understorey life forms. The pair-wise associations are then based only on a matrix of 26 sites and 12 objects. Regrowth and mature samples are clearly separated along axis 1 (Figure 15), and the spatial autocorrelation response evidence in the classification using the full suite of species in Figure 15 is absent. The magnitude of the difference between the regrowth and mature sites using the life form categories was greatest in the immature canopy tree and ground fern life forms (Table 7). The extent to which these differences relate to the benchmark species richness and cover values for undisturbed lowland forest varies across life forms (Table 8). In many cases the mature forest sampled was still beneath the published bioregional EVC benchmark values for either species richness or percent cover for the life form, and the regrowth forests lower again. The regrowth forests were however much

closer to the ‘local’ benchmark figure, which is based on the pre-logging stand score, not the bioregional benchmark following the procedures outlined in the Victorian net gain policy.

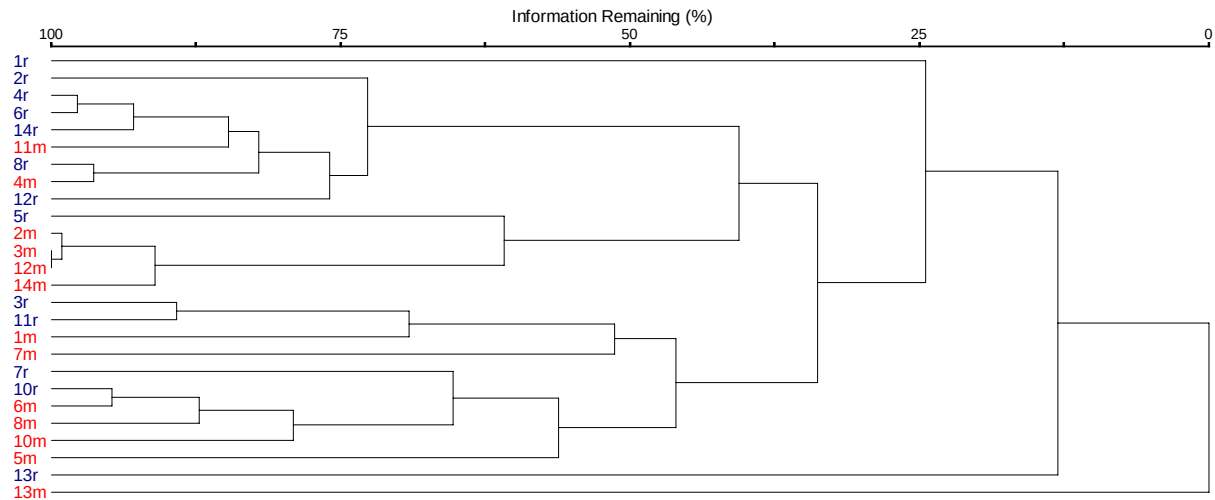


Figure 16 UPGMA cluster dendrogram of understorey life form cover data for 13 pairs of regrowth and mature lowland forest, East Gippsland. The sites are labelled as red (mature) and black (regrowth) with their corresponding paired plot numbers.

Table 7 Relative abundance (average abundance of a given life form in a regrowth or mature sites over the average abundance of that life form in all sites expressed as a %) of life form groups for regrowth and mature forest.

Life Form	maximum group	regrowth	mature
Immature Canopy Tree	regrowth	71	29*
Understorey Tree or Large Shrub	mature	41	59
Medium Shrub	mature	48	52
Small Shrub	mature	40	60
Prostrate Shrub	regrowth	56	44
Large Herb	mature	42	58
Medium Herb	regrowth	53	47
Large Tufted Graminoid	regrowth	55	45
Large Non-tufted Graminoid	regrowth	53	47
Medium to Small Tufted Graminoid	regrowth	51	49
Medium to Tiny Non-tufted Graminoid	mature	38	62
Ground Fern	mature	25	75
Tree Fern ¹	mature	17	83
Scrambler or Climber	regrowth	52	48

* $p < 0.05$, monte carlo randomisation test

¹ present but not in the EVC 16 Lowland Forest benchmark description

Table 8 Comparison of benchmark number of species and % cover of understorey life forms with regrowth and mature forest, East Gippsland.

Life form	Benchmark #spp	Regrowth	Mature	Benchmark %Cover	Regrowth	Mature
Immature Canopy Tree				5	17	7.1
Understorey Tree or Large Shrub	2	2.7	2.8	10	5.8	8.4
Medium Shrub	10	3.6	3.8	30	15	17
Small Shrub	6	1.4	2.3	15	6.6	10
Prostrate Shrub	2	1.6	1.3	5	1.7	1.3
Large Herb	1	2.3	1.6	1	0.85	1.2
Medium Herb	6	6.4	4.9	10	3.1	2.7
Large Tufted Graminoid	2	3.1	2.7	10	3.7	3.1
Large Non-tufted Graminoid	1	1	0	5	2.2	1.9
Medium to Small Tufted Graminoid	6	5.1	5.4	10	10	9.9
Medium to Tiny Non-tufted Graminoid	2	1.5	2.1	5	1	1.6
Ground Fern	3	1.2	1.5	10	3.4	10
Scrambler or Climber	3	2.7	2.5	5	2.2	2
Bryophytes/Lichens	na	na	na	10	7.4	6



Figure 17 Forest stands with a more diverse range of understorey life forms and with a foliage cover and species richness in excess of 50% of the benchmark number scored more highly in their Habitat Hectares site condition score. EVC 16 Lowland Forest, West Bemm East Gippsland.

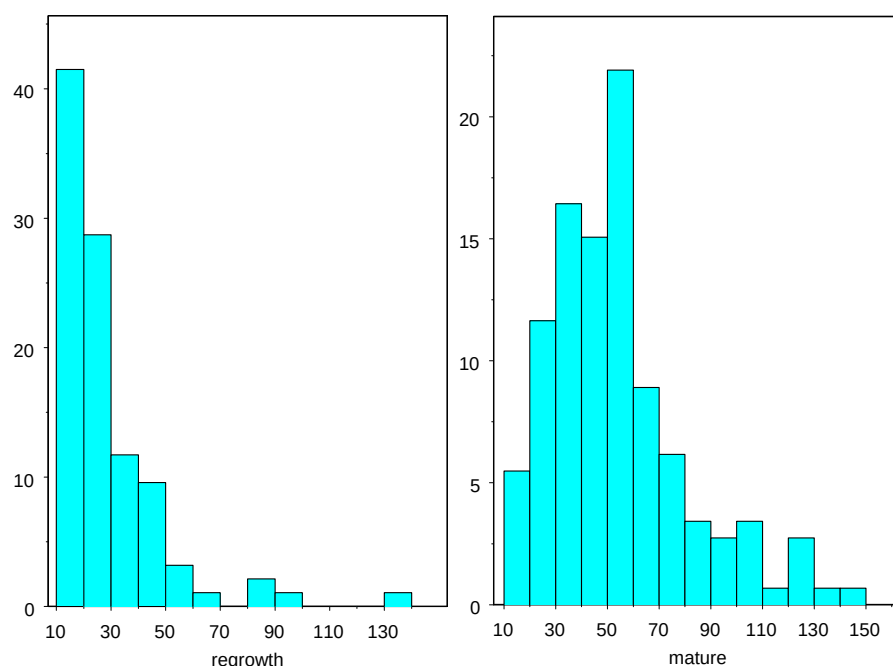


Figure 18 Proportional (%) distribution of stems in 10 cm diameter classes for the regrowth and mature forests sampled, East Gippsland.

Stand structure differed markedly between the regrowth and mature forests sampled, with a preponderance of smaller stems in the regrowth and an approximately bivariate normal distribution in the mature forest (Figure 18). The presence of a small proportion of larger stems in regrowth is typical of harvesting systems which employ some form of seed tree retention, similarly the presence of smaller stems in the mature forests is indicative of either continuous recruitment or growth suppression, or both. The significant difference between the two size class histograms is in the much reduced density of larger trees in regrowth (Figure 19), which is defined in the EVC benchmark as stems >70 cm dbh at a density of 20/ha. Based on data from fixed area plots, both the mature and regrowth forests sampled were below the benchmark figure for large trees (Table 9).

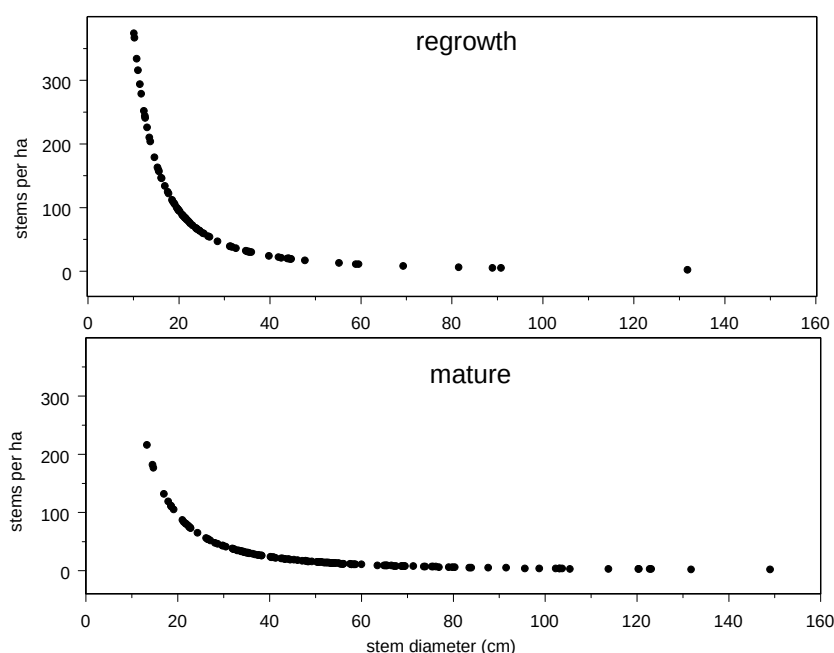


Figure 19 Relationship between stem density and diameter for the regrowth and mature forests sampled, East Gippsland, based on variable radius plot sampling.

Table 9 Density per ha of large trees in regrowth and mature forest, East Gippsland, based on fixed area plot sampling of 78m² per stand.

	Regrowth	Mature
Tree size		
10-70 cm	754	372
>70 cm	0	9.7

Fallen logs represent a significant ecological resource in the lowland forests studies (Figure 21-22) and were allocated 5% of the total site scores in Habitat Hectares and Biometric and equal benchmarks for mature forests of 20 m/0.1 ha. Regrowth lowland forests had the greatest biomass in terms of log length (Table 10) and the number of log pieces (Figure 20), although mature forests had a greater biomass of large logs > 20 cm diameter. The variation in the mean log lengths was high for both regrowth and mature forests. Both regrowth and mature forest exceeded the benchmark minima figure. The characteristics of fallen logs from regrowth and mature forests were highly variable on an individual log basis (Figure 23), although in terms of the log decay process, more advanced stages of decay were more prevalent in larger diameter but shorter length logs (Figure 24).

Table 10 Total log length of fallen logs [m/0.1 ha with 95% confidence intervals (CI)] within regrowth or mature forests in East Gippsland differed depending on the mid point diameter size class used. Habitat Hectares and Biometric both use a 10 cm minimum threshold.

	regrowth			mature		
	Mean	Lower CI	Upper CI	Mean	Lower CI	Upper CI
Logs 10-20 cm diameter	31.5	15	48	22	-8	53
Logs >20 cm diameter	17.7	6.2	29.2	19	3.5	34.5
Total log length (m/0.1ha)	49.2	24	75	40.9	5.8	76

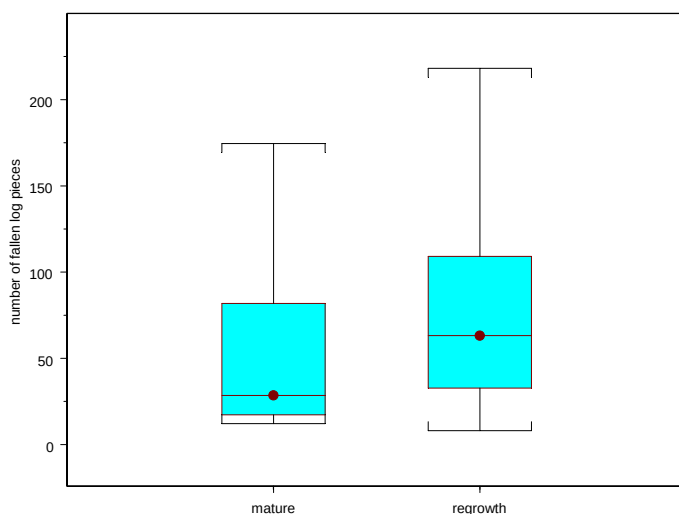


Figure 20 Total number of log pieces > 10cm diameter at their mid-point within regrowth or mature forests in East Gippsland.



Figure 21 An example of log decay class 2 (some bark present, twigs absent, signs of decay present) at Patrol Track, West Bemm East Gippsland. Despite the intensification of management due to regrowth thinning, woody debris remains an important ecological attribute, although the supply of larger logs such as this is reliant on tree fall from agents such as fire, disease and wind.



Figure 22 An example of log decay class 5 (Extensive decay -collapsed and/or flattened) at Patrol Track, West Bemm East Gippsland.

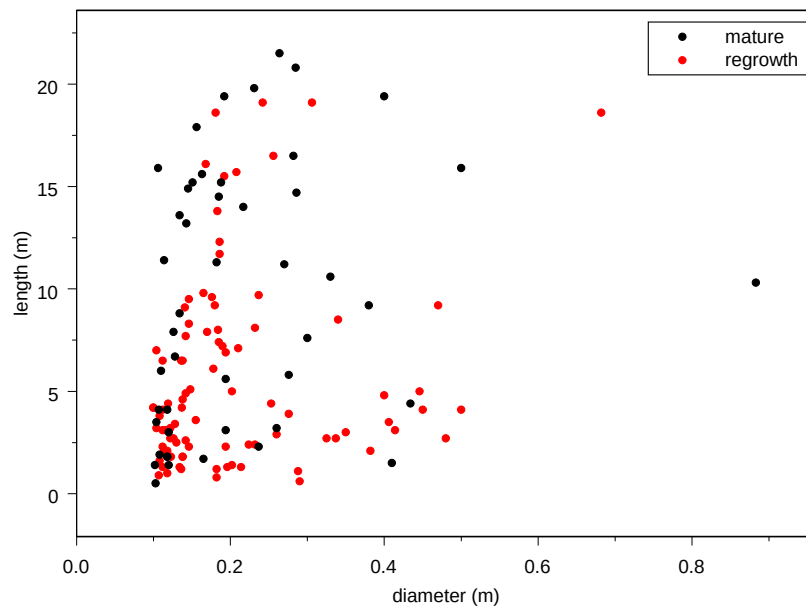


Table 23 Fallen log length characteristics for the regrowth and mature forests sampled, East Gippsland.

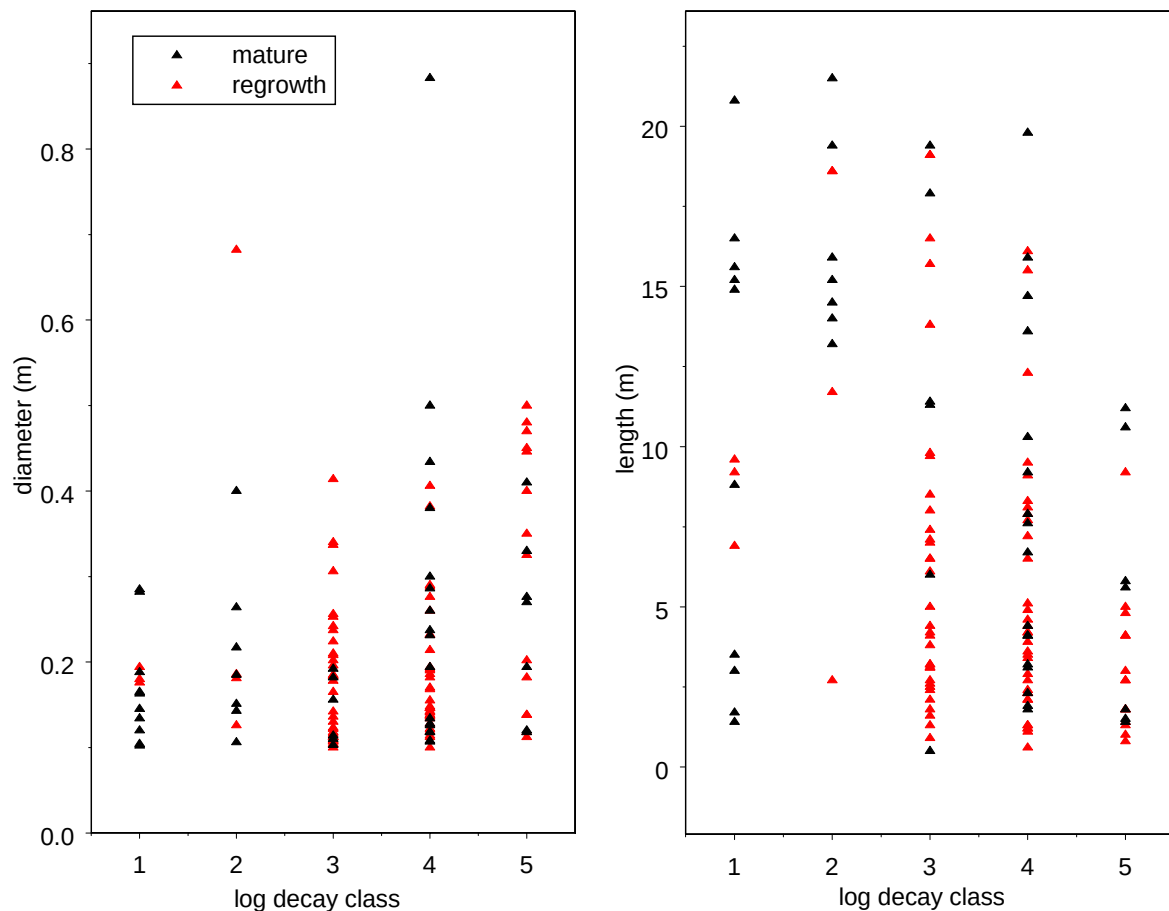


Figure 24 Relationship between fallen log dimensions and decay class in regrowth and mature forests, East Gippsland. Log decay classes; (1) Fresh, solid wood, bark & twigs present, (2) Some bark present, twigs absent, signs of decay present, (3) Bark absent, more extensive decay but structurally sound, maybe some termite damage, (4) Severe decay - breaks apart when kicked and (5) Extensive decay - collapsed and/or flattened.

Hollows represent a significant component of the total site score in Biometric, being allocated 12.5% while in Habitat Hectares 10% of the site score is allocated to the large tree benchmark of 20 trees per hectare over 70 cm dbh (assuming large diameter trees are an effective surrogate for the hollow bearing large tree resource). The presence of hollows is positively correlated with tree diameter (Figure 25), although hollows can occur in small trees, and not all large trees have hollows. Hollows are also not restricted to mature forests. Hollow density is however clearly greater in mature forest where approximately 20 trees per hectare contain hollows, compared to approximately 5 in regrowth (Figure 26). In this case the mature forests meet the benchmark minima for Biometric (20/ha), although if the same benchmark is interpreted in terms of large tree density per hectare (>70 cm dbh Table 9), they do not. The significance of tree diameter in predicting hollow density is described in Figure 27, the distinction between regrowth and mature forest hollow densities is at its greatest in the moderate tree size class (51-100 cm dbh), and is of less significance in the smaller size class (10-50 cm dbh).

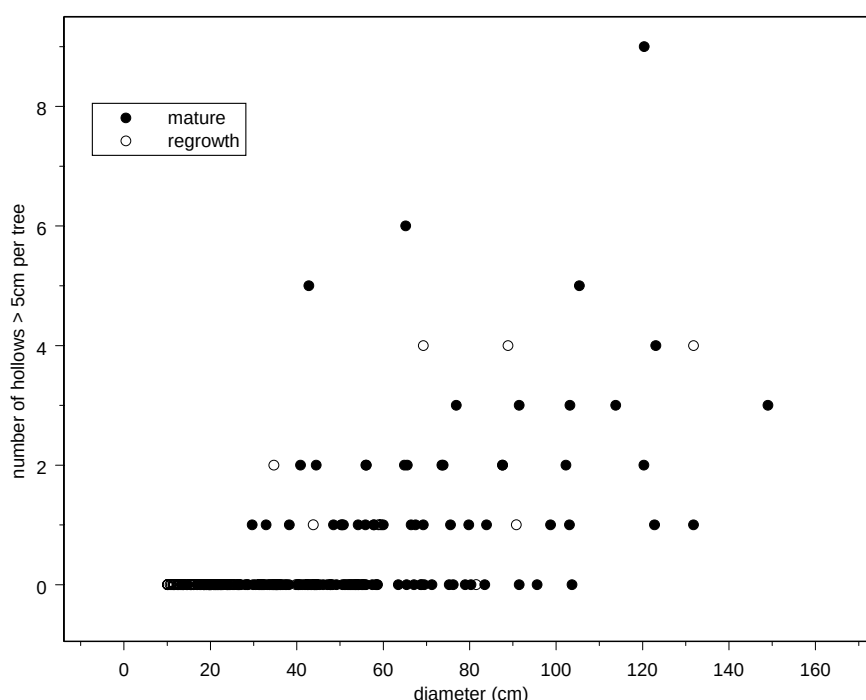


Figure 25 Relationship between number of trees with hollows greater than 5cm at their opening and tree diameter for regrowth and mature forest East Gippsland. Pearson product moment correlation coefficient $r=0.580$.

Total bird species composition was poorly related to stand management history, in both the multivariate space (Figure 29) and the classification of pair wise association measures (Figure 30). There was however a weak differentiation between regrowth and mature stands along axis 2. Bird species feeding guilds provided a clearer differentiation between the two stand types, particularly from the classification of site bird feeding guilds (Figure 32). Total bird count or density was higher in mature forest and weakly correlated with the Habitat Hectares score, but was unrelated to the Biometric score (Figure 33). Bird species richness similarly was greater in mature stands but was unrelated to either of the site scores (Figure 33). Hollow nesting birds were more abundant in mature forest, the effect was more pronounced for small hollow nesters than large hollow nesters (Figure 34). The correlation of hollow nesting birds with the site scores was moderate only for the small hollow nesters. None of the other nesting guilds (Appendix 1) were related to either stand type or the site scores. The richness of arboreal mammal species and micropteran bats was moderately correlated with both the Habitat Hectares and Biometric site scores (Figure 35). Arboreal mammals such as Greater Gliders, Common Ringtail Possums and Yellow-bellied Gliders were more abundant in mature forest compared to regrowth, while Sugar Gliders and Common Brushtail Possums were not differentiated between mature and regrowth forest.

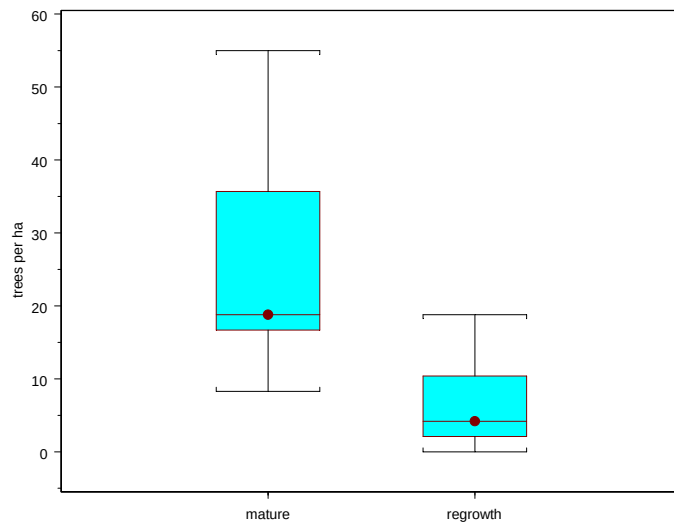


Figure 26 Relationship between number of trees per hectare with hollows (> 5cm opening diameter) and stand history (regrowth and mature) in East Gippsland.

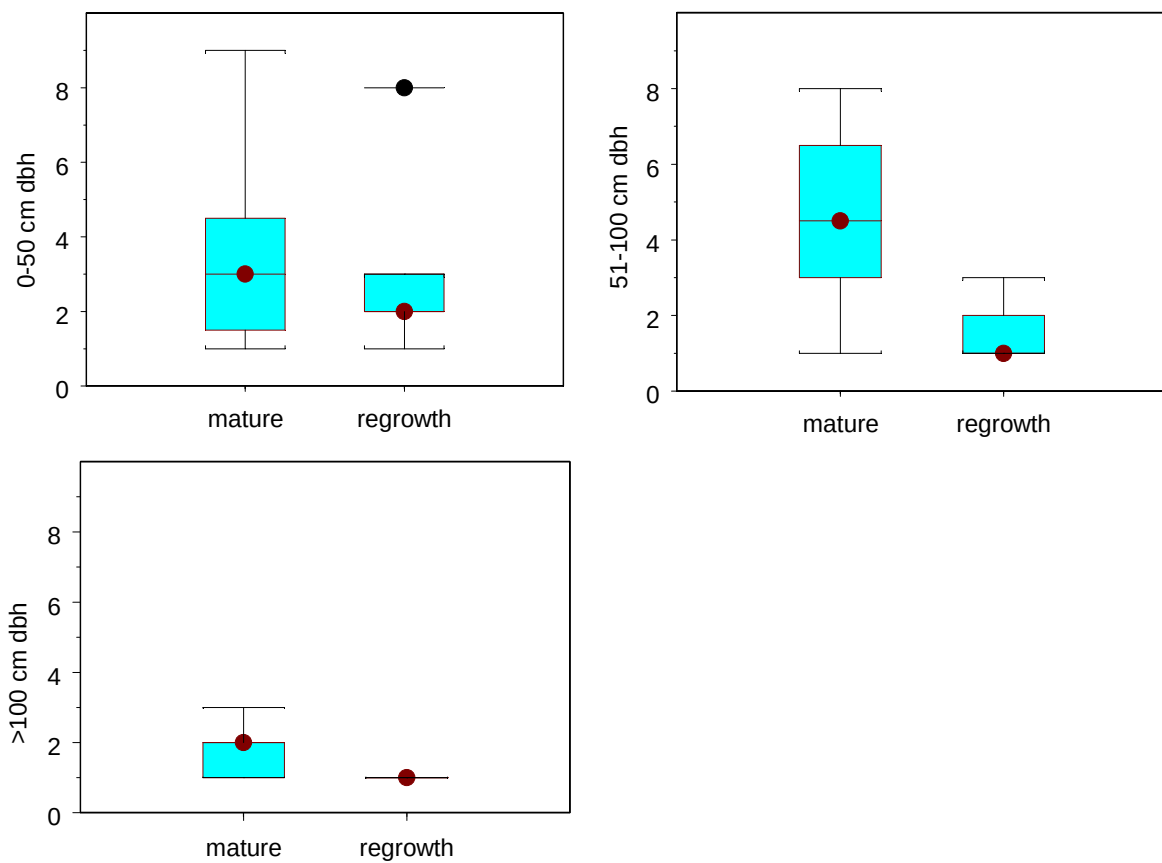


Figure 27 Relationship between tree diameter (10-50 cm, 51-100 cm, >100 cm) and number of hollows observed per 0.1 hectare in hollow bearing trees for the regrowth and mature forests sampled, East Gippsland.



Figure 28 Typical examples of large (>10 cm opening) hollows which form on the main trunk or on large limbs. Hollows formed on large limbs are more likely to arise from storm damage than those on the main trunk.

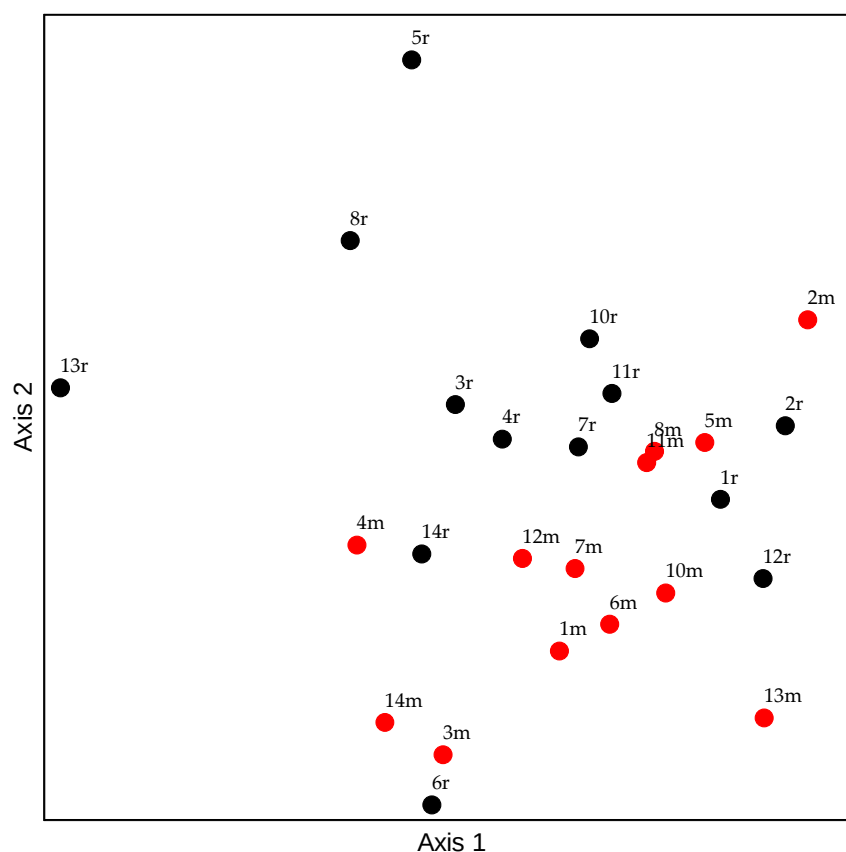


Figure 29 Ordination of bird species abundance (count) data for 13 pairs of regrowth and mature lowland forest, East Gippsland. The sites are labelled as red (mature) and black (regrowth) with their corresponding paired plot numbers.

Table 11 Model fitting statistics for the ordination of bird species abundance (count) data.

Axis	r-squared		Minimum stress in real data	r-squared and % orthogonality with	
	increment	cumulative		axis 1	axis2
1	0.465	0.465	43.7	-	-0.072, 99.5%
2	0.195	0.660	20.6	-	-
3	0.101	0.762	14.8	-0.048, 99.8%	0.031, 99.9%

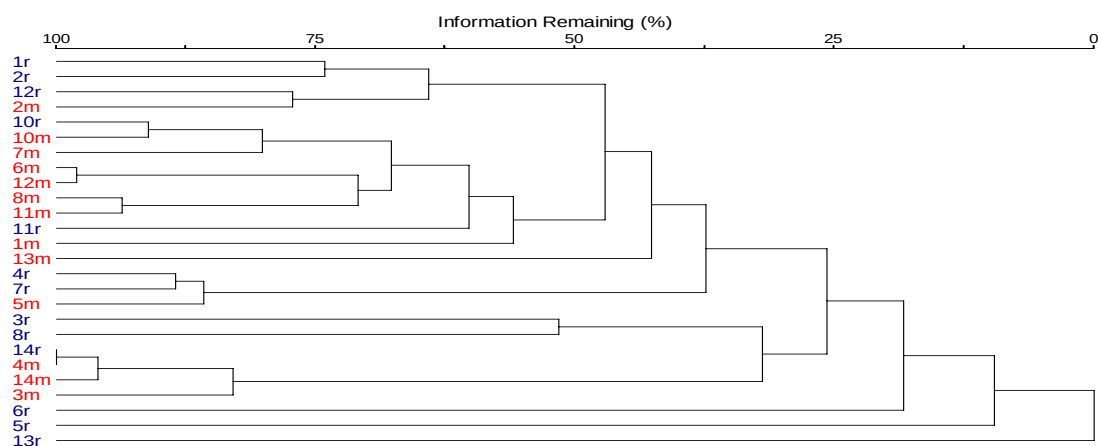


Figure 30 UPGMA cluster dendrogram of understory life form cover data for 13 pairs of regrowth and mature lowland forest, East Gippsland. The sites are labelled as red (mature) and black (regrowth) with their corresponding paired plot numbers.

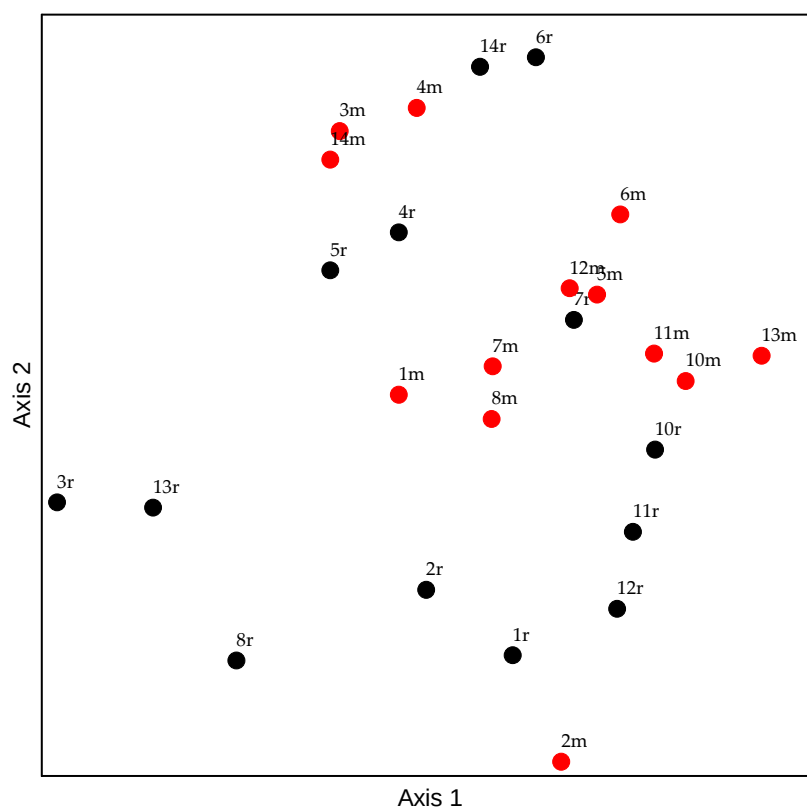


Figure 31 Ordination of bird species feeding guilds (counts per guild) for 13 pairs of regrowth and mature lowland forest, East Gippsland. The sites are labelled as red (mature) and black (regrowth) with their corresponding paired plot numbers.

Table 12 Model fitting statistics for the ordination of bird species feeding guilds data.

Axis	r-squared		Minimum stress in real data	r-squared and % orthogonality with	
	increment	cumulative		axis 1	axis2
1	0.324	0.324	43.8	-	-0.017, 100%
2	0.364	0.688	20.7	-	-
3	0.191	0.879	12.9	-0.105, 98.9%	0.195, 96.2%

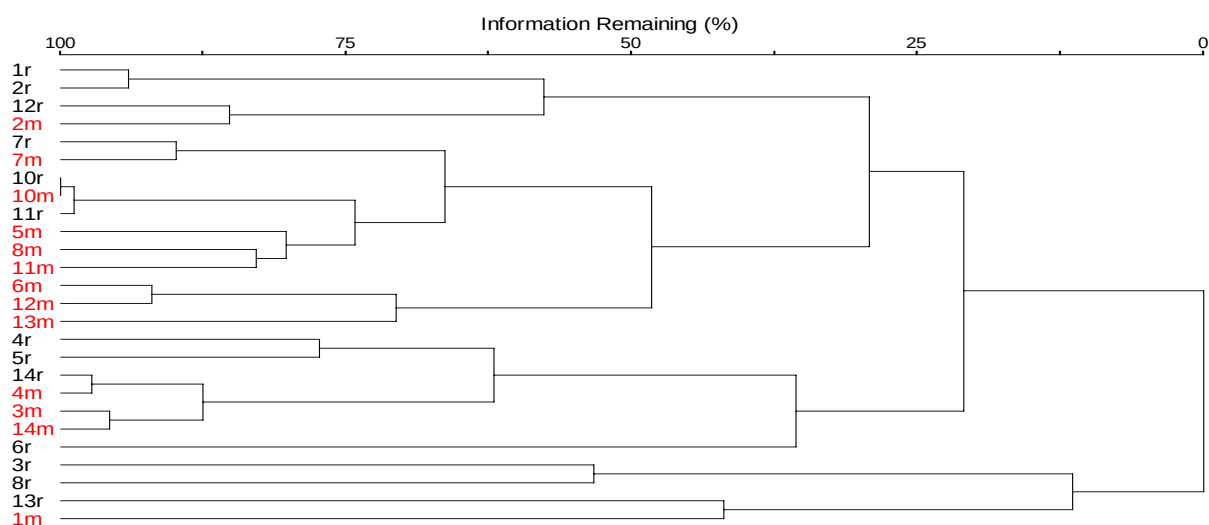


Figure 32 UPGMA cluster dendrogram of bird species feeding guilds (counts per guild) for 13 pairs of regrowth and mature lowland forest, East Gippsland. The sites are labelled as red (mature) and black (regrowth) with their corresponding paired plot numbers.

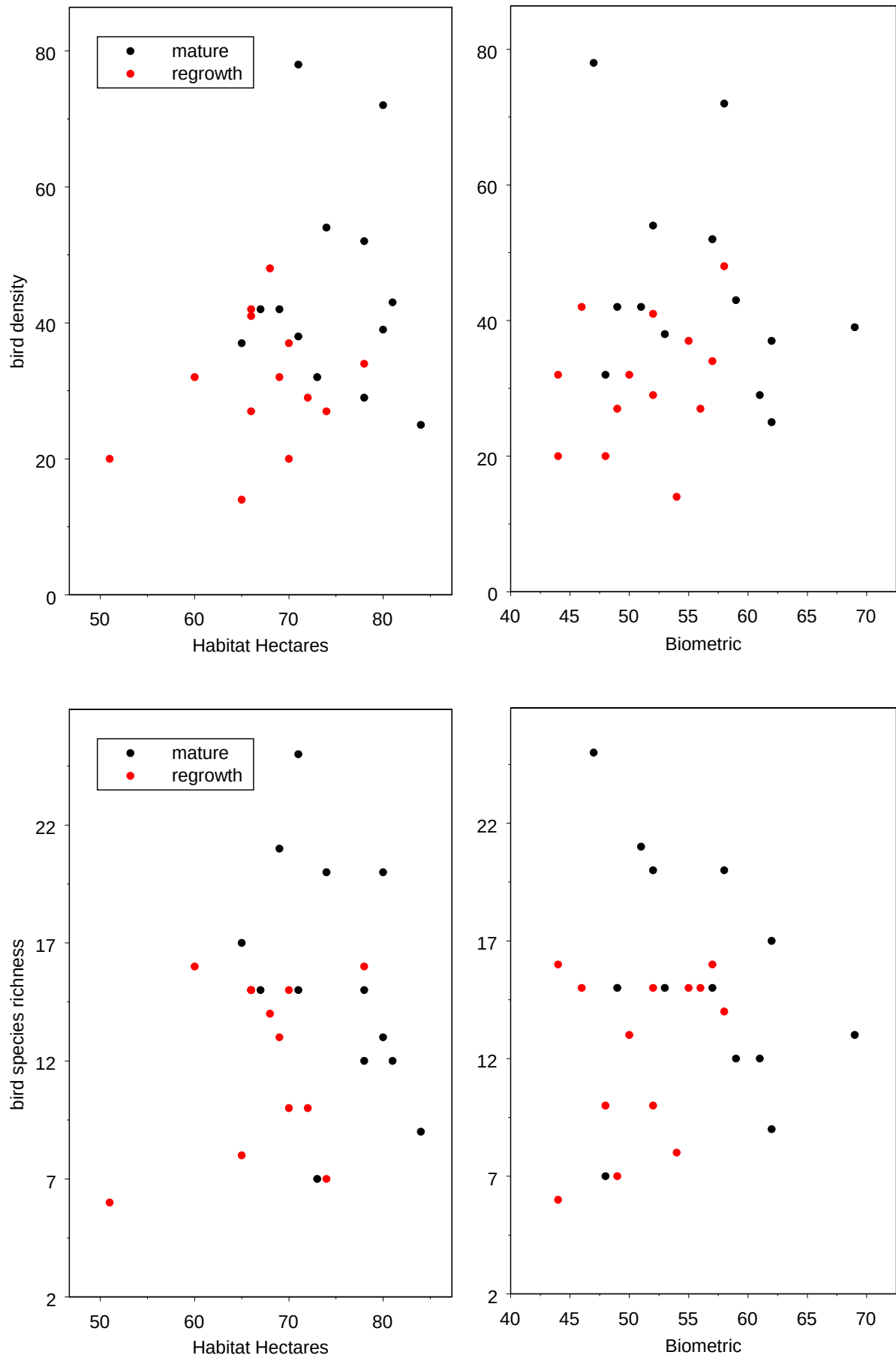


Figure 33 Bird density and species richness in mature and regrowth lowland forest, East Gippsland.

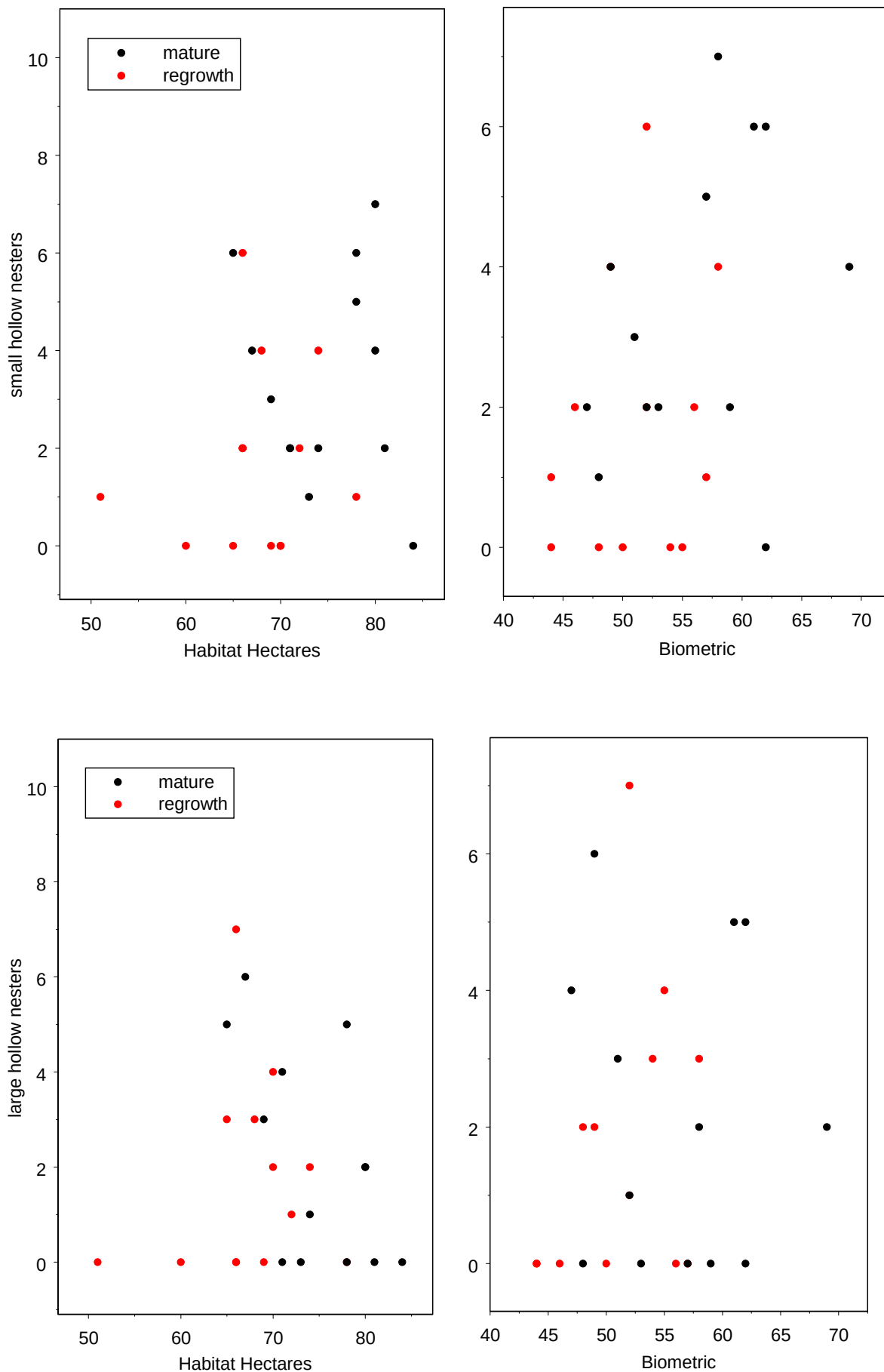


Figure 34 Density of hollow nesting birds in mature and regrowth lowland forest, East Gippsland.

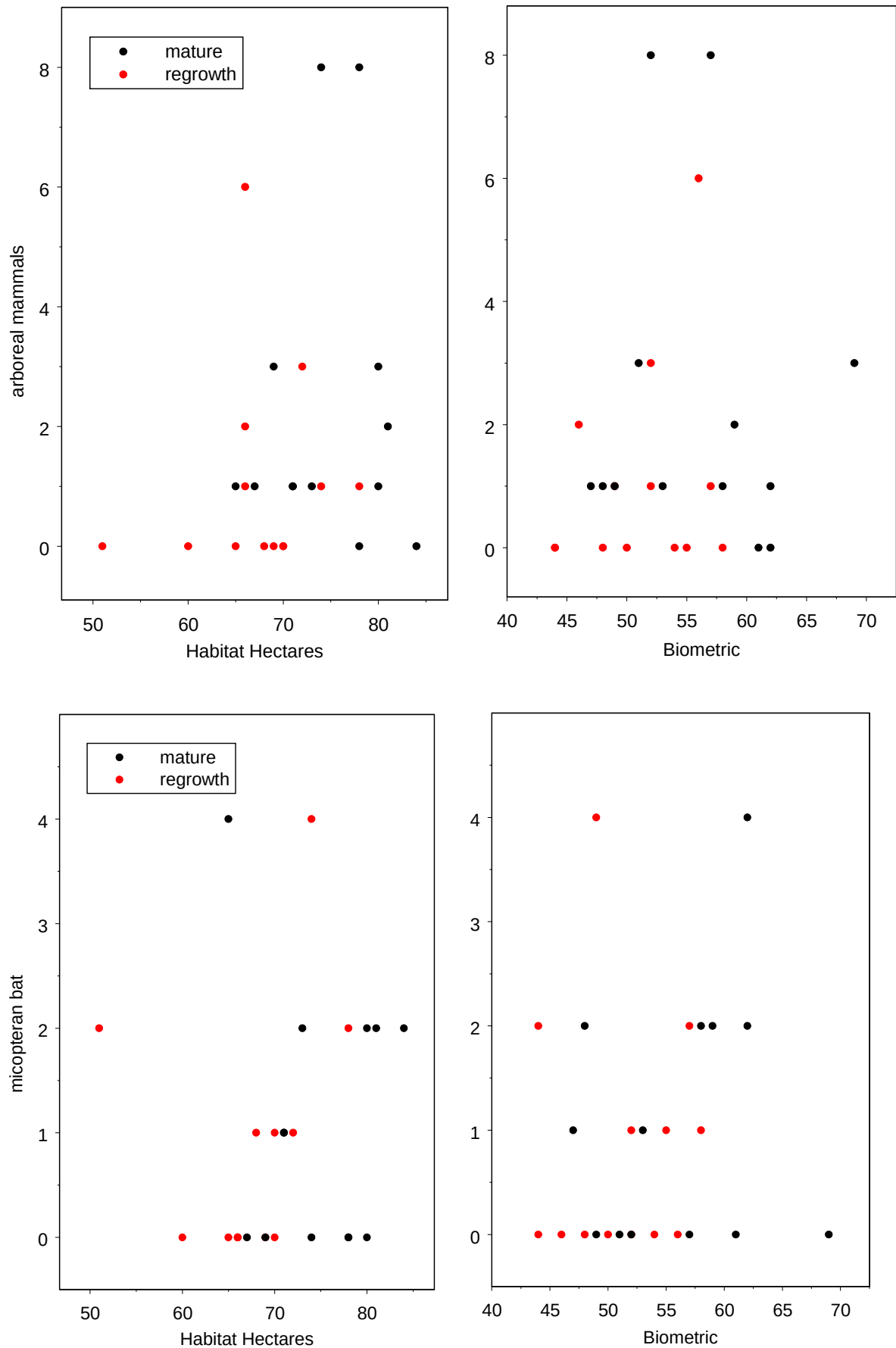


Figure 35 Richness of arboreal mammal and micropteran bat species in mature and regrowth lowland forest, East Gippsland.

3. Comparison of mature and regrowth forest, northern NSW

3.1 Objectives

The objective of this field study was to examine the correspondence between a range of quantitative stand and ecological descriptors with the discriminatory power of the Habitat Hectares and Biometric scoring systems and their component biodiversity surrogates.

3.2 Methods

3.2.1 Study Area

The study was conducted in north eastern NSW on four private properties in the Drake, Rappville, Whiporie and Nymboida areas. The experiment focussed on Clarence Dry Sclerophyll Forest (Keith 2005). The study area is described by Jay (2006).

3.2.2 Experimental Design

The study design adopted a stratified random approach with six treatments representing contrasting forest stand histories, four properties and between two and four replicates per treatment. The treatments were initially described in terms of stand management history and landscape context (Table 13). The study design was subsequently revised for this report in order to increase the number of replicates and simplify the description of treatments and therefore their cross comparison with the other field studies described in this report. The stratification was reduced to two types: mature and regrowth with 8 and 13 replicates respectively across the four properties. In this design, inter-site difference are assumed to be negligible.

Table 13. Original and revised survey stratification in north eastern NSW.

Original stratification (Jay 2006)	Replicates	revised
Ready for harvest or nearly so (next year or two)	4	mature
Longest possible period without harvest, some big old trees and surrounded by other forest (i.e. not isolated or fragmented)	4	mature
Disconnected or fragmented patch (0.5 to 1.5 ha) with otherwise fairly good canopy cover (i.e. not simply a sparse woodland grazing site which is contiguous with adjoining forest)	2	regrowth
Logged fairly recently (in last year or two) and fairly intensively rather than light (e.g. pole-only), preferably also with some remaining debris piles. Area also subject to past burning/grazing.	3	regrowth
Young regrowth (e.g. <25-30cm DBH) dominant biomass on site, >150m from riparian zone vegetation	4	regrowth
Regrowth near (<50m) permanent water and riparian vegetation	4	regrowth

3.2.3 Vegetation and Tree Sampling

Vegetation, tree, stand, habitat variables and fauna sampling protocols are described in Jay (2006).

3.2.4 Data Analysis

The data analysis procedures follow those described for section 2.2.4. The classification of bird species into nesting and feeding guilds follows the scheme in Appendix 1.

3.3 Results

Benchmark summaries were derived for Clarence Dry Sclerophyll Forests following the Habitat Hectares approach using a sample of floristic plot data within the same region (Table 14). The benchmarks for the Biometric system used are those published by NSW Department of Environment and Conservation.

Table 14 Habitat Hectares site benchmark values for Clarence Dry Sclerophyll Forests (Keith 2004), north eastern NSW. Derived from a sample of floristic plot data following the methods described in NSW Department of Sustainability and Environment (2005)

	Species richness	% cover	weighting
Large trees	70 cm	20/ha	10
Tree canopy cover		30	5
Understorey: Life Form			25
Immature Canopy Tree	3	31	
Understorey Tree or Large Shrub	2	5	
Medium Shrub	3	7	
Small Shrub	1	3	
Prostrate Shrub	1	2	
Large Herb	2	5	
Medium herb	1	5	
Small or Prostrate Herb	3	12	
Large Tufted Graminoid	3	14	
Medium to Small Tufted Graminoid	1	16	
Large Non-tufted Graminoid	1	16	
Medium to Tiny Non-tufted Graminoid	1	2	
Ground Fern	1	3	
Epiphyte	1	2	
Scrambler or Climber	3	12	
Bryophytes and lichens			
Recruitment	continuous		10
Organic Litter	70% cover		5
Logs	20m/0.1 ha		5
Weediness	No consistent weeds		15

Table 15 Biometric site benchmark values for Clarence Dry Sclerophyll Forests (Keith 2004), north eastern NSW.

	lower	upper	weighting
Native over-storey cover (%)	20	20	10
Native mid-storey cover (%)	5	40	20
Native ground cover (%) - grasses	10	60	10
Native ground cover (%) - shrubs	5	60	2.5
Native ground cover (%) - other	10	50	2.5
Exotic plant cover (%)	Proportion of ground cover		2.5
Native plant species richness count	-	30	25
Number of trees with hollows (>5cm)	-	1	12.5
Overstorey regeneration (<5cm DBH) spp%			10
Total length of logs>10cm	10m/0.1 ha		5

Site condition (Habitat Hectares) and site value (Biometric) scores for the thirteen regrowth and eight mature forests in north eastern NSW had a modest correlation (Figure 36). The scores for Biometric had more discriminatory power for the same sites than Habitat Hectares did when the scores were re-scaled from 0-100. Regrowth and mature forests were poorly discriminated by both scoring systems, and the median scores for Habitat Hectares and Biometric were very similar for both regrowth and mature forest (Figure 37). Habitat Hectares scores offered less insight into the differences between the regrowth and mature forests sampled (Figure 38).

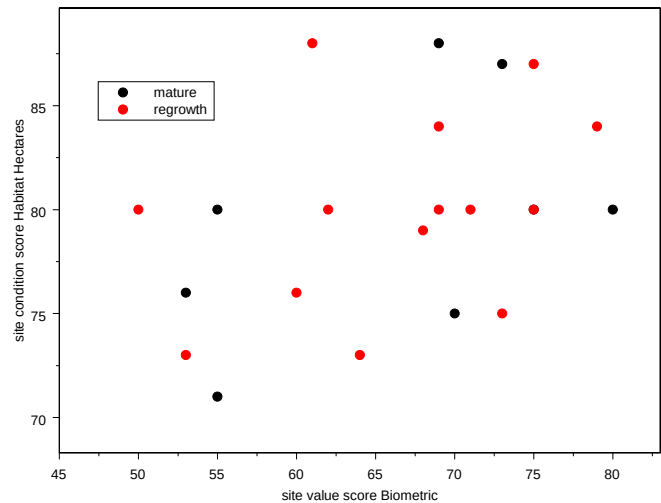


Figure 36 Relationship between Habitat Hectares and Biometric site scores in northern NSW. Pearson product moment correlation coefficient $r=0.501$.

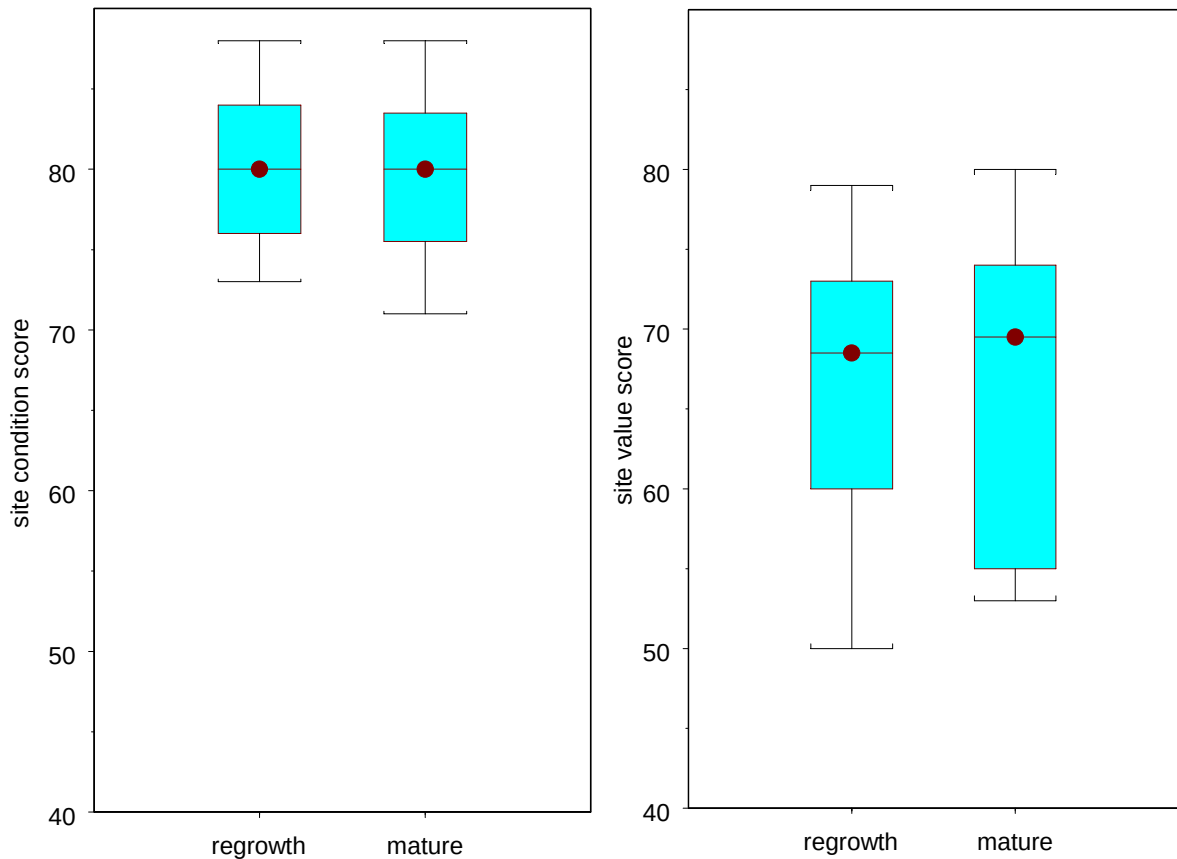


Figure 37 Site condition scores (Habitat Hectares) and site value scores (Biometric) in northern NSW. The site value scores (two-sample t-test, $p > 0.05$) and site condition scores are not significantly different (two-sample t-test, $p > 0.05$).

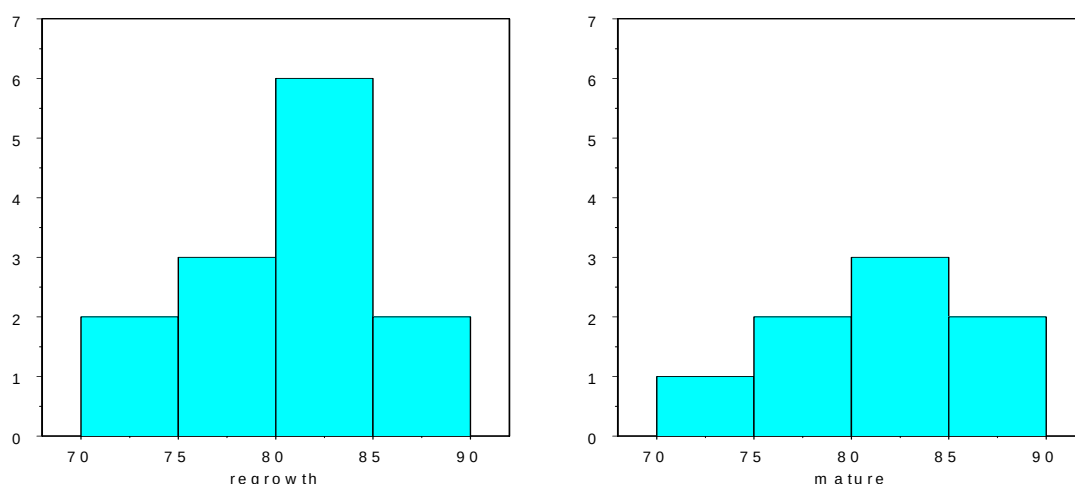


Figure 38 Site condition scores of the Habitat Hectares index for 14 regrowth and 8 mature forest stands in northern NSW

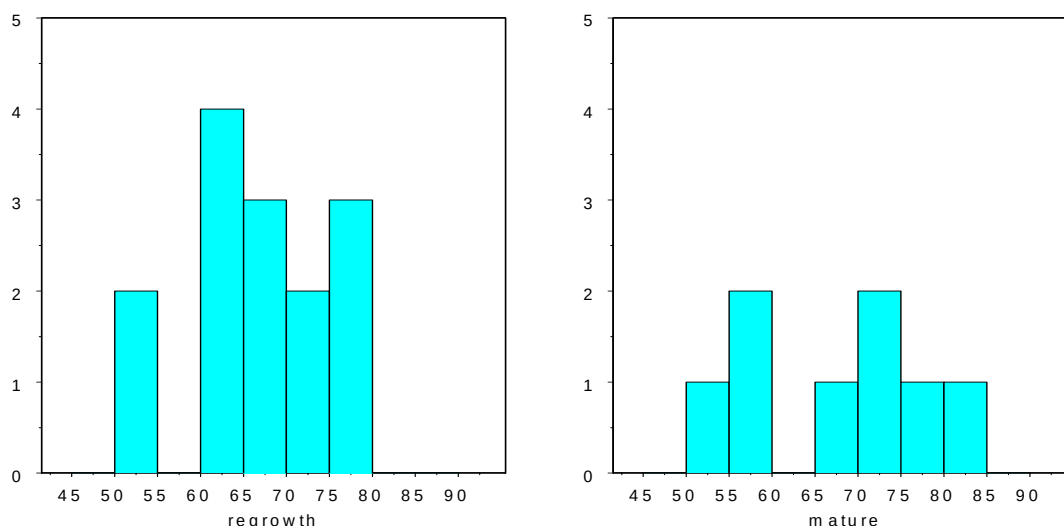


Figure 39 Site value scores of the Biometric index for 14 regrowth and 8 mature forest stands in northern NSW.

Floristic compositional differences between regrowth and mature forests were examined using the cumulative foliage cover of the Habitat Hectares understorey life forms. No trends were evident in understorey composition and cover according to stand management history (Figure 40). The co-occurrence of stands from the same properties (first letter in site label, Figure 41) in the same cluster group is indicative of spatial autocorrelation confounding the sampling of different management histories. The comparison of benchmark understorey life form richness and % cover also revealed divergent trends for different life forms, some were below the benchmark thresholds, others were in excess of them (Table 17). The only statistically significant difference between the regrowth and mature forests sampled and their benchmark values was for the number of trees with hollows (>5cm) and total length of logs >10cm diameter in the Biometric scheme (Table 18).

The shape of the distribution of tree stems in 10 cm diameter classes did not differ markedly between the regrowth and mature stand types. Similarly the presence of trees with nil, small or large hollows did not differ between regrowth and mature forest, and the variability around the median value for tree diameter for hollow bearing trees was large (Figure 42-43).

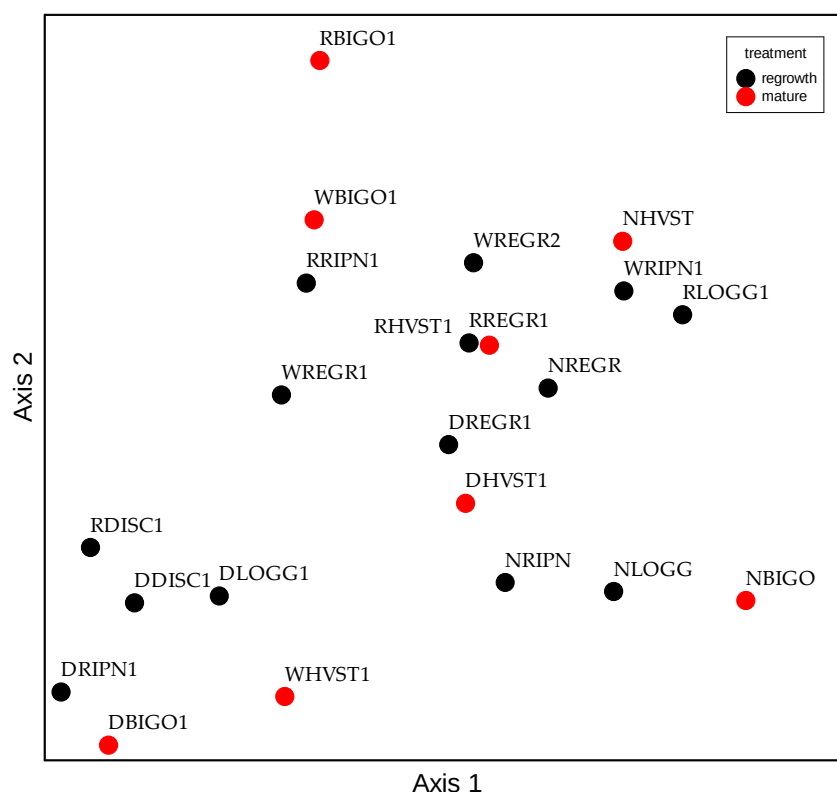


Figure 40 Ordination of understory life form cover data for regrowth and mature forest, northern NSW.

Table 16 Model fitting statistics for the ordination understory life form data, regrowth and mature forest, northern NSW.

Axis	r-squared		Minimum stress in real data	r-squared and % orthogonality with	
	increment	cumulative		axis 1	axis2
1	0.439	0.439	49.2	-	0.362, 86.9%
2	0.184	0.623	17.8	-	-
3	0.260	0.588	9.6	-0.183, 96.7%	-0.028, 99.9%

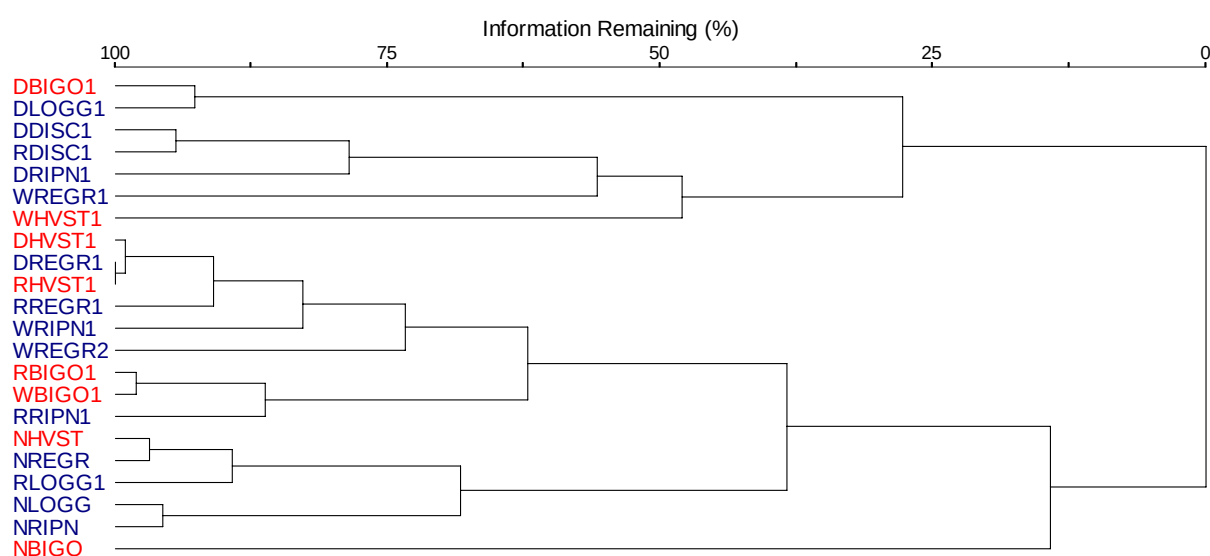


Figure 41 UPGMA cluster dendrogram life form data, regrowth and mature forest, northern NSW. The sites are labelled as red (mature) and black (regrowth) with their corresponding paired plot numbers.

Table 17 Comparison of Habitat Hectares benchmark number of species and % cover of understorey life forms with sampled Clarence Lowlands Spotted Gum regrowth and mature forest, north eastern NSW.

Life form	Benchmark #spp	Regrowth #spp	Mature #spp	Benchmark %Cover	Regrowth %Cover	Mature %Cover
Immature Canopy Tree	3	6.8	5.6	31	47	45.9
Understorey Tree or Large Shrub	2	-	-	5	-	-
Medium Shrub	3	1.7	2.5	7	14.1	14.3
Small Shrub ¹	1	1.4	1.4	3	10.9	7.6
Prostrate Shrub ¹	1	-	-	2	-	-
Large Herb	2	-	-	5	-	-
Medium Herb	1	0.5	0.5	5	0.5	0.5
Small or Prostrate Herb	3	7.0	5.8	12	4.0	7.1
Large Tufted Graminoid	3	0.9	1.0	14	2.9	1.1
Medium to Small Tufted Graminoid	1	2.7	2.3	16	16.2	17.0
Large Non-tufted Graminoid	1	-	-	16	-	-
Medium to Tiny Non-tufted Graminoid	1	5.0	3.4	2	8.7	6.4
Ground Fern	1	0.9	0.8	3	0.8	0.6
Epiphyte	1	0.5	0.5	2	2.4	8.8
Scrambler or Climber	3	0.5	0.5	12	0.5	0.8
Bryophytes/Lichens	-	0.7	0.6	-	0.6	0.6

¹Combined into a single category.

Table 18 Comparison of Biometric Habitat Hectares benchmark number of species and % cover of understorey life forms with sampled Clarence Lowlands Spotted Gum regrowth and mature forest, north eastern NSW.

	regrowth mean	mature mean
Native over-storey cover (%)	26.0	28.3
Native mid-storey cover (%)	4.3	6.4
Native ground cover (%) - grasses	7.2	7.3
Native ground cover (%) - shrubs	0.1	0.3
Native ground cover (%) - other	3.0	1.7
Exotic plant cover (%)	0.4	0.1
Native plant species richness count	24.6	22.8
Number of trees with hollows (>5cm)	1.0	1.9*
Overstorey regeneration (<5cm DBH) spp%	0.9	0.8
Total length of logs>10cm diameter	58.1	31.6**

Significantly different (two-sample t-test,* $p < 0.05$, ** $p < 0.01$).

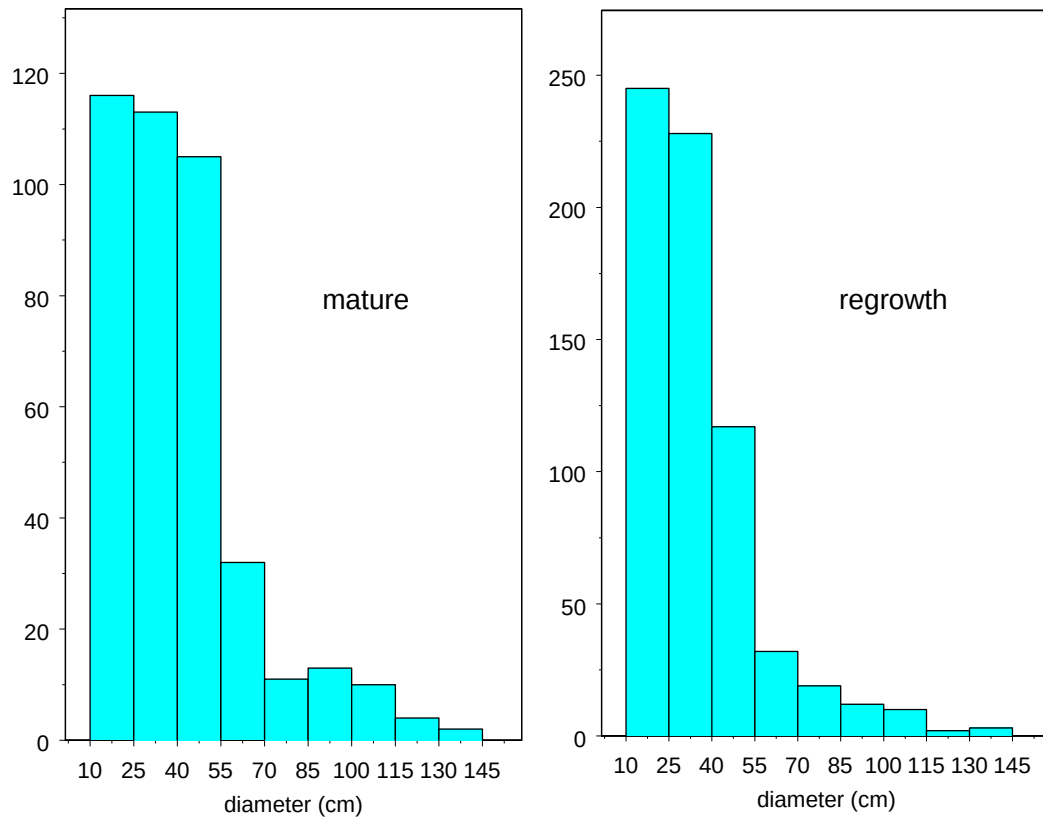


Figure 42 Distribution of stem diameter size classes in sampled Clarence Lowlands Spotted Gum regrowth and mature forest, north eastern NSW.

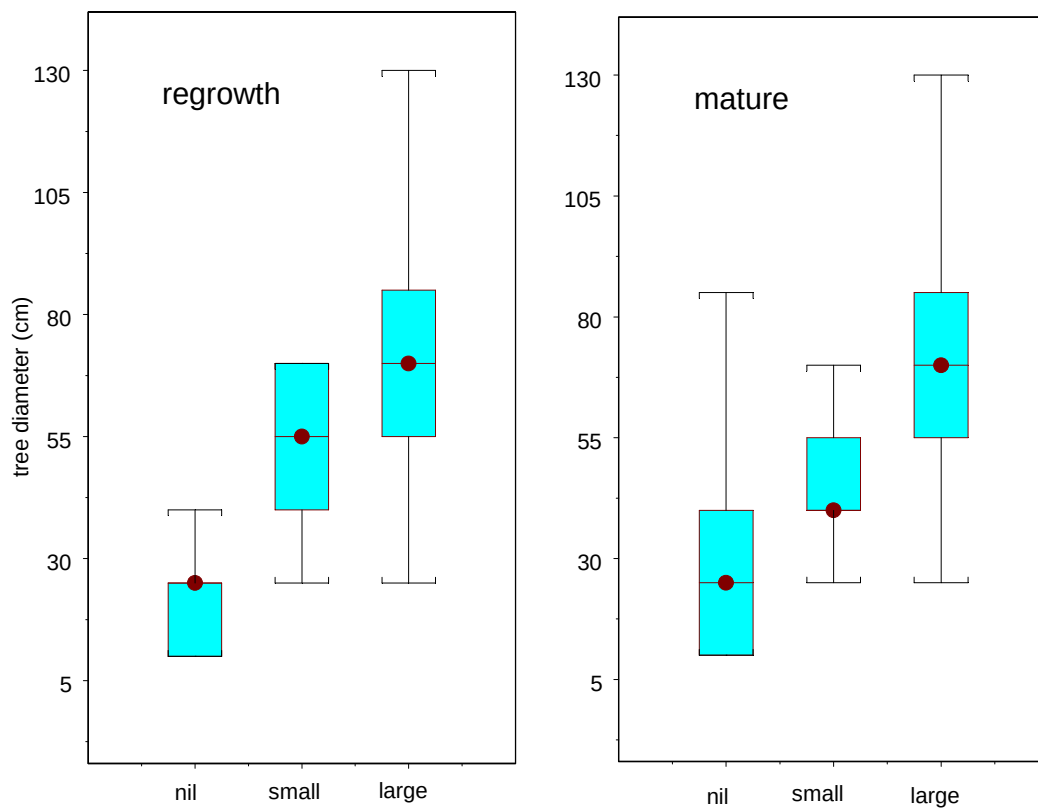


Figure 43 Characteristics of regrowth and mature forest stands with trees with nil hollows, small (<10 cm) or large (>10 cm) hollows in Clarence Lowlands Spotted Gum regrowth and mature forest, north eastern NSW.



Figure 44 Clarence Dry Sclerophyll Forest, north eastern NSW photographed 1998. Understorey species richness and cover varies with the landholder burning regime and the longevity of understorey *Acacia* species.



Figure 45 Clarence Dry Sclerophyll Forest, north eastern NSW photographed 2005. Overstorey structures are variable and typically un-even aged and understoreys open with a grassy herbaceous cover.

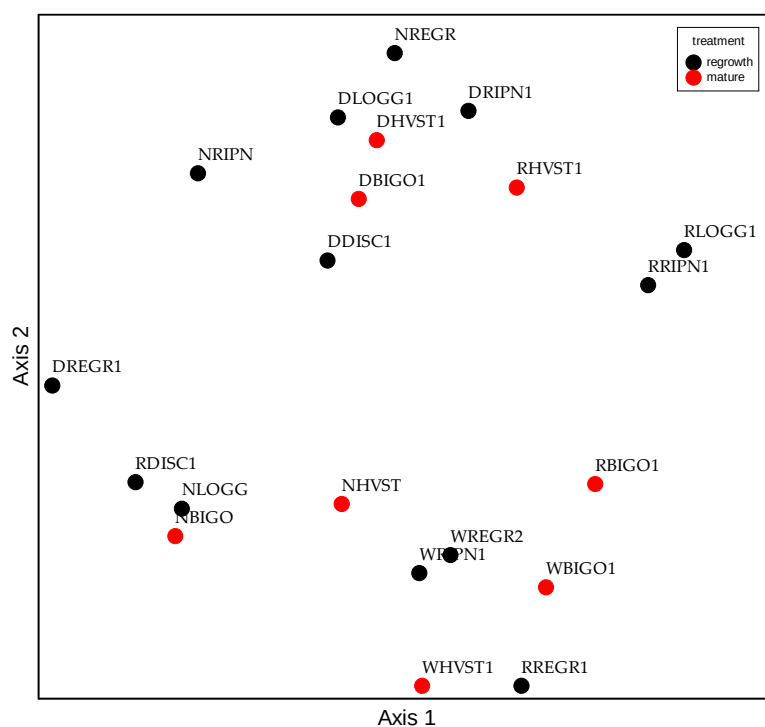


Figure 46 Ordination of total bird species counts for regrowth and mature Clarence Dry Sclerophyll Forest, north eastern NSW. The sites are labelled as red (mature) and black (regrowth) with their corresponding plot labels.

Table 19 Model fitting statistics for the ordination of total bird species counts, regrowth and mature forest, northern NSW.

Axis	r-squared		Minimum stress in real data	r-squared and % orthogonality with	
	increment	cumulative		axis 1	axis2
1	0.068	0.068	43.3	-	-0.025, 99.9%
2	0.124	0.192	23.5	-	-
3	0.337	0.530	22.3	-0.004, 100%	-0.141, 98.0%

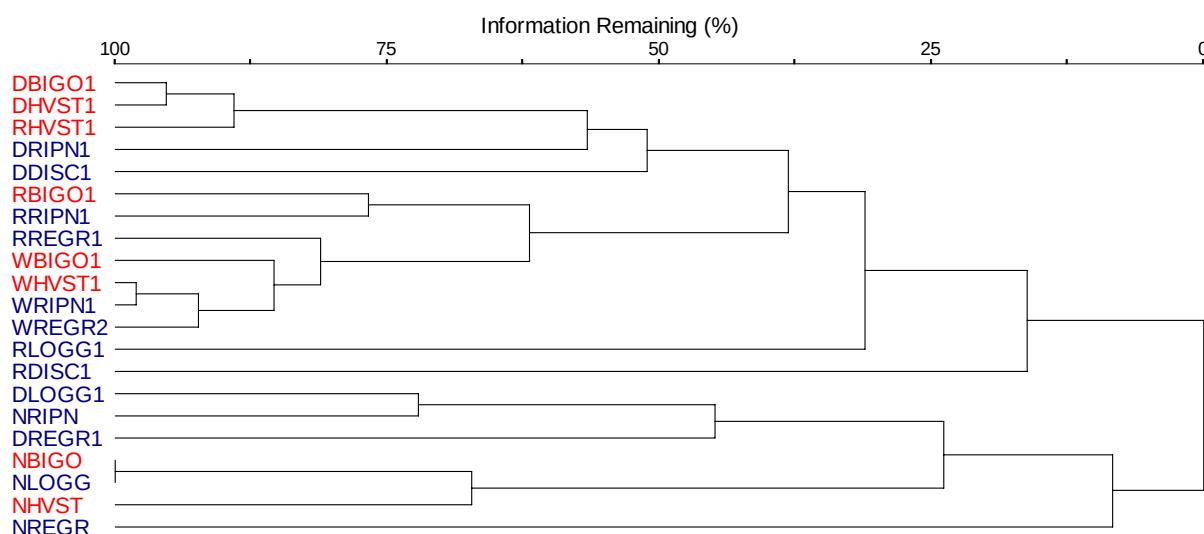


Figure 47 UPGMA cluster dendrogram of total bird species counts, regrowth and mature forest, northern NSW. The sites are labelled as red (mature) and black (regrowth) with their corresponding site numbers.

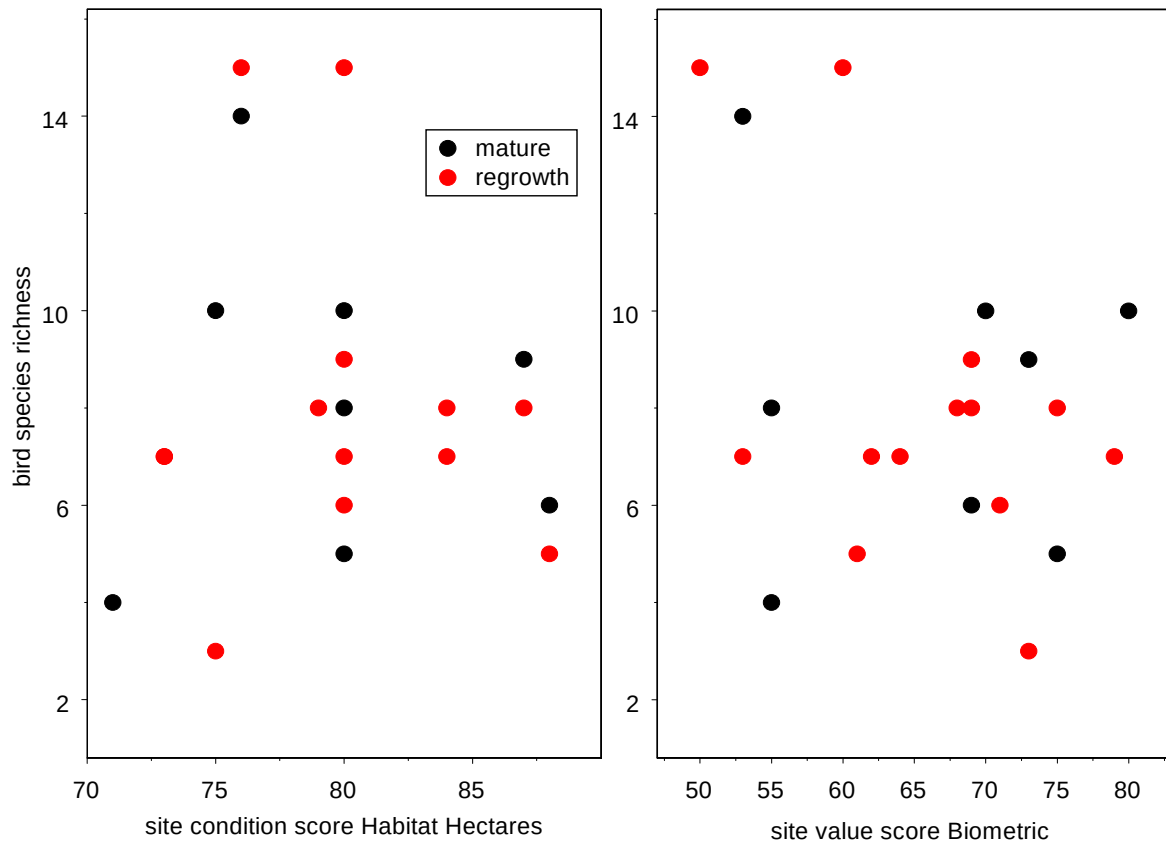


Figure 48 Relationship between bird species richness and site scores in northern NSW. Pearson product moment correlation coefficient, r , bird species richness versus Habitat Hectares, -0.070
bird species richness versus Habitat Hectares -0.420.

Compositional differences were lacking between regrowth and mature forests for the bird counts data (Figure 46). The co-occurrence of stands from the same properties (first letter in site label, Figure 47) in the same cluster group was also indicative of spatial autocorrelation confounding the sampling of different management histories. Relationships between fauna species richness and abundance and the two site scores were poor, with the exception of a weak relationship between bird species richness and the Biometric Site value score (Figure 48). The richness of bird species within nesting guilds across the regrowth and mature sites was highly variable (Figure 49-51). With the exception of small hollow nesters and nectivores [a bird which takes nectar along with other food such as seeds (e.g. parrots) and fruit or invertebrates] which were more diverse in mature forests, all other nesting guilds were highly variable in their abundance in regrowth and mature forests. Other fauna groups such as amphibian, reptile and mammal species were unrelated to the site scores or the regrowth and mature forest types (Figure 52-54).

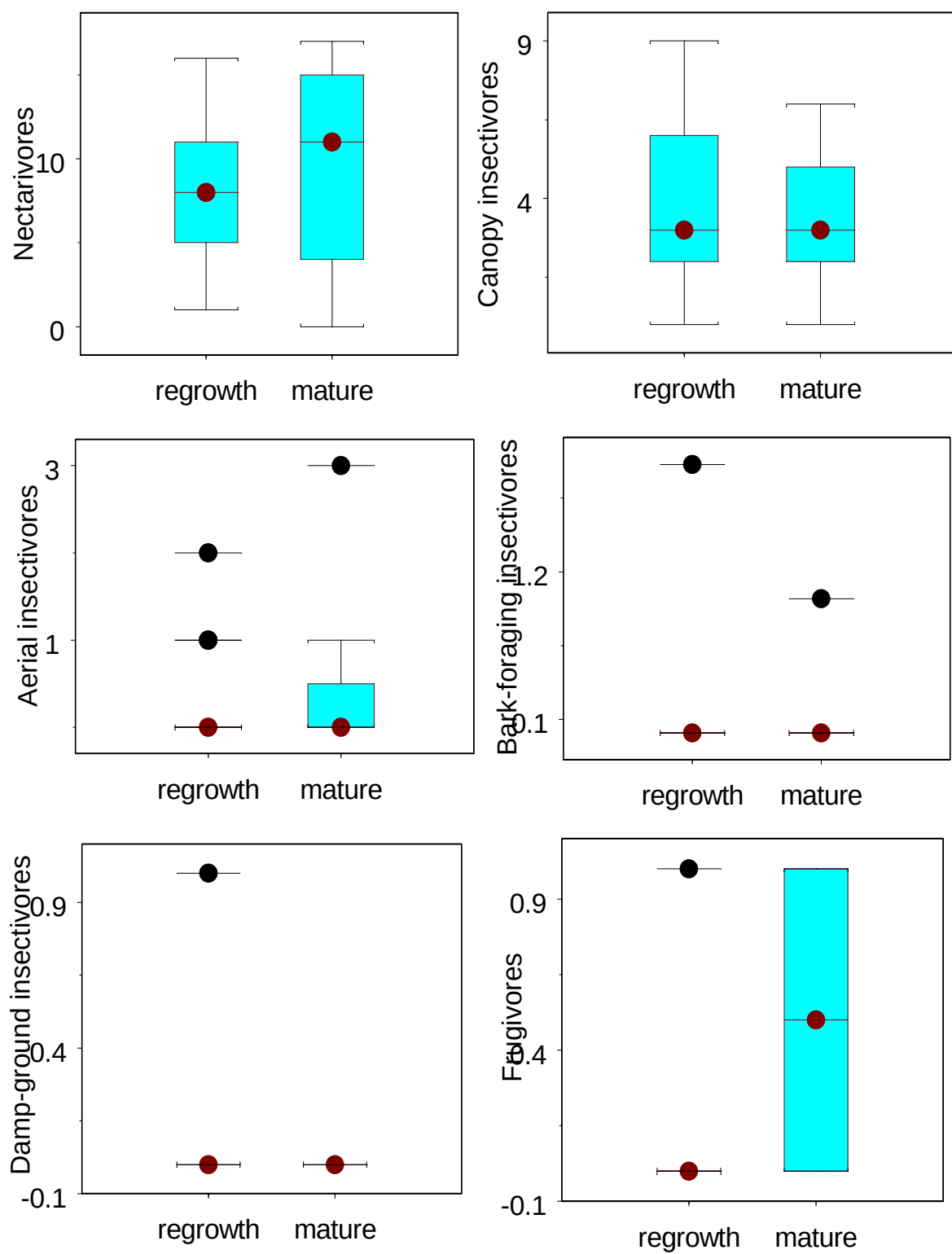


Figure 49 Abundance of bird species in feeding guilds in regrowth and mature forest, northern NSW.

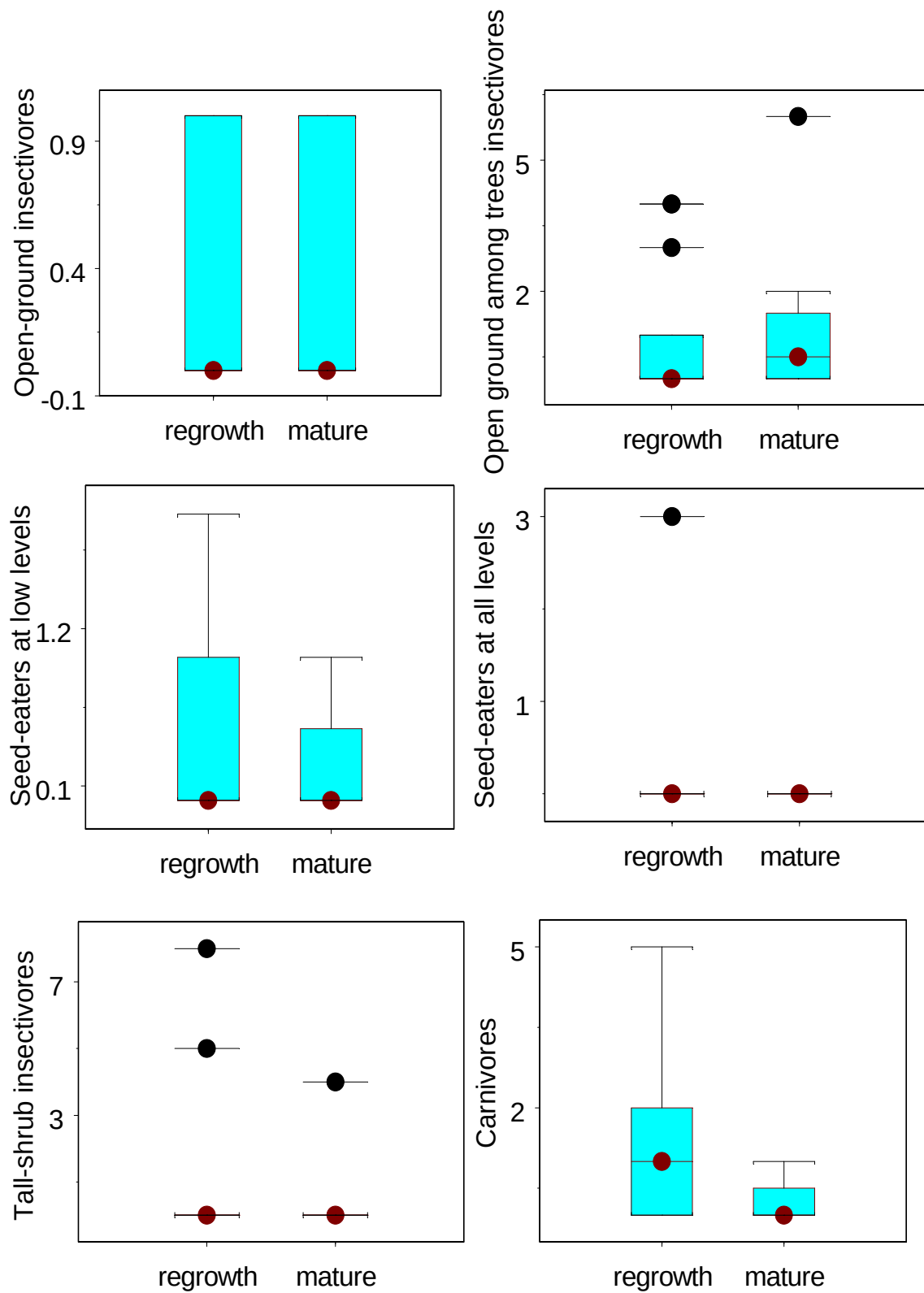


Figure 50 Abundance of bird species in feeding guilds in regrowth and mature forest, northern NSW.

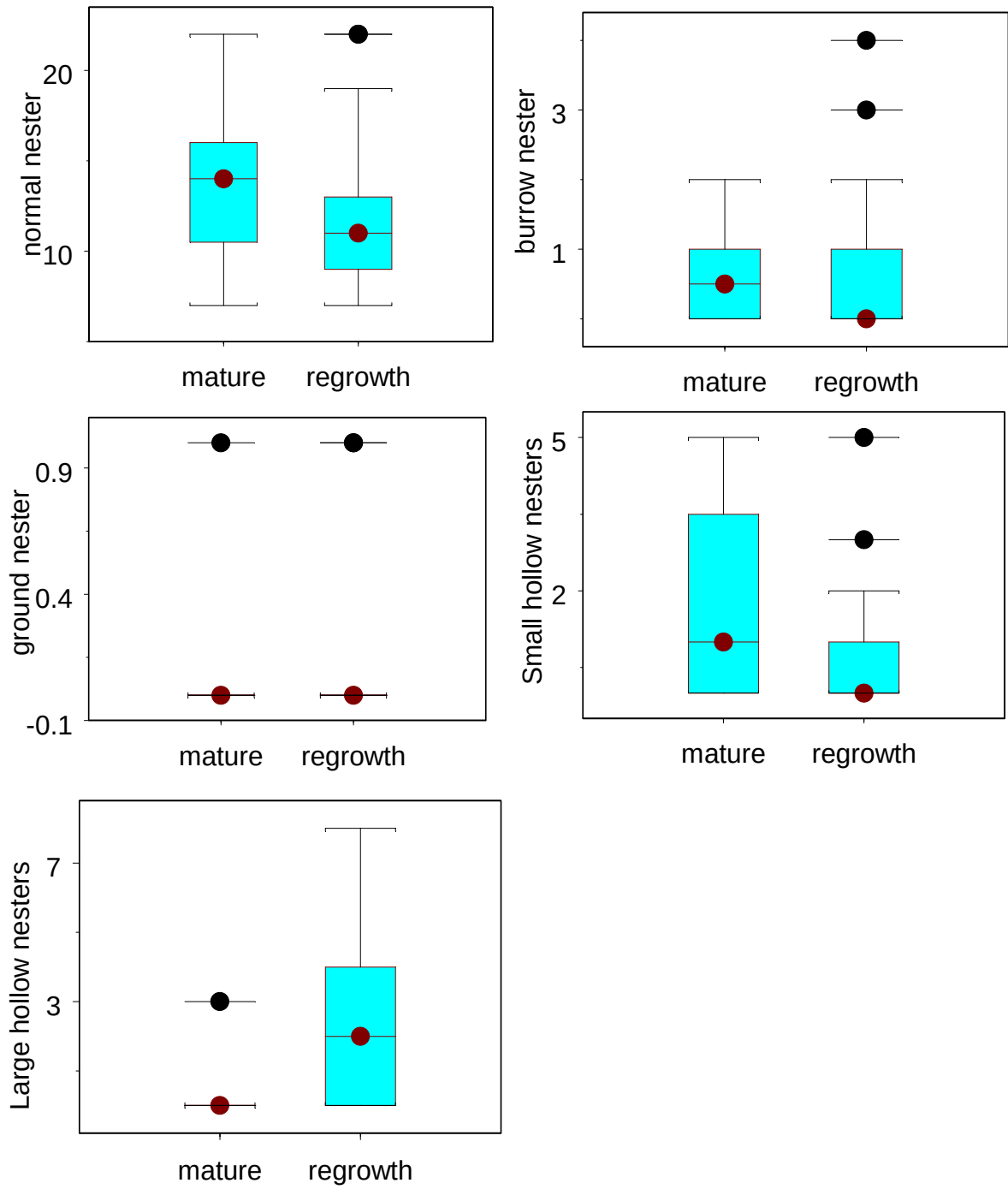
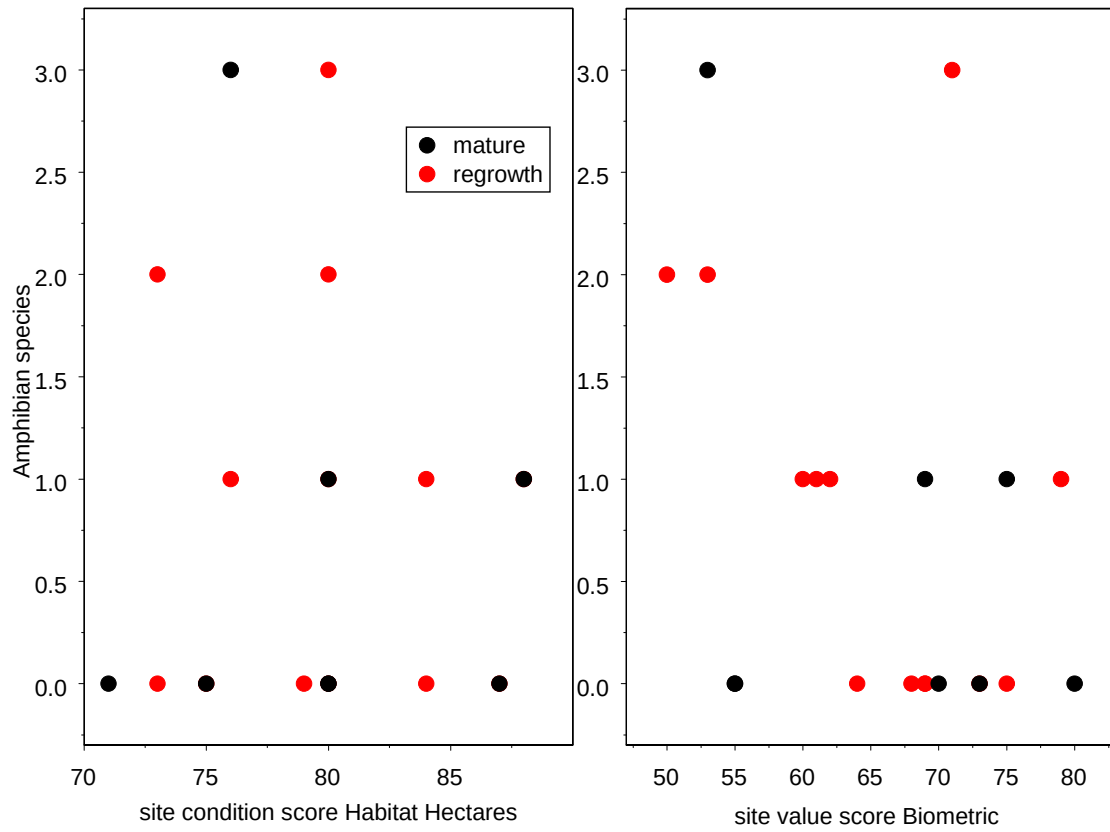


Figure 51 Abundance of bird species in nesting guilds in regrowth and mature forest, northern NSW.



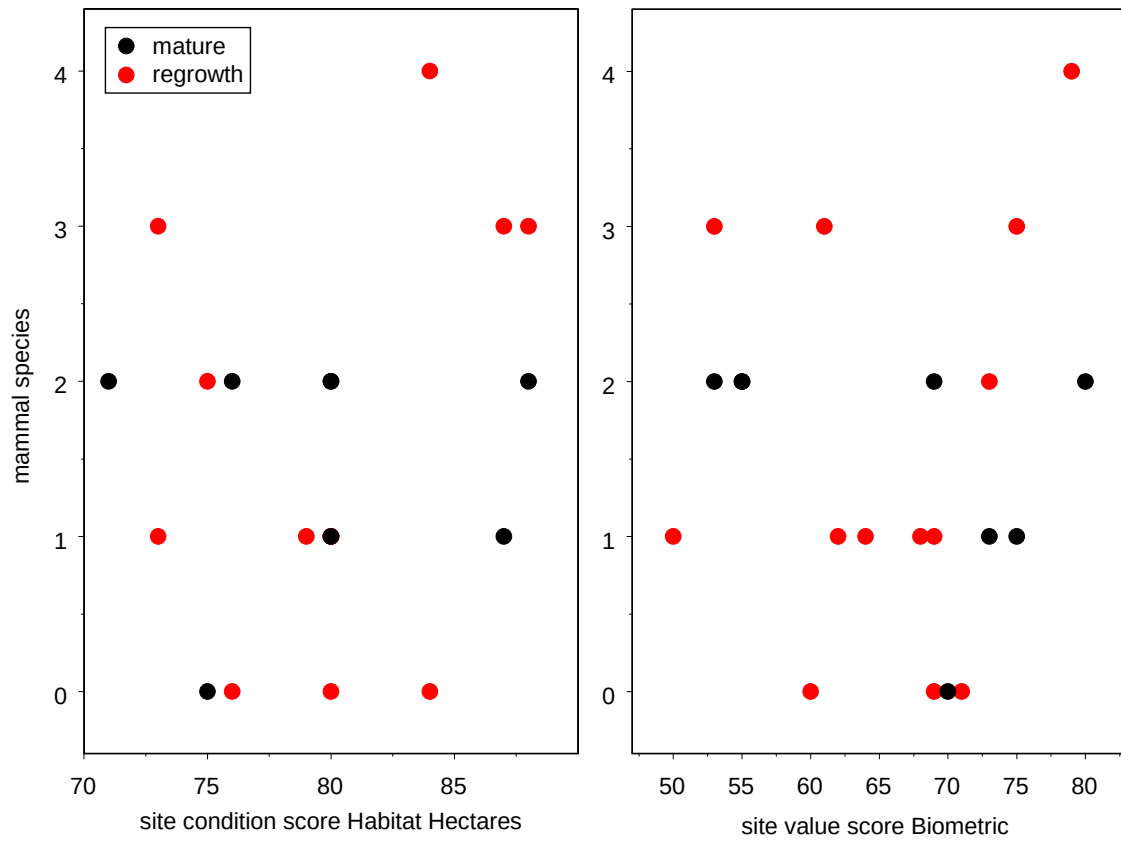


Figure 54 Richness of mammal species in regrowth and mature forest, northern NSW.

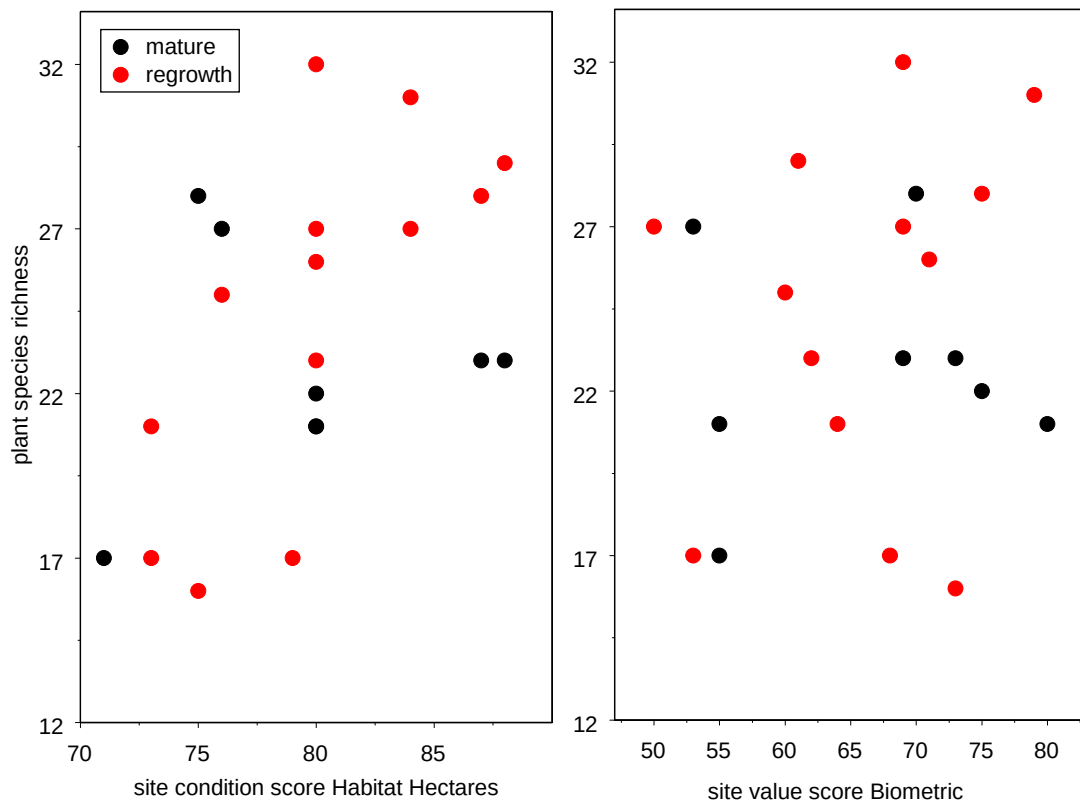


Figure 55 Richness of plant species in regrowth and mature forest, northern NSW.

4. Temporal trends in biodiversity metrics

4.1 Objectives

Biodiversity metrics operate in a spatial and temporal framework which is often understated in their application during on-ground measurements. Recent developments with the use of offsetting criteria in the measurement of net gain vegetation policy have required achievement of a target, within 10 years, of 50% of the quality (Habitat Hectares final score) of the vegetation that was harvested to be recovered through effective regeneration. While the previous case studies from East Gippsland and northern NSW adopted a retrospective approach in testing the veracity of this offset criteria, further testing is required using temporal data from carefully implemented field observations. This section of the report presents two cases studies involving repeated measurement of permanent plots which allows the two regional studies to be validated in the absence of intersite differences.

4.2 Methods

4.2.1 Study Area

Two study areas are examined, one in southern Tasmania, the other in East Gippsland in the general vicinity of the regional case study presented in section 2 of this report. The study areas are described in detail in Peacock (2006).

4.2.2 Experimental Design

The aim of these studies was to address the extent to which temporal vegetation changes since thinning can be described by the composite site condition and site value scores required for Habitat Hectares and Biometric. The study conducted in East Gippsland at West Bemm (between Cann River and Orbost townships) was established in 1988 Lowland Forest (EVC 16) and has continued to 2005. Plots established in 1988 prior to thinning were subsequently re-measured in 1989 (year 1), 1999 (year 10) and 2005 (year 17). The study conducted in southern Tasmania in the Florentine Valley consists of even-aged *Eucalyptus regnans* silvicultural regrowth originating from logging in 1961. Thinning and pre-treatment inventory was conducted in 1991, the vegetation was thinned in 1991, and the vegetation re-measured in 1992 and 2005 (Figure 56). The experimental design is described in detail in Peacock (2006).

4.2.3 Vegetation and Tree Sampling

Vegetation and tree sampling methods are described in detail in Peacock (2006).

4.2.4 Data Analysis

The initial phase of the data analyses concerned the derivation of benchmark values for Habitat Hectares and Biometric to provide a basis for assessing the temporal trends from these experiments. For the southern Tasmania study, benchmark values were derived for mature *Eucalyptus regnans* wet sclerophyll forest (REG1001 and REG101 in Kirkpatrick *et al.* 1988) in southern Tasmania following the protocols outlined for both the Biometric and Habitat Hectares (Department of Sustainability and Environment 2005) schemes. Floristic plot data representing least disturbed stands from Kirkpatrick *et al.* (1988) and Peacock (2003) was pooled and the methods described for both schemes for deriving benchmark values followed. Where data was lacking for variables in the prescribed format such as fallen logs (> 10 cm)/0.1 ha, benchmarks were derived with reference to comparable Victorian EVC benchmarks from the Otway Ranges and Central Victorian Uplands Bioregions and from the woody debris volume estimates in southern Tasmania (Meggs 1996, Grove *et al.* 2002, Grove and Meggs 2003) and Victoria (Lindenmayer *et al.* 1999).

The West Bemm study used the published benchmark values for EVC 16 Lowland Forest. A Biometric benchmark summary was derived from a sample of mature floristic plots (n=1038) for EVC 16 (section 2.2.4). Variables not available in this large floristic data set (e.g. hollows, fallen logs) were derived from pre-treatment plot data (Brown *et al.* 1991) from the thinning experiment.

The analysis of the vegetation and stand data from these experiments has been documented in Peacock (2006). In this report, only the biodiversity score metrics are presented in order to examine the implications of the 10 year offset net gain policy. For the site value and site condition scores, mean and 95% confidence intervals are presented. The limitation of this approach is recognised - generating confidence intervals around these compiled multivariate indices is potentially complex and could not be pursued with the limited replication available.



Figure 56 Regrowth *Eucalyptus regnans* forest in 1991 (1 year following thinning) and 2005 (14 years following thinning).



Figure 57 Thinned example of EVC 16 Lowland forest at West Bemm, thinned in 1988 and photographed in 2005.

4.3 Results

The derived Habitat Hectares and Biometric benchmarks for *Eucalyptus regnans* wet sclerophyll forest in southern Tasmania are presented in Table 20-21. Assuming these values are representative of mature forest with a theoretical value of 100, the logged forest should have a value of at least 50 units after 10 years in order to offset successfully the habitat loss as a result of the harvesting event. Scores for Biometric at year one post-thinning (31 year old silvicultural regrowth) were in the range of 40-50 for Biometric, and increased to 50-60 at 14 years after thinning (45 year old silvicultural regrowth, Figure 58). The Biometric site values scores for the unthinned control, while initially higher than the thinned sites at year 1, declined over the 14 years of observation. The results were broadly similar for the Habitat Hectares site condition score, with all thinning treatments improving their score from 50-55 following thinning to 60-70 14 years after thinning (Figure 59). In the control plots, there was only a modest increase with time in the site condition score.

The results for the West Bemm thinning experiment were similar, but are presented as mean and 95% confidence intervals due to the slightly increased number of replicates (Figure 60-61). Site values fall immediately following overstorey thinning, and gradually increase to their pre-thinned regrowth forest value 10-17 years following treatment. The temporal trends are similar for each metric, except for the immediate post-thinning reduction in the metric score being greater with Habitat Hectares.

Table 20 Habitat Hectares site benchmark values for *Eucalyptus regnans* wet sclerophyll forest (REG1001 and REG101in Kirkpatrick *et al.* 1988). 97 plots representing mature least disturbed vegetation were sourced from Kirkpatrick *et al.* (1988) and 71 from Peacock (2003).

	Species richness	% cover	weighting
Large trees	90 cm	20/ha	10
Tree canopy cover		30	5
Understorey: Life Form			25
Understorey Tree or Large Shrub	3	52	
Immature Canopy Tree	2	49	
Medium Shrub	3	44	
Small Shrub	2	9	
Large Herb	1	3	
Small or Prostrate Herb	4	3	
Large Tufted Graminoid	1	1	
Medium to Small Tufted Graminoid	1	1	
Tiny tufted graminoid	1	1	
Large Non-tufted Graminoid	1	2	
Medium to Tiny Non-tufted Graminoid	2	1	
Ground Fern	3	19	
Tree Fern	1	14	
Epiphyte	6	4	
Scrambler or Climber	1	1	
Bryophytes and lichens		30	
Recruitment			10
Organic Litter	70		5
Logs		100 m/0.1 ha	5
Weediness	<i>Hypochoeris radicata</i>		15

Table 21 Biometric site benchmark values for *Eucalyptus regnans* wet sclerophyll forest (REG1001 and REG101in Kirkpatrick *et al.* 1988). 97 plots representing mature least disturbed vegetation were sourced from Kirkpatrick *et al.* (1988) and 71 from Peacock (2003).

	lower	upper	weighting
Native over-storey cover (%)	18	40	10
Native mid-storey cover (%)	20	60	20
Native ground cover (%) - grasses	1	3	10
Native ground cover (%) - shrubs	1	10	2.5
Native ground cover (%) - other	10	60	2.5
Exotic plant cover (%)			2.5
Native plant species richness count		28	25
Number of trees with hollows (>5cm)		2	12.5
Overstorey regeneration (<5cm DBH) spp%			10
Total length of logs >10cm		100	5

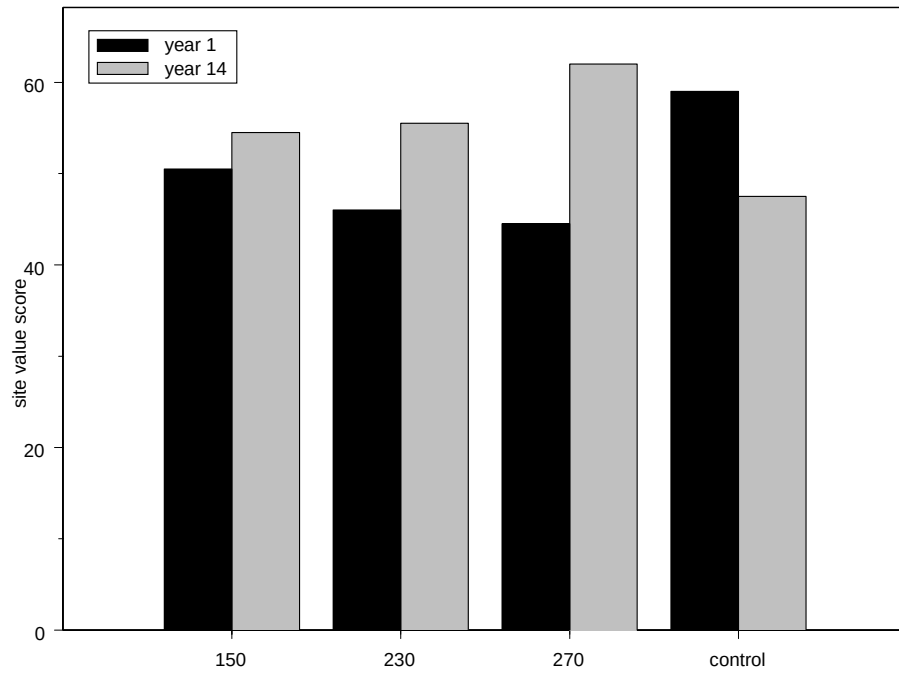


Figure 58 Biometric site value scores for *Eucalyptus regnans* regrowth forest one and fourteen years following thinning. Thinning treatments are 150, 230 and 270 stems per hectare and a control unthinned plot. There are two replicates per treatment.

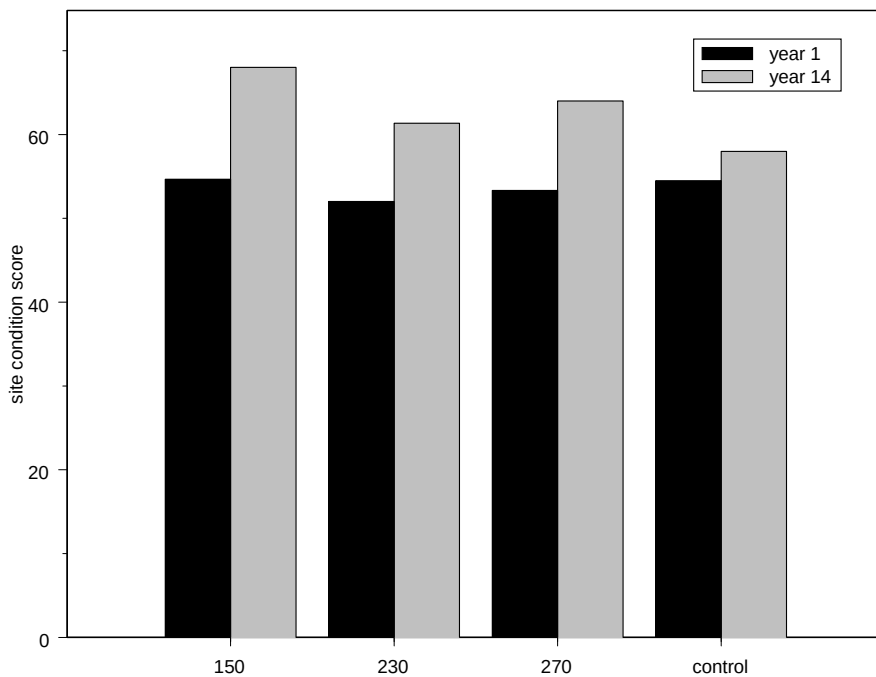


Figure 59 Habitat Hectares site condition scores for *Eucalyptus regnans* regrowth forest one and fourteen years following thinning. Thinning treatments are 150, 230 and 270 stems per hectare and a control unthinned plot. There are two replicates per treatment.

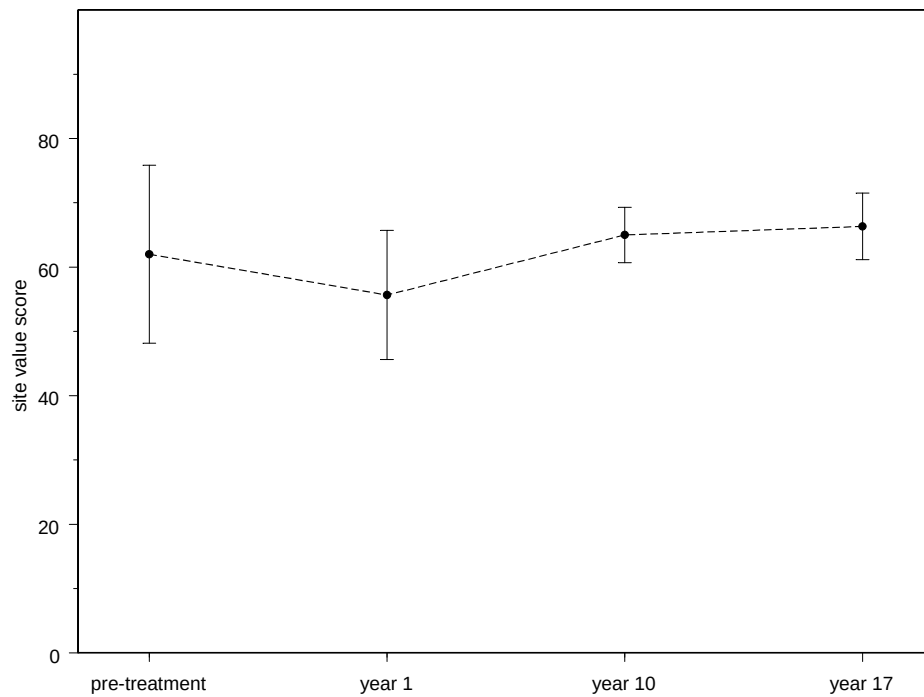


Figure 60 Biometric site value scores for EVC 16 Lowland Forest at West Bemm East Gippsland, prior to and 1, 10 and 17 years post-thinning. There are three plots per treatment, error bars are 95% confidence intervals.

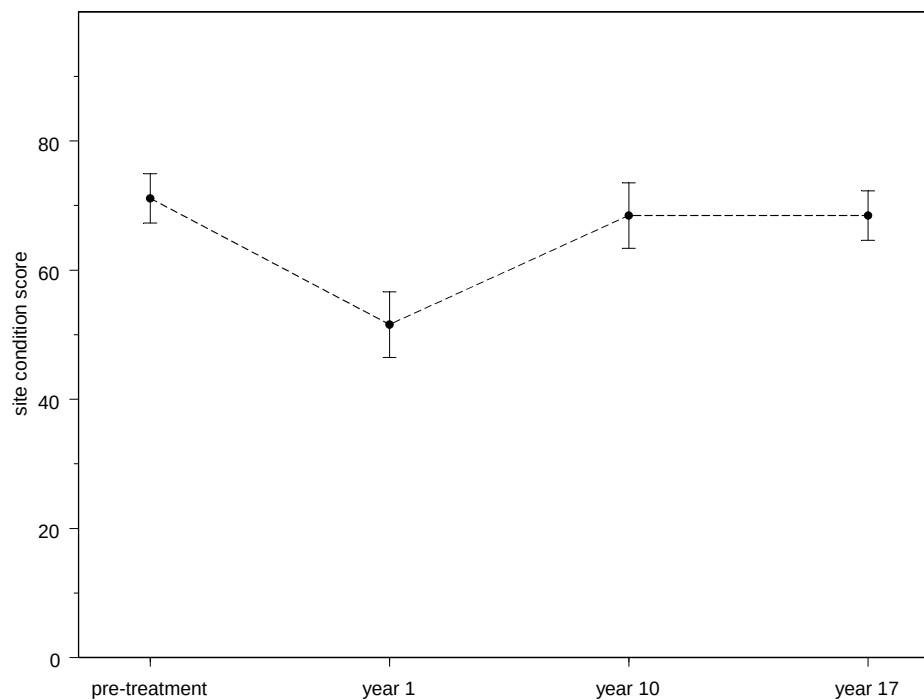


Figure 61 Habitat Hectares site condition scores for EVC 16 Lowland Forest at West Bemm East Gippsland, prior to and 1, 10 and 17 years post-thinning. There are three plots per treatment, error bars are 95% confidence intervals.

5. Discussion

Biodiversity surrogates offer a convenient means of efficiently assessing a forest stand's structural and compositional status and therefore its inferred ability to provide habitat and other resources to support local populations of plants and animals. Indices or metrics based on summarising these surrogates also offer a convenient approach to ranking or comparing different stands and then translating those results into monitoring frameworks or on-ground actions. The convenience of these approaches, and the tendency to relate index scores to stand management history and by inference a cause and effect relationship is problematic.

Habitat Hectares and Biometric are systems designed to assess habitat quality or condition and 'maintain' or 'improve environmental outcomes' test respectively. Their intuitive appeal to also assess the ecological sustainability of private native forestry is problematic considering the ambiguity and context-dependency of the vegetation condition concepts (see Keith and Gorrod 2006) they were designed to address. Both Habitat Hectares and Biometric differ in their attributes, weightings and details of calculation. The full expression of their indices is context-dependent and varies with landscape values and the particular benchmark values applicable for the relevant ecological community under consideration. It is not immediately obvious from a change in the value of an index or score whether a key resource has increased or decreased in quantity. It is also difficult to attach threshold values to these indices, although the component surrogates are normally allocated benchmark values either in absolute terms or as a minimum and maximum range. The additive or multiplicative schemes used to compile the indices also introduce both structural and parameter uncertainty to their use, thus providing no clear statistical pathway to generating confidence intervals around their values. Any measure which purports to be an environmental indicator in the broad sense which cannot readily have confidence intervals generated is possibly of limited empirical value. For this reason the surrogate variables, rather than the compiled metrics, are recommended for assessing the sustainability of private native forestry.

The results of the East Gippsland retrospective examination of 26 sites within lowland forest were particularly informative in several respects. The benchmarks for Habitat Hectares capture a range of variability and then allocate a score based on the value occurring in typical least disturbed mature forest. In many environments subject to private native forestry the stands have already been subject to repeated forest management and grazing disturbance, and therefore may not match the initial condition state required of the published EVC benchmark. This circumstance is specifically recognised in the Victorian Native Vegetation Management Framework, although it has the potential to perpetuate a 50% reduction in Habitat Hectares score over several cutting cycles and therefore fail to achieve a net gain in vegetation quality as described by the published region EVC benchmark, relative to a local pre-logging benchmark field assessment.

The two metric scoring systems were generally not highly sensitive to change brought about by silvicultural treatments, although they were more sensitive than the flora and fauna survey data collected independently from the sites. The greatest sensitivity was evident in individual surrogate measures such as several understorey plant life forms, the density of large trees and tree hollows and the total length of fallen logs, although the sensitivity of tree hollows and fallen log length was dependent on tree size or fallen log diameter and decay class. The performance of these surrogate measures was to some extent dependent on the environmental characteristics of the study areas, and the silvicultural systems used. Where silvicultural systems were poorly differentiated, for example in the lowland forests of north eastern NSW where adequate tree regeneration can be achieved using any system from single tree selection to clearfelling, understorey life forms were poor discriminators. In the East Gippsland study, the relative paucity of surrogate measures with discriminatory power may be related to the method of harvesting applied which retained unmerchantable large trees, or the general resilience of the sclerophyllous understorey flora to related disturbances such as fuel reduction burning.

The absence of significant differences in the response of flora and fauna to the silvicultural treatments in East Gippsland represents a quandary that requires further examination as it is not necessarily consistent with other studies of lowland forest in East Gippsland (Alexander *et al.* 2002, Mueck and Peacock 1992, Peacock 1995). In some cases the mature forest benchmark values for understorey life forms did not reach the regional Ecological Vegetation Class values for mature forest, or the values in regrowth and mature forest were undifferentiated. These examples question the use of Ecological Vegetation Class benchmarks for assessing the sustainability of private native forestry. The absence of clearer differentiation between the mature and regrowth forests for fauna, particularly mammal species, may be an artefact of the sampling procedures used. Fauna sampling for wide ranging species such as arboreal mammals is often difficult to relate to the site scale used for vegetation sampling, and the methods used employed both area and time limited approaches, or wider ranging call playback mechanisms. The effect of sampling scale on the results can therefore not be discounted, especially where there is an inconsistency between the scale of measurement of the stand attributes and the scale at which the fauna are detected or are responding to the forest management regime.

The application of Biometric to assessing the condition of regrowth and mature forest stands, and by inference forest management inputs, is outside of the formal specification of this metric. Biometric assesses proposed activities (such as land clearing) and predicts their likely outcomes in the context of ameliorative measures (offsets). Scores for the component variables are adjusted in Biometric using an ordinal scoring process which is designed to be consistent across sites and between assessing officers; it is not a metric for detecting temporal changes on a site. In this study the metric was calculated differently, the predicted scores were not modified by proposed management actions, they were simply re-calculated using field data grouped by management history – regrowth and mature. By collapsing continuous field data into a metric composed of attributes each with few classes (e.g. 0-3) it is inevitable that the scores would lack sensitivity to the management history of each plot. A further departure from the formal specification of Biometric applied in this study is the use of the metric to examine the consequences of private native forest management. In Biometric, no analogous scenario exists to private native forestry, perhaps the closest analogy is the procedures in Biometric to assess proposals for incentive funding of management actions to improve vegetation condition. In these cases, monitoring will be conducted in terms of the inputs stated in the incentives management agreement (e.g. weed control or grazing exclusion), not the outcomes as indicated from measures of the surrogates used in the assessment.

The correlation between the two scoring systems, Habitat Hectares and Biometric was generally moderate in the Victorian study, and poor to moderate in the north eastern NSW study. The component surrogates also varied in their correspondence with the summary metric score between these regional studies. Habitat Hectares was reasonable at distinguishing between the mature and regrowth East Gippsland forests, with sites receiving the lowest scores also being ones subject to ongoing post-logging disturbance. Site value scores from Biometric were less distinct, and this is interpreted as a result of the greater weighting given to understorey life form components in the Habitat Hectares system, and the sensitivity of understorey vegetation to harvesting. Methodological differences are also relevant here, the Habitat Hectares metric had thirty four variables to measure while Biometric had ten. Habitat Hectares is a plot-less technique that is simpler to implement in the field while Biometric requires plots to be established and measured.

The additional expense and expertise of undertaking flora and fauna surveys and reporting actual measures of species composition frequently provided little further insight to vegetation condition post-logging than the surrogate habitat variables did. The correlation between most fauna groups and the habitat variables was often weak, and this is interpreted as a consequence of limited survey effort, limited plot replication, the geographic spread of the replicate plots and differences related to the scale of sampling used by the vegetation condition and quality metrics and the standard fauna survey protocols. The scale of measurement of the stand attributes was therefore unlikely to be consistent with the scale at which the fauna data was collected or the likely scale in which the fauna species are responding to forest management.

Stand structure was one component which differed between the regrowth and mature forests in East Gippland and which has the potential to limit the general applicability of the existing scoring systems. Where key ecosystem components were lacking or below the benchmark threshold, for example hollow bearing or large trees, the summary metric score was still able to exceed the minimum offsets policy requirement due to the presence and weighting allocated to other score components. Other ecosystem structural attributes such as fallen woody debris, were able to exceed the benchmark thresholds for the EVC, but on closer examination it was clear that the method of measurement of the attribute was the key to exceeding the threshold. Regrowth forests had lower total lengths of large logs on the ground, but greater total lengths when smaller diameter logs are included. The implication is that fauna or other life forms dependent on large fallen logs are not being adequately considered by this surrogate.

The performance of the two metrics in the Clarence Lowlands Spotted Gum forests was much more difficult to assess, due to the inherently variable nature of these uneven-aged sub-tropical dry forests, the variable stand management histories, and inter-site differences between the four case study properties in northern NSW. Biometric scored the sites across a greater range of total values than Habitat Hectares did, but the implications of this result are unclear as the understorey life form assessments in north eastern NSW did not follow the prescribed Habitat Hectares field method, and consequently the weightings applied may not be indicative of the field conditions. The results of the fauna surveys across the sites were highly variable and lacked correspondence with both the prescribed stand management histories and the metric scores. Care needs to be taken not to interpret this as a failure of either of the metrics to detect important differences in stand condition, or that the relative high metric scores across all sites is evidence that the existing management regimes are ecologically sustainable.

The ease with which the regeneration sampled in all the regional case studies that was at least ten years old met the policy test of the Victorian Native Vegetation Management Framework test of 50% of the pre-logging Habitat Hectares score should not be interpreted by private forest growers as proof their management actions are ecological sustainable in the broad sense. In the East Gippland study, clearfell harvesting had a significant impact on the large tree component, a surrogate for hollow-bearing trees. Fauna such as hollow nesting birds were associated with the mature forests sampled, a key component of most fauna management strategies and for assessing ecological sustainable forest management. The fact that this policy test was easily met in forest types ranging from dry sub-tropical forest in northern NSW to cool wet forests in southern Tasmania could be interpreted either as 1) the forests studied had been generally well managed, 2) the benchmark values, which quantitatively describe the condition of the respective ecological community in its undisturbed state were too broad, 3) the surrogate weighting criteria were too generous, 4) the biodiversity metric scores were insensitive to variation in stand condition, or 5) potentially a range of other scenarios. The standard scientific approach is averse to concluding there is no effect of forest management on biodiversity values when there is one (Type II error, Walshe and Wintle 2006). To a private forest grower, this can translate into a false sense of security. Explicit consideration of statistical power is required when outcomes are sensitive to Type II errors, but in terms of assessing the sustainability of a forest management regime, this requires a reasonable burden of proof to be articulated and applied to the calculation of statistical power. In this study, where a measurable definition of sustainability is lacking, or the study designs adopted do not permit formal hypothesis testing and frequentist statistics, graphical means of data analysis and the presentation of confidence intervals were used instead of hypothesis testing. With the data provided from the field trials in NSW and Victoria, determining if the observed effects of private native forest management are large enough to be of ecological importance was to some extent a separate exercise to determining whether these effects were statistically significant (cf Di Stephano 2004, 2005).

Several modifications to the Victorian Native Vegetation Management Framework test of 50% of the pre-logging Habitat Hectares score should be considered. Firstly, by using as a reference point the score at the time and place of harvesting, not the regional average published for the appropriate EVC, the test simply considers the ability of the site to recover half of the initial score after ten years, not whether the site was comparable to the long undisturbed reference benchmark, or whether any longer term improvement in vegetation quality is likely to occur towards the regional EVC benchmark. In other words, if the forest stand was in poor to fair condition at the time of harvesting, after ten years

the stand is only required to reach half of that poor to fair state. The inherent uncertainty regarding the outcomes of forest management actions is not considered in the 50% threshold, nor is good management rewarded compared to relatively poor silvicultural or biodiversity maintenance practices. Placing the risk on the landholder given the uncertainty in their outcomes is not considered appropriate. The time frame for monitoring (10 years) is also too short to examine biodiversity changes brought about by management, however it is recognised that a longer monitoring period may be difficult to effectively implement. A monitoring process with sufficient statistical power to detect change is also considered beyond the resources of an individual Habitat Hectares site assessment.

6. Implications

The results of this study indicate that biodiversity metrics have a potentially useful role in assessing and monitoring environmental and operating compliance with standards for vegetation and ecologically sustainable forest management. Both of the metrics examined were designed to meet specific legislative, policy and duty of care requirements within their existing jurisdictions, and with the exception of the Victorian private forestry offsets policy component, were not specifically designed to be applied in a forest management framework. Components of the metrics and scoring systems were useful in examining the sustainability of private native forestry, however the framework they were developed for (vegetation quality or condition) is not the same framework needed to examine native forests managed for, among other values, a flow of wood products. Criticisms of these metrics need to be mindful of their intended application through Commonwealth-State natural resource management partnership agreements, and implementation by regional catchment authorities. Both Habitat Hectares and Biometric were developed with a specific suite of policy and operation criteria, and any metric developed for a private native forestry application would presumably need to do the same.

For a new biodiversity metric to be derived to assess the condition of private native forests, clear objectives and operational setting are required. Five steps have been recommended in developing new approaches to assessing vegetation condition for biodiversity (Gibbons and Freudenberger 2006); a similar approach could be employed to assessing ecological condition in managed forests.

1. Define management or policy objectives and operational constraints

The management or policy objectives would be defined through the legislative and policy process, examples include Victorian Native Vegetation Management Framework (DSE 2002) and Code of Forest Practices for Timber Production (DSE 1996), or in NSW the Native Vegetation Act (2003) and the associated Native Vegetation Regulation 2005 Environmental Outcomes Assessment Methodology. Operational constraints involve considerations such as cost, efficiency, availability of training and expertise. Complex approaches can be difficult to understand and communicate to landholders and are generally avoided by risk-averse regulators concerned with implementation and support costs. Defining policy objectives and sustainability measures is also complex where multiple objectives exist and compromises are required to be made between maintaining resource stock and flow (Popp *et al.* 2001), or where multiple services are required, for example biodiversity and landscape functional services.

2. Develop an appropriate conceptual framework for the ecosystems under consideration

Conceptual frameworks for ecosystems are typically complex due to the dimensionality of the data and processes involved. Different conceptual frameworks are available (Gibbons and Freudenberger 2006), however difficulties arise where a metric or index is used to predict and diagnose site condition with expectations that exceed our scientific understanding of ecosystem functioning (Andreasen *et al.* 2001) or there is a risk of omitting some key element of the forest management process. Gibbons *et al.* (2005) draw upon the state and transitional model (Westoby *et al.* 1989) to predict the outcomes of management activities on vegetation condition. However in the forested environments examined in this study, where management actions are both intermittent (harvesting) or pulse like (e.g. fuel reduction burning, cattle grazing), other conceptually related models may be more appropriate which place greater recognition on nonequilibrium concepts (see Rohde 2005, Biske *et al.* 2006). For example, the lowland East Gippsland forests studied in Victoria have a long history disturbance from harvesting, burning, cattle grazing, infestations of root disease agents such as *Phytophthora* and *Armillaria* and consequently it could be argued that a model of species persistence in the landscape is more appropriately considered in the context of frequent small disturbances keeping the system open and in local nonequilibrium. Similar management histories exist elsewhere in forests subject to private native forestry. The Clarence Lowlands Spotted Gum forests reported in this report have an equally long history of recurrent disturbance, and in some cases forests have been recruited back into the landscape following their effective removal for grazing in the late 1800's. Under these circumstances, species co-existence is maintained under an intermediate disturbance hypothesis regime (Connell

1978), or one in which a complex of mechanisms involving temporary patch dynamics occurs (Roxburgh *et al.* 2004). The reliance of one particular ecosystem model with an inferred stable state represented by a suite of benchmark or reference site values (as is in the case with Biometric and Habitat Hectares) may therefore not always be the appropriate model when the forest manager will use continuous disturbance as a silvicultural tool to manage the stand. The lack of congruence between the Biometric benchmark values for native ground cover in Clarence Lowlands Spotted Gum and those recorded in this study from mature examples of this forest type forest considered to have been managed sympathetically for biodiversity and timber values illustrates the difficulty of the benchmark process in a managed forest context.

3. Select an appropriate suite of indicators or vegetation attributes

Various reviews of indicators or vegetation attributes suitable for assessing vegetation condition and fauna habitat value exist (e.g. Oliver 2002, Oliver *et al.* 2007, McElhinny *et al.* 2005, 2006), with further studies now available of the use of threshold or benchmark values (Burgman *et al.* 2001, Briske *et al.* 2006). The choice of the attributes is probably only limited by ease of use, the experience of the observer and their inferred value as surrogates for ecosystem functioning or species presence. While opinions have differed on how the indicators should be chosen (McCarthy *et al.* 2004, Parkes *et al.* 2004) there is now a reasonable level of agreement on the core set of attributes for measuring vegetation condition (Oliver *et al.* 2007). What is lacking is a suite of indicators measuring the condition of multiple services (e.g. Popp *et al.* 2001), in this case the integration of biodiversity and silvicultural objectives and outcomes. Attributes for measuring stand condition from a silvicultural perspective exist (e.g. top height, bole volume, other product class volumes) in a form analogous to some of the core structural attributes identified by McElhinny *et al.* (2006). Where repeated measurements were undertaken, data on tree volume and height growth (e.g. periodic annual increment) could be readily incorporated into the standard suite of ecological indicators. While an appropriate breadth of indicators exists to examine the condition of vegetation and the silvicultural state of the forest stand, what is lacking is a means of combining them into a single index and therefore making the difficult decisions on how the different indicators are weighted or scored relative to each other.

Of the surrogate measures studied, several indicated their potential for use in assessing the sustainability of private native forestry across the different regional study areas. Of the vegetation life forms assessed in Habitat Hectares, the immature canopy tree and ground fern categories were useful in discriminating between regrowth and mature forests. Fallen logs were good discriminators, however their method of measurement and scoring in Habitat Hectares did not realise their discriminator power, as log decay class and diameter were key attributes in the lowland East Gippsland study, not the existing surrogate of total fallen log length. Similarly, tree hollow density was good at discriminating between mature and regrowth forests in East Gippsland and northern NSW, although it was a better discriminator if combined with tree diameter, as hollows were not restricted to mature forests or large diameter trees. Stand structure also differed markedly between the regrowth and mature forests sampled, and if expressed using an appropriate measure of tree diameter distribution or diameter class diversity, has the potential to express a significant amount of forest structural data as a new surrogate variable.

4. Consider the options available for combining these into an index

Approaches to combining indicators or vegetation attributes into an index based on rule sets or decision trees, additive or multiplicative scoring systems, univariate predictors or multivariate scores are described by Gibbons and Freudenberger (2006). The option chosen should reflect the operational and policy setting of the vegetation assessment. Simple silvicultural indices exist to scale age structures of stands (Skovsgaard 2000) or contrast tree size diversity (Lexerød and Eid 2006). Indices for stand productivity, stocking and growth also exist, although their application in uneven-aged stands is less clear. A possible approach for the private native forestry context would be to adopt a stand structural complexity index following McElhinny *et al.* (2006) and a second index measuring stand productivity in terms of stocking, regeneration in-growth and product volume increments, and then present both indices in terms of the vegetation condition and private native forestry objectives. A

minimalist approach which attempted to combine the two indices would require the adoption of assumptions which may not have widespread policy support or may involve complex modelling tools.

5. Use data collected at broader scales to place the site in a landscape context.

Landscape contextual information is an existing component of the most common metrics, and is used to define threshold or benchmark values or ranges of values, and landscape connectivity values. If a metric was developed to measure silvicultural outcomes, data would also be required on stand growth rates, stocking, basal areas, and product types to define threshold values for different vegetation types under various silvicultural systems. Such data would necessarily be derived from broader studies across a stratified landscape.

7. Recommendations

1. Further development is required to introduce the most appropriate surrogates and elaborate on the definition of ecologically sustainable forestry before certification schemes, regulatory agencies and reporting organisations could adopt them. Biodiversity surrogates and to a lesser extent compiled metrics have considerable potential in the assessment and monitoring of private native forestry. New variables which are responsive to forest management for production and changes over time should be considered.

Ideally, biodiversity metrics applied in a forest management framework need to be more inclusive of parameters such as desired stand structures, growth rates, forest product volumes, and tree and habitat feature regeneration. New surrogate variables which are relatively simple to measure, such as an expression of tree diameter distribution or diameter class diversity should now be examined for their sensitivity to forest management inputs. Focussing on the individual surrogate variables, and not the summary metric scores, is likely to be a more intuitive approach to developing tools to assess the ecological sustainability of private native forestry. Surrogate measures and their metrics should ideally also incorporate a component of a market-based instrument which recognises and rewards the environmental benefits that flow from sustaining a broader suite of biodiversity components within a productive private native forest.

2. The regional studies examined in this report indicate that the existing surrogates and metrics have varied applicability across the ecological communities and stand management types examined. Where these studies are lacking is in the availability of study areas with improved experimental control and environmental stratification. As part of evaluation, it is important that sites which represent experimental controls and environmental stratification are included; without this control, the assessment of the sensitivity of the surrogates and metrics will be limited.

3. If considered important enough to be applied to private native forestry, biodiversity surrogates and metrics must undergo prior testing against real long term ecological data collected over at least ten years to reflect the time frames and thresholds that current policies are using.

4. There is an opportunity to use existing long term, replicated and well managed ecological experiments to test how the surrogates reflect ecological changes over time, and to examine options for reconfiguring a metric to assess the sustainability of private native forestry.

Several long term, replicated and well managed ecological experiments exist in south eastern Australia where a reconfigured suite of biodiversity or PNF reporting metrics could be trialled. The experiments at Cabbage Tree (East Gippsland, Victoria), Tanjil Bren (Central Highlands, Victoria), Warra and upper Florentine (southern Tasmania), Wauchope (mid north coast NSW) and Bago (southern NSW tablelands) cover the range of forest types from montane, cool wet, lowland maritime and warm temperate environments typical of those managed by private native forest growers. Most have existed since the late 1980's and consequently have a large suite of existing measurements to examine the temporal response of different metric parameters, and importantly a range of independent variables to assess their surrogacy value for other forest values. These existing experiments would provide an ideal basis for further research to examine options for reconfiguring a metric to assess the sustainability of private native forestry. Specific forest management activities could also be examined, for example fuel reduction burning and thinning, and retention systems which have the potential to be considered as part of the offset calculations.

5. Several alternative approaches to the analysis of the data presented in this report are worthy of consideration. This would aim to detect more subtle continuous variation between plots. The *a priori* division of plots into management histories such as regrowth and mature in East Gippsland, or the revision of the stratification design used in north eastern NSW could have been improved by characterising silvicultural treatment along a continuum using an independent measure such as dbh distribution or a size/age class diversity index. Jay (2006) used stand basal area and forest structure as an independent variable in the analysis of the north eastern NSW plots, however that approach was not

adopted in this study. The lack of clear differences between the treatments therefore may be a result of the study design and analysis procedures adopted, masking more subtle continuous variation between plots.

6. Definition of consistent methodologies for assessing sites, benchmarks and forest management inputs is warranted.

Despite the apparent ease with which the studies examined reached their policy threshold (defined by offsets criteria for regeneration) significant differences still existed between the mature and regrowth forests, particularly in surrogates which are slow to recruit such as hollow bearing trees, large trees in excess of the benchmark size class, and a small number of late successional faunal groups. The variable results between the mature and regrowth forests were in part due to inter-site differences, and also to the retention of mature forest components in the stand which increased the overall site scores. The implication is that harvesting systems which retain a component of mature forest stand structures, either via variable retention of patch retention systems, will be more likely to score highly in the offsets policy 10 year threshold. The difficulty however is that metric scoring systems are highly context specific, are reliant on realistic ecological classifications and benchmarks, and are still in their early stages of theoretical and practical development. The metric scores derived from the managed forest stands were also highly dependent on how the metric was compiled, the method of deriving the benchmark threshold or range of values, and how the individual surrogate was measured in the field.

7. These metrics have direct applicability in certification audits because they are based on repeatable methods and measurable environmental outcomes, unlike other certification systems based on assessment of management inputs. Any proposed use of biodiversity surrogates and metrics for certification should consider the following issues:

The costs for the private native forestry industry of adopting metric scoring systems to assess their ecological sustainability are difficult to estimate until such a system is developed and implemented, presumably by Governments. Private growers who have attained or are seeking certification under systems such as the Australian Forestry Standard, Forest Stewardship Council or an ISO14001 EMS already bear the cost of third party monitoring and public reporting of their compliance with the chosen standard. Monitoring and reporting systems being developed by different companies and jurisdictions are increasingly exposed to criticism for lacking cross-compatibility and sufficient statistical power (e.g. Walshe and Wintle 2006) to monitor on-ground management performance. National reporting standards, adopted from one of the existing frameworks such as the Montreal Process, and reconfigured to resemble an offset policy outcome are required. Environmental indices can be reconfigured to more specific circumstances, however doing so involves trade offs between dimensionality (how many parameters or surrogates), flexibility (can compromise sensitivity) and representation (Hoag 1992, 2005).

8. Appendices

Appendix 1. Bird species feeding, nesting and migratory guilds (Loyn unpublished)

Feeding guild	Explanation
Aerial insectivores	aerial feeder, taking insects in open air, usually far from foliage
Bark-foraging insectivores	bark forager, taking invertebrates from bark on trunks and branches of eucalypts and other trees
Canopy insectivores	canopy forager, taking invertebrates from foliage of eucalypts and other large trees
Damp-ground insectivores	takes invertebrates from damp ground below shrubs, or among damp litter in wet forests or rainforest
Frugivores	frugivore, taking soft fruit along with other food such as nectar, invertebrates or seeds (parrots)
Nectarivores	nectarivore, taking nectar along with other food such as seeds (parrots) and fruit or invertebrates
Open-ground insectivores	takes invertebrates from open ground (which may be far from trees or shrubs)
Open ground among trees insectivores	takes invertebrates from open ground among trees
Seed-eaters at low levels	takes seeds from ground or low plants such as grasses, herbs and saltmarsh
Seed-eaters at all levels	takes seeds from trees and shrubs or wide range of strata, or other food such as gall insects or insect larvae extracted from wood
Tall-shrub insectivores	takes invertebrates from foliage of tall shrubs, which may form middle storey of eucalypt forests
Understorey insectivores	takes invertebrates among dense understorey or the ground below
Carnivores	carnivore, taking vertebrates as an important part of diet, often along with large invertebrates and other food such as fruit (in case of passerines such as currawongs)
excluded	
Nesting guild	
Brood parasites	cuckoos
Large hollow nesters	nests in large or medium-sized hollow in tree or termite mound
normal nester	i.e. not in a hollow or other species nest
Small hollow nesters	nests in small hollow in tree
not in Australia	does not nest in Australia
ground-nester	nests on ground
burrow-nester	nests in burrow in ground
Migratory	
non migratory	
Summer migrants	mainly summer visitor (i.e. absent or rare in these forests for a predictable period each winter)
excluded	

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