Forest&Wood
Products Australia
Knowledge for a sustainable Australia

RESOURCES

PROJECT NUMBER: PNC142-0809 OCTOBER 2012

Persistence of mature forest biodiversity elements in a production forest landscape managed under a Regional Forest Agreement

This report can also be viewed on the FWPA website
www.fwpa.com.au
FWPA Level 4, 10-16 Queen Street,
Melbourne VIC 3000, Australia
T +61 (0)3 9927 3200 F +61 (0)3 9927 3288
E info@fwpa.com.au W www.fwpa.com.au

Persistence of mature-forest biodiversity elements in a production-forest landscape managed under a Regional Forest Agreement

Prepared for

Forest & Wood Products Australia

By

Tim Wardlaw, Simon Grove, Jayne Balmer, Andrew Hingston,
Lynette Forster, Christina Schmuki and Steve Read

Publication: Persistence of mature forest biodiversity elements in a production forest landscape managed under a Regional Forest Agreement

Project No: PNC142-0809

ISBN: 978-1-921763-57-1

Researchers: Wardlaw, T.; Grove, S.; Hingston, A.; Read, S.
Forestry Tasmania
79 Melville St.
HOBART, Tas. 7000

Balmer, J.; Forster, L. and Schmuki, C.
University of Tasmania
Churchill Ave,
SANDY BAY, Tas. 7005

Final report received by FWPA in October, 2012

Forest & Wood Products Australia Limited
Level 4, 10-16 Queen St, Melbourne, Victoria, 3000
T +61 3 9927 3200 F +61 3 9927 3288
E info@fwpa.com.au
W www.fwpa.com.au

Executive Summary

The study explored a key objective of the biodiversity conservation strategy delivered through Regional Forest Agreements (RFA), which we paraphrase as:

> *forest-dependent species should be able to persist throughout their range, equally in landscapes dominated by production-forests as in landscapes dominated by reserves.*

We focused on the **mature-forest** element of biodiversity, because mature forest is more likely to be in short supply in production-forest landscapes than is younger forest. Our assumption is *not* that production forest must support mature-forest biodiversity in all places at all times, but that any local losses arising through forest harvesting should be temporary, with all areas of native forest at least retaining the potential to regain over time those lost mature-forest species. In this respect, species dynamics after forest harvesting and regeneration can resemble species dynamics after wildfire and forest regrowth.

We developed two hypotheses to test the extent to which the RFA is achieving this 'persistence' objective. They were:

(i) the biodiversity in mature eucalypt forest would be independent of the intensity of disturbance in the surrounding landscape;

(ii) that the recolonisation of silvicultural regeneration by mature-forest species would be independent of the intensity of disturbance in the surrounding landscape.

We then used the findings from testing these hypotheses to suggest some simple metrics and other planning tools that could guide future management and planning in relation to the spatial and temporal arrangement of mature forest in production-forest landscapes.

We tested our hypotheses in the Southern Forests Experimental Forest Landscape (SFEFL) - a 1120 km^2 region of predominantly tall, wet eucalypt forest in southern Tasmania. The SFEFL provides a gradient of landscape disturbance-intensity that reflects the patterns of European settlement and developing land-management practices. It manifests in varying ratios of anthropogenic to natural-origin vegetation types when measured across a broad range of spatial scales (in our study, from 500 m to 2 km radius around each sample plot). In the most highly disturbed landscapes, these anthropogenic : natural-origin area ratios were 80%: 20%, while in the least disturbed landscapes, the area ratios were 11% : 89%. Our study did not explicitly compare pre- and post-RFA production forest landscapes. Nonetheless, those parts of the SFEFL with intermediate and low intensity of landscape disturbance represented predominantly post-RFA land-use, while those with high intensity of landscape disturbance represented predominantly pre-RFA land-use.

We used plot-based approaches to intensively survey or sample three ecologically diverse focal groups – birds, vascular plants and flighted beetles. Half of our plots were in mature eucalypt forest, the structural attributes of which implied little influence of major disturbance events over the past century or more. The other half were in eucalypt silvicultural regeneration that had arisen from clearfelling 30-50 years previously: we chose forest of this age (i.e. post-canopy closure) because we considered that ecological succession would be advanced enough for such forest to be at least capable of supporting mature-forest species, should they have attempted recolonisation. We established seven replicate 50 x 50 m plots of each forest type in each of four classes of landscape disturbance intensity (56 plots in total).

Regarding our **first hypothesis**, we found that the biodiversity in retained mature forest was indeed largely independent of the intensity of disturbance in the surrounding landscape: all but a small subset of disturbance-sensitive beetles maintained similar populations in mature

eucalypt forests in the least disturbed through to the most disturbed parts of the landscape. The subset of disturbance-sensitive beetles was less species-rich in the most disturbed parts or the SFEFL due to the combined effects of forestry and long-term natural disturbance processes.

Regarding our **second hypothesis**, we found the recolonisation of silvicultural regeneration was not uniform across the disturbance gradient: the abundance and species- richness of three particular sub-sets of our focal groups – dense-forest birds, rainforest plants and disturbance-sensitive beetles –declined as the intensity of landscape disturbance increased.

Given these findings, we then explored the relationships between plot-level biodiversity in silvicultural regeneration and the amount (and, indirectly, the configuration) of mature forest in the surrounding landscape. The reduction ns in abundance and / or species richness evident in dense-forest birds, rainforest plants and disturbance-sensitive beetles were correlated with a decline in the amount of mature eucalypt forest in the surrounding landscape. These correlations were equally strong in small-scale landscapes (125 – 250 m radius around a sample plot) as in large-scale landscapes (4 km radius around a sample plot). These multi-scale correlations could be captured quite effectively by a simple metric – **proximity to mature forest**. *The closer the silvicultural regeneration was to mature forest, the higher was the abundance and / or species richness of these subsets of our three focal groups*. Importantly, these proximity relationships showed 'inverse-threshold' responses: for plots within a certain (threshold) distance of mature forest, the abundance / richness rapidly increased with decreasing distance to mature forest; for plots beyond that threshold distance, the abundance / richness remained low and unresponsive to changes in distance from mature forest. The threshold distances varied by focal group and unit of measurement: for the cover of rainforest plants and for the species richness of disturbance-sensitive beetles, the threshold distance was about 150 m; for abundance of dense-forest birds, the distance was 400 m; and for the richness of rainforest plants, the threshold was 600 m.

Parts of the SFEFL dominated by post-RFA forestry activities currently have sufficient mature eucalypt forest to provide proximity benefit to assist the recolonisation of silvicultural regeneration by the disturbance-sensitive subsets of the three focal groups. By contrast, those parts of the SFEFL shaped primarily by pre-RFA forestry activities had insufficient mature forest to provide a proximity benefit to assist the recolonisation of silvicultural regeneration by disturbance-sensitive species. Past wildfires, particularly the 1967 wildfire, coupled with post-fire salvage harvesting and pre-1960s forestry have each contributed to the insufficiency of mature eucalypt forest in the pre-RFA parts of the SFEFL. However, subsequent RFA reservation and protection (in long-term retention) of wildfire regrowth in the more disturbed parts of the SFEFL could provide sufficient mature forest in the future to enable the persistence of mature-forest biodiversity. On this basis, we conclude that, in the case of the SFEFL, **the RFA has so far been effective in maintaining mature-forest biodiversity**.

Caveats to this conclusion include the facts that our study was confined to three focal groups (though this is broader than most other studies), and that it represents a snap-shot in time. It is possible that the ease with which mature-forest species recolonise first-rotation silvicultural regeneration may not persist into successive rotations. It is also possible that future natural disturbance events, such as extensive, intense wildfire, may interact negatively with disturbance caused by production forestry. We further recommend that key elements of this study be replicated in other RFA regions before its findings can be more widely generalised.

Table of Contents

Introduction

The Regional Forest Agreements (RFA) between the Commonwealth Government and (individually) the states of Victoria, Tasmania, Western Australia, New South Wales and Queensland were established in the mid-1990s. Among other things those agreements implemented the National Forest Policy (Commonwealth of Australia 1992) provisions on biodiversity conservation. Specifically, the National Forest Policy sought to deliver biodiversity conservation objectives on public forests through a combination of reservation and complementary management of forests outside reserves. Reservation was based on the principles of comprehensiveness, adequacy and representativeness (CAR) (JANIS 1997). The JANIS criteria had a general target to reserve 15% of the pre-European extent of all mapped forest communities, although higher levels of reservation were targeted for old-growth forests and some rare or vulnerable ecosystems.

In Tasmania, the implementation of the RFA greatly improved the reservation status of forest communities (Mendel and Kirkpatrick 2002). Nevertheless the outcome could have been more optimal had scientific principles for reserve design been better implemented during reserve selection (Kirkpatrick 1998). For these and many other sociological and ecological reasons, the RFA failed to quell the forest conflict in Tasmania, as elsewhere in Australia. In the 15 years since signing the RFA, further attempts have been made. The Tasmanian and Commonwealth governments instituted a supplement to the RFA, the Tasmanian Community Forest Agreement (Commonwealth of Australia and the State of Tasmania 2005); Forestry Tasmania was forced to defend a legal challenge to the RFA by Senator Brown; and the governments are now finalising negotiations for an Inter-governmental Forests Agreement (Commonwealth of Australia and the State of Tasmania 2011).

Across Australia the CAR reserve system is one of the two central elements of the strategy provided by RFAs to maintain biodiversity in forest landscapes. However given the target for reservation is generally only 15% of the pre-European extent it is likely that this mechanism will be insufficient to maintain biodiversity at desired levels across all regions. The JANIS criteria are primarily a design framework for the reserve system, although their functional objective is to maintain forest biodiversity. Evaluation of the performance of the RFA for biodiversity conservation has to date focussed on the extent to which the JANIS criteria have been met by the CAR reserve system (Mendel and Kirkpatrick 2002, Pressey *et al.* 2002). However, what happens to forests outside reserves is likely to more strongly influence the overall outcome for biodiversity conservation.

A pressing question is thus whether the RFA has maintained the biodiversity of an entire forest community, not just those sections of the community that have been reserved. The extent to which complementary management of the forest community outside reserves (management by prescription, such as under codes of practice) has maintained biodiversity is critical to answering this question. Apart from wildfire, timber harvesting is the major disturbance likely to occur in those parts of the permanent forest estate that are outside reserves.

Timber harvesting, like wildfire, dramatically alters the forest community in the short term. This has been used as evidence that timber harvesting is permanently destructive, particularly when effected through clearfelling (Green *et al.* 2004). However, numerous studies have shown that clearfelling and wildfire follow a similar trajectory of recolonisation after disturbance (Hickey 1994, Baker *et al.* 2004, Browning *et al.* 2010, Hingston and Grove 2011), although divergent responses have been detected in hygrophilous species such as filmy ferns and some bryophytes (Hickey 1994, Turner and Kirkpatrick 2009). The divergent responses shown by some elements of the biodiversity are widely considered to be due to the loss of structural legacies following clearfell harvesting that are retained following natural disturbance (Franklin 1990, Franklin *et al.* 2007, Baker and Read 2011).

There is increasing recognition in south-eastern Australia that many wildfires in tall, wet eucalypt forests are not stand-replacing (Hickey *et al.* 1999, Turner *et al.* 2009) as had once been supposed, and result in legacies of the mature forest being retained at much finer spatial scales than can be provided within the widely scattered formal CAR reserves. The network of informal CAR reserves and areas excluded from harvesting to meet Forest Practices Code requirements provides a mechanism for retaining mature forests at finer spatial scales in the production-forest landscape (Williams *et al.* 1990). Studies have shown that these informal reserves (typically wildlife habitat strips and riparian reserves) and other excluded areas within production-forests continue to provide habitat for many of the species dependent on mature-forest structures (Lindenmayer *et al.* 1993, Grove 2004, Grove *et al.* 2004, MacDonald *et al.* 2005), although in some situations (e.g. damp sclerophyll forest) they are less effective (Grove 2001, Grove and Yaxley 2004). At even finer spatial scales, the retention of mature forest as aggregates within variable retention coupes has been used to successfully maintain many elements of mature-forest biodiversity (Lefort and Grove 2009, Baker *et al.* 2009, Lindenmayer *et al.* 2010).

Ascalar assessments of biodiversity responses to local site conditions, as detailed in the previous sections, fail to account for the influence of the surrounding landscape in that response. Lindenmayer *et al.* (1999) found the topography and amount of mature forest in the surrounding 80 ha landscape were strong predictors of the presence of yellow-bellied gliders in Victorian *E. regnans* forests. This landscape-scale was comparable with the home range of the glider. In New South Wales, Kavanagh and Bamkin (1995) found that logging history of the surrounding landscape was less important a predictor of the presence of a range of nocturnal birds and mammals than were elevation and vegetation types in the landscape. Each of these studies were limited in that they examined the response of only small subsets of forest biodiversity to a limited range of landscape variables and scales.

Evaluating the effectiveness of the RFA conservation strategy in maintaining dependent biodiversity needs to consider the intensity of disturbance in various sections of the landscape, as the formal reserves are restricted to discrete areas in the landscape, each surrounded by a differently composed matrix of production-forest and informal reserves. We are interested in knowing if mature forest (the life-stage usually targeted for reservation) supports mature-forest species equally in landscapes dominated by mature forests as in landscapes more dominated by younger forests originating from forestry or wildfire disturbance. Similarly, we are interested in knowing the extent to which younger regenerating forests acquire mature-forest elements, and how that acquisition depends on the amount of mature forest in the surrounding landscape. Such studies are rare. In one of the few examples, McGarigal and Cushman (2003) found species-richness and abundance of birds responded to both the area and level of fragmentation of mature forest in the landscape of a northern hemisphere coniferous forest: landscapes dominated by mature forest had significantly lower richness and abundance than more heterogeneous landscapes with a mix of mature forest and younger seral forest.

To address landscape-level research and management questions, Forestry Tasmania established the Southern Forests Experimental Forest Landscape (SFEFL) site in 2007. The SFEFL is a 112,000 ha landscape where the dominant land cover is tall eucalypt forest. It is anchored on the Warra Supersite in the west and extends eastwards to the Huon estuary. The SFEFL provides a gradient in land-use intensity within a relatively uniform biophysical environment. An extensive network of CAR reserves within the SFEFL provides an opportunity to measure the biological responses of selected taxa along that gradient of land-use intensity and to test the extent to which those responses are influenced by proximity to, and concentration of, mature forest in the surrounding landscape (among many other variables).

Supporting the SFEFL is a detailed knowledge-base of the local biodiversity developed through studies carried out in the Warra Supersite and its environs (e.g. Alcorn *et al.* 2001, Corbett and Balmer 2001, Grove and Bashford 2003, Doran *et al.* 2003, Baker *et al.* 2004, Baker 2006, Tabor *et al.* 2007, Baker *et al.* 2009, Lefort and Grove 2009, Browning *et al.* 2010, Hingston and Grove 2010, Grove and Forster 2011a and b, Law and Law 2011). Based on these studies, birds, vascular plants and beetles were selected as appropriate focal groups for a landscape study. Each shows strong contrast between mature and recently disturbed forest, are feasible to survey or sample, are taxonomically tractable and have members with strong affinities to mature forests.

In this study we test two key hypotheses:

(i) the intactness of biodiversity in mature eucalypt forest is independent of the intensity of disturbance in the surrounding landscape;

(ii) the recolonisation of silvicultural regeneration by mature-forest species is independent of the intensity of disturbance in the surrounding landscape.

In the event of either hypothesis not being supported, we test if this is the result of insufficient mature forest remaining in the landscape and the extent to which any such mature-forest deficiency arose prior to, or after the introduction of the RFA and Forest Practices Code.

Methodology

Southern Forests Experimental Forest Landscape

The study was conducted in the Southern Forests Experimental Forest Landscape (SFEFL), an experimental area formally endorsed by Forestry Tasmania in September 2007 as a place to conduct landscape-level studies. The SFEFL is situated approximately 60 km southwest of Hobart, Tasmania. The Huon River estuary forms the eastern boundary of the SFEFL while the western boundary extends into the Tasmanian Wilderness World Heritage area (Figure 1). The SFEFL is anchored on the Warra Supersite (www.warra.com.au), which is a member site of the Australian Supersites Network (www.tern-supersites.net.au/) under the auspices of Australia's Terrestrial Ecosystems Research Network (www.tern.org.au).

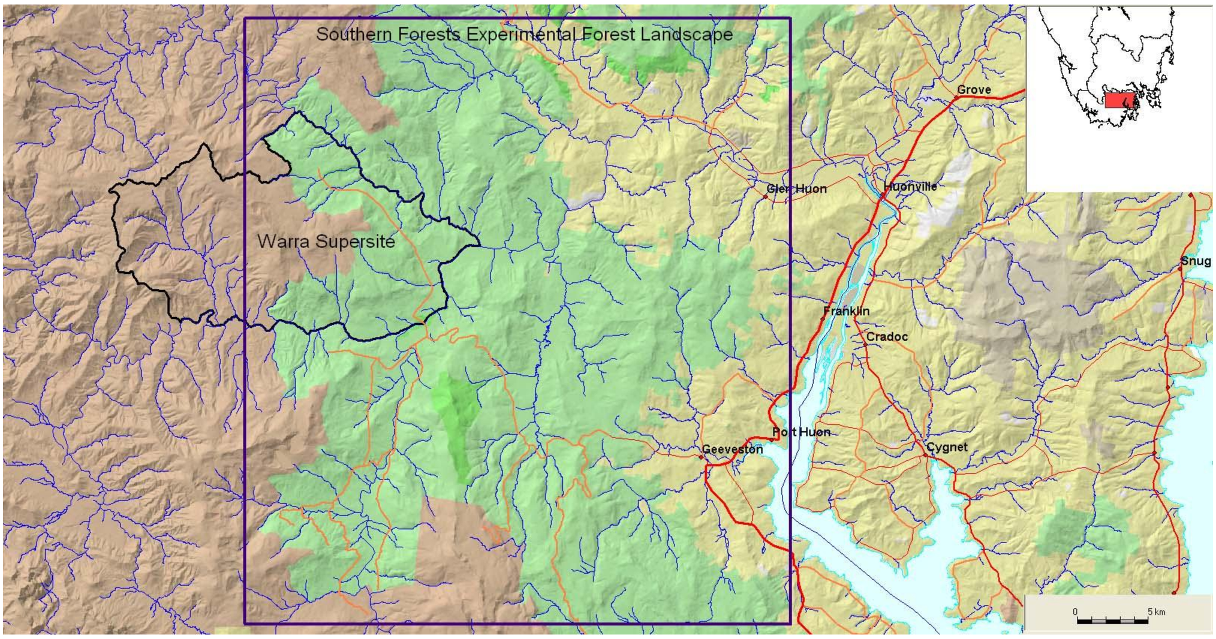


Figure 1. The Southern Forests Experimental Forest Landscape (blue rectangle), anchored on the Warra Supersite and extending from the Tasmanian Wilderness World Heritage Area in the west to the Huon River estuary in the east. Areas in shades of green are State forest, brown are National Parks / World Heritage Area and cream are private land.

Topography of the SFEFL

The SFEFL is a 32 x 35 km (E-W x N-S) landscape between the latitudes 43°S and 43°15.7′S and longitudes 146°37.74′E and 147°E. The middle reaches of the Huon River approximately bisect the SFEFL east-west. The SFEFL fully contains the catchments of the Arve and Little Denison Rivers, as well as containing the lower catchments of the Picton and Weld Rivers, and the Kermandie River and its tributaries (Figure 2). Two major north-south ridges divide the eastern parts of the SFEFL: Scott's Divide in the east, and Blue Hill (extending to Hartz Mountains) in the centre, enclosing the Arve River catchment. In the western half of the SFEFL the Snowy Ranges – Barn Back separate the Little Denison and Weld River catchments; Weld Ridge (contained within Warra Supersite) divides the Huon and Weld River catchments and the Picton Range separates the Huon and Picton River catchments. Relief ranges from about 80 metres in the valley floors to 1,300 metres at the top of the ridges, although Scott's Divide only reaches about 530 metres at its highest point.

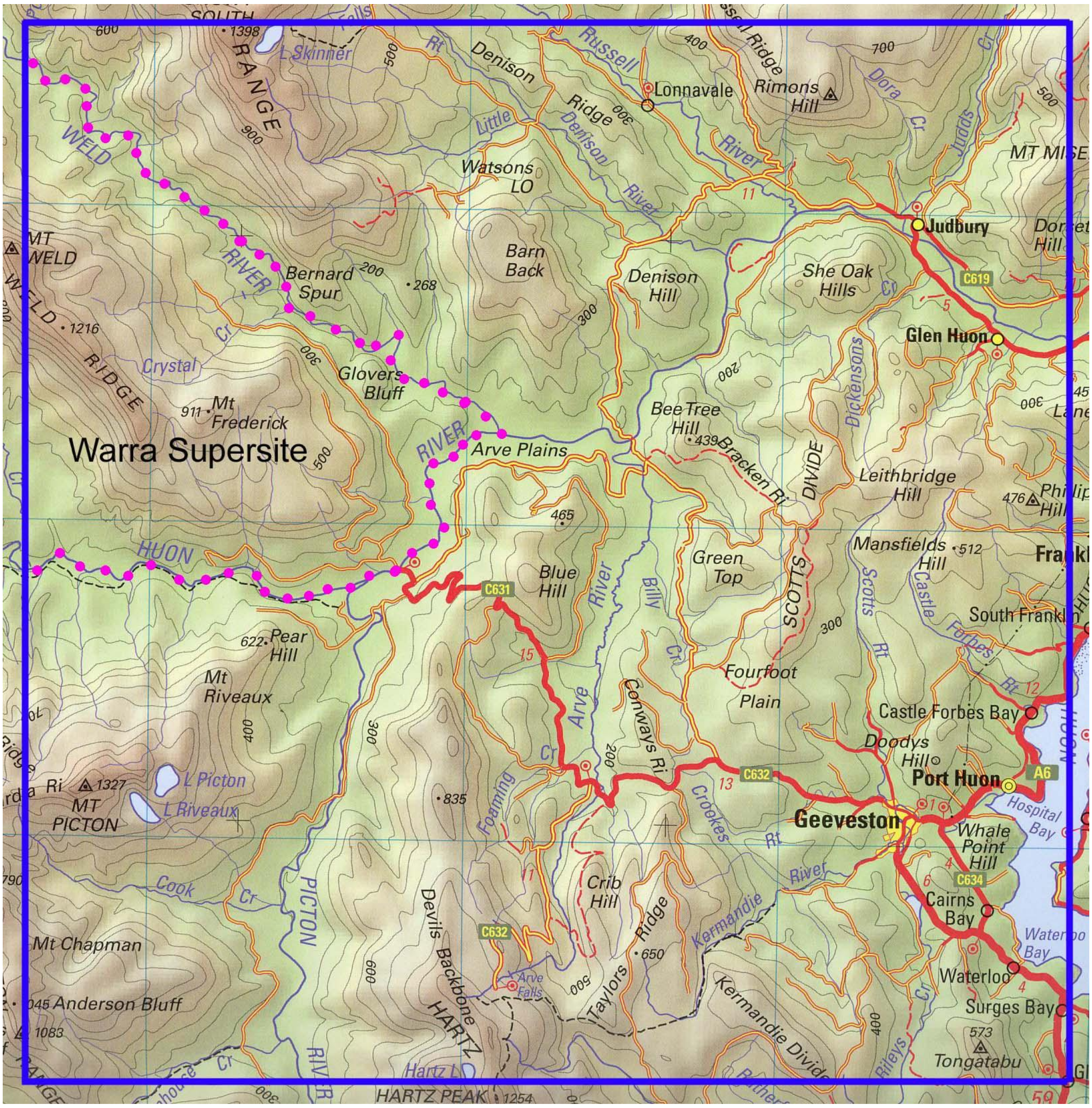


Figure 2. Topography of the Southern Forests Experimental Forest Landscape (bold blue rectangle). The image was extracted from 1:250,000 South East Tasmap (2010 Edition).

Climate of the SFEFL

The SFEFL is within the Temperate Climate Zone (Kőppen classification), with uniform-to-winter-dominated rainfall, mild-to-warm summer temperatures and cold winter temperatures (Commonwealth of Australia 2008). Most of the rainfall occurs during the passage of cold fronts embedded in westerly airstreams, resulting in strong west-east and south-north gradients of rainfall: the rainfall at Geeveston and Denison River at the eastern and northern edges of the SFEFL, respectively, is about half that recorded at Warra on the western edge of the SFEFL, while Tahune Forest Reserve is midway between those extremes (Figure 3). The mean (1971-2011) annual rainfall at Geeveston is 882 mm, while Tahune Forest Reserve has a mean annual rainfall of 1256 mm over the same period. Mean summer (January) temperature ranges between 21.7°C at Geeveston and 19.9°C at Warra. Mean winter (July) temperatures range between 12°C and 8.5°C for the same two stations.

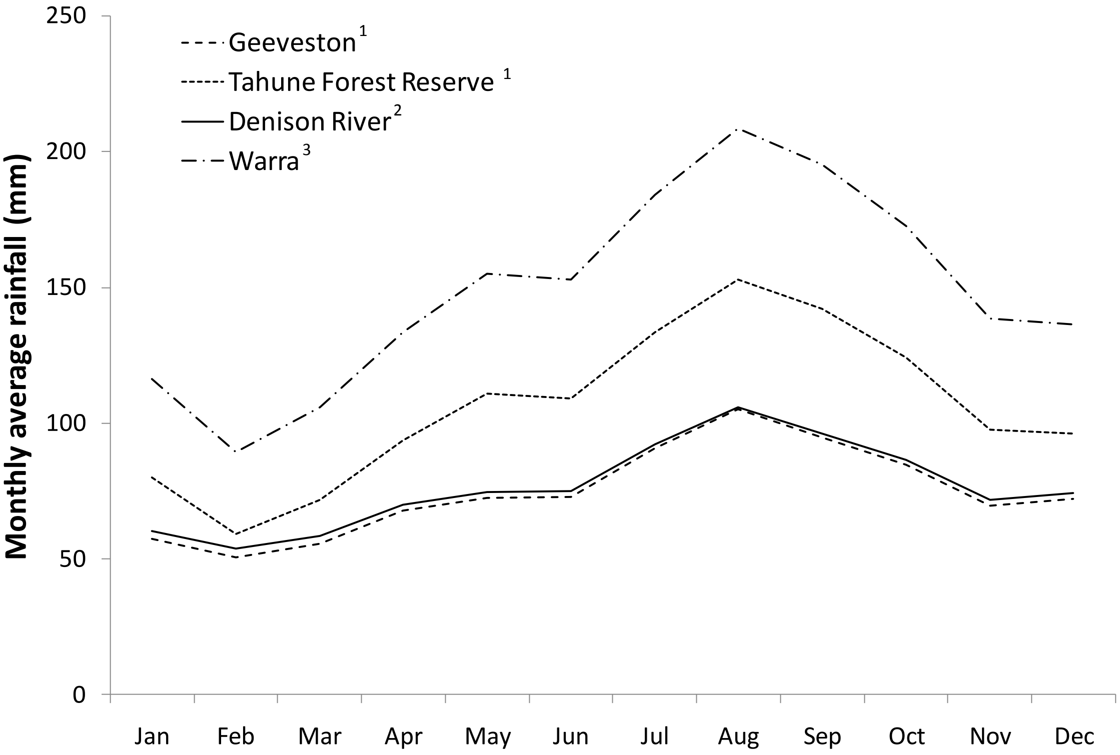


Figure 3. Monthly average rainfall of four weather stations located within the SFEFL.

[1.] Data for Geeveston (BOM station number 94137) and Tahune Forest Reserve (BOM station number 94137) are based on the average of monthly records between 1971-2011.

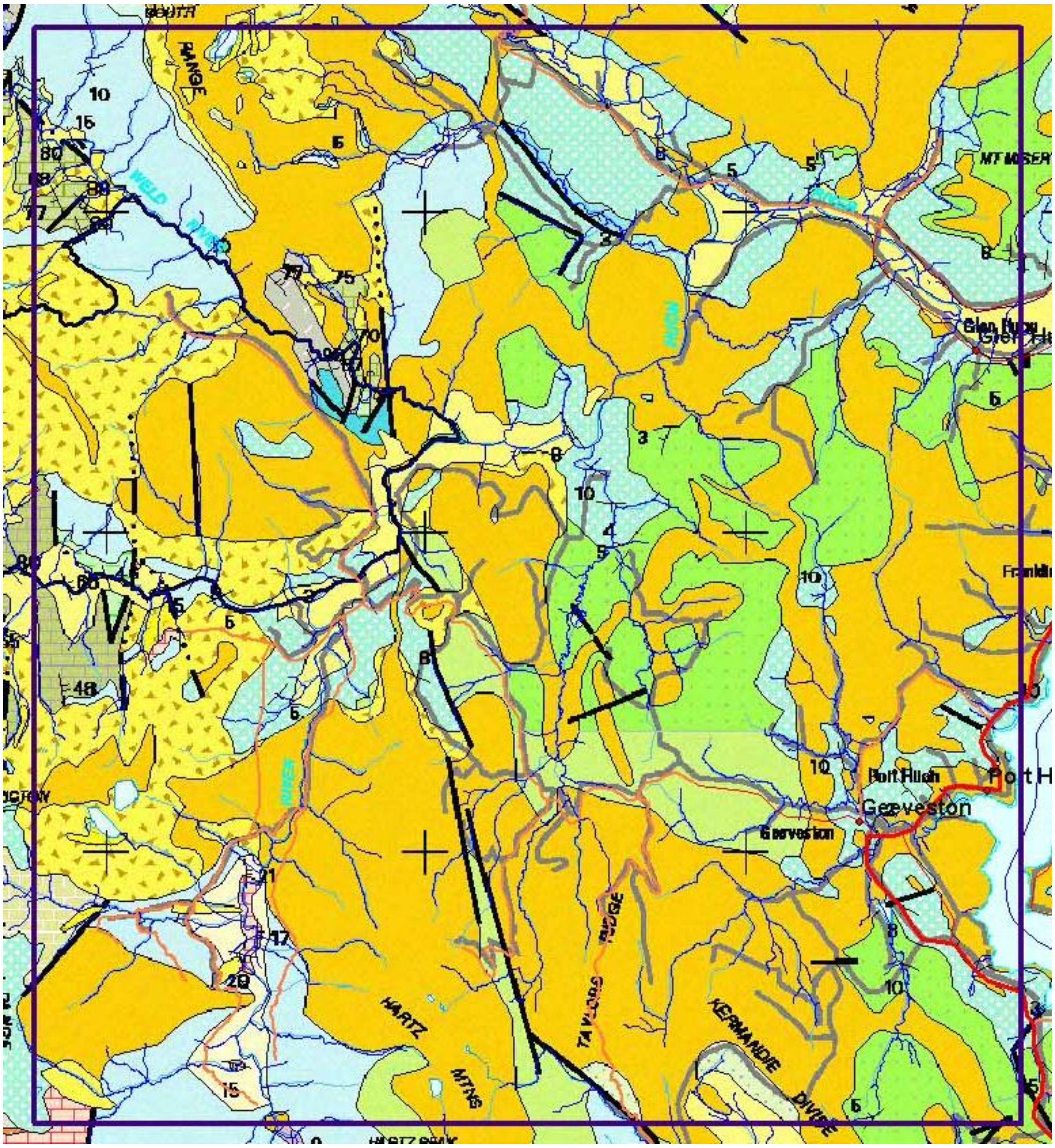
[2.] Data for Denison River (BOM station number 94137) is based on predictions from a linear regression model (Denison River = 5.14 + 0.958*Geeveston; R^2=91.7%) constructed from overlapping monthly records (1992-2011) with Geeveston.

[3.] Data for Warra (BOM station number 97024) is based on predictions from a linear regression model (Warra = 14.2 + 1.273*Tahune; R^2=86.4%) constructed from overlapping monthly records (2005-2011) with Tahune.

Geology and soils of the SFEFL

The SFEFL has geology typical of the eastern province of Tasmania where Jurassic dolerite outcrops form the major ridges and peaks (Figure 4). The valleys throughout the SFEFL are formed from Permian and Triassic sediments, with the Permian sediments dominating in the western half of the SFEFL and Triassic sediments in the eastern half. Quaternary alluvial deposits dominate the floodplains in the middle and lower reaches of the Huon Rivers. Quaternary talus deposits occur at the base of the high dolerite peaks in the western sections of the SFEFL.

Representative descriptions of the soils within the SFEFL are provided in Grant *et al.* (1995). The four main soil types represented in the SFEFL are summarised in Table 1. Despite the apparent uniformity suggested by just four main soil groups within the SFEFL, there is considerable fine-scale variation in soil properties within a soil group (Laffan 2001). Mapping of this fine-scale soil variation has not yet been carried out across the SFEFL.



QUATERNARY	🟨	Talus, fan and other deposits	JURASSIC	🟧	Dolerite
	🟨	Sand, gravel mud of alluvial, lacustrine and littoral origin	ORDOVICIAN	🟥	Dominantly shallow marine limestone
TRIASSIC	🟩	Dominantly quartz sandstone	LATE NEOPROTEROZOIC	🟫	Dolomite, diatomite and mudstone
	🟩	Undifferentiated fluviolacustine sequences of sandstone, siltstone and mudstone	NEOPROTEROZOIC - MESOPROTEROZOIC	⬛	Dominantly shallow marine orthoquartzite
PERMIAN	🟦	Undifferentiated glacial, glaciomarine and non-marine sedimentary rocks		▦	Dominantly carbonate
	🟦	Freshwater sandstone with coal measures		⬜	Dominantly mudstone and siltstone
	🟦	Lower glaciomarine sequences			
	🟦	Basal tillite			

Figure 4. Geology of the Southern Forests Experimental Forest Landscape. Base map is from Mineral Resources Tasmania (2008).

Table 1. Summary of the main soil types represented in the Southern Forests Experimental Forest Landscape.

Parent material	Australian soil classification	Grant et al. (1995) classification
Permian mudstone	Mottled, brown kurosol	13.1 Mottled grey and brown clayed soils under wet forest
Triassic sandstone	Bleached, dystrophic, brown kurosol	14.2 Sandy over clayey soils under wet forest
Jurassic dolerite	Mottled, brown ferrosol	15.3 Yellowish brown mottled clayey soils under wet forest
Jurassic dolerite	Haplic, red ferrosol	15.4 Red to brown clayey soils under wet forest

Vegetation of the SFEFL

The great majority of the SFEFL supports tall eucalypt forest (Figure 5) grading to rainforest in fire-protected situations, particularly in the high-rainfall western section, and to non-forest communities (buttongrass moorlands and alpine moorlands) in alpine areas and on poorly drained, infertile soils. Low eucalypt forests are restricted to the drier north-eastern section of the SFEFL, particularly on north-facing slopes, and to high-altitude communities just below the tree-line.
The tall eucalypt forests are dominated by the three species *Eucalyptus obliqua*, *E. regnans* and *E. delegatensis*, which form the canopy above a lower stratum of broadleaved trees and shrubs. *E. delegatensis* is the dominant of the three above about 600 m until it transitions into a sub-alpine eucalypt woodland at about 900 m (Corbett and Balmer 2001). Below 600 m altitude *E. obliqua* and *E. regnans* predominate, with the latter tending to occur primarily in moist, relatively fire-protected situations (Ashton 1981). This study was restricted to areas of the landscape below about 600 m where *E. obliqua* tends to be the dominant eucalypt in the tall forests.

The understorey stratum of the tall eucalypt forest in the SFEFL is a spatially heterogeneous mixture of sclerophyllous and rainforest communities. The composition of the understorey is dictated by the position of sites along two gradients, one temporal (time since last fire or harvest), and one spatial (soil fertility). With increasing time since last fire the understorey progresses along a successional pathway, with sclerophyllous species dominating the initial period after the fire followed by a progressive enrichment with rainforest elements as the interval since the last fire increases. After a sufficiently long fire-free period (>100 years) the understorey can become floristically identical to rainforest, assuming propagules are present in the vicinity – the whole forest is then called mixed forest (Gilbert 1959). The gradient in soil fertility modifies the composition of the sclerophyllous and rainforest elements along the time-since-last-fire successional pathway. On fertile and better drained soils broad-leaved species such as *Pomaderris apetala*, *Olearia argophylla* and *Acacia dealbata* dominate the early successional period. As soil fertility and drainage declines understoreys become increasingly dominated by smaller, prickly-leaved species such as *Monotoca glauca, Acacia verticillata, Melaleuca squarrosa, Leptospermum species* and *Gahnia grandis* during the early successional period. On fertile, better drained sites the succession appears to progress towards a callidendrous-type rainforest community dominated by *Nothofagus cunninghamii* and *Atherosperma moschatum* (*sensu* Jarman *et al*. 1984). On less fertile and poorly drained sites progressed to a structurally more complex thamnic rainforest community (*sensu* Jarman *et al*. 1984)which was intermediate between a Callidendrous and Thamnic rainforest community (*sensu* Jarman et al 1984) and typified by the addition of *Anodopetalum* *biglandulosum*, *Cenarrhenes nitida*, *Eucryphia lucida* and *Phyllocladus aspleniifolius* in particular, to the rainforest component.

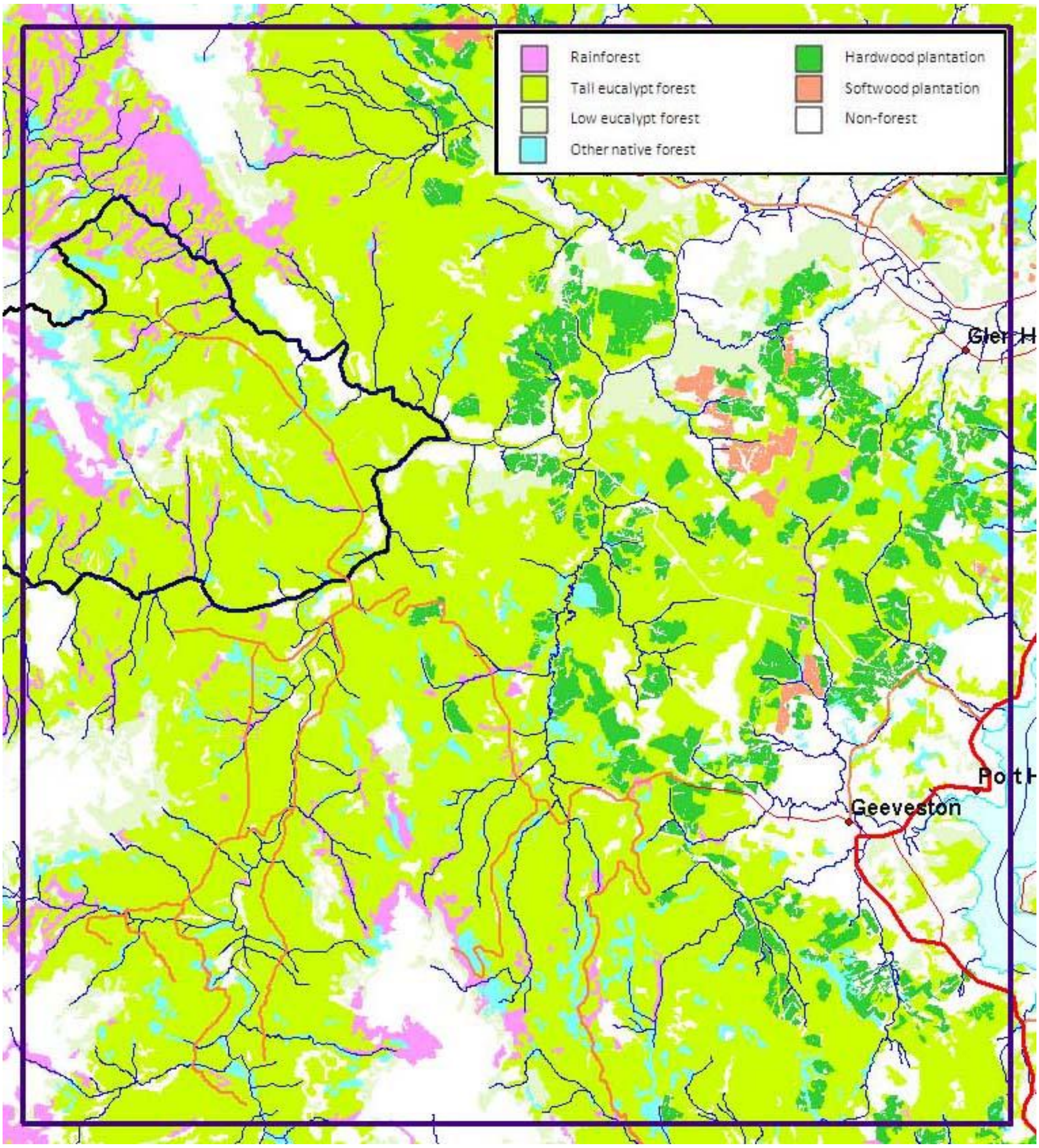


Figure 5. Distribution of broad vegetation groups within the Southern Forests Experimental Landscape.

Disturbance history of the SFEFL

The SFEFL captures a gradient of land-use and wildfire disturbance-intensity typical of many parts of south-eastern Australia. The land-use gradient extends from the more modified landscapes in the coastal lowlands and adjacent hinterlands through to relatively natural landscapes in the more mountainous interior. Kostoglou (1995) has documented the post-European timber harvesting in and around the SFEFL up until the commencement of modern forestry operations in the mid 1960s. The anthropogenic disturbance history of the forests within the SFEFL can be summarised as follows:

1830s – 1890s: Forest clearance for agriculture, largely restricted to within 1-2 km of the Huon River and of the Kermandie River and its tributaries (Crookes Rivulet and Scott's Rivulet).

Early 1900s – mid-1950s: Logging accompanied by steam haulage of logs on tramways to large, centralised sawmills, on State forest in the south-eastern corner of the SFEFL (Figure 6).

Mid-1950s – mid-1960s: Spot sawmills in previously logged areas of State forest in the south-eastern corner of the SFEFL.

Mid-1960s – present day: Modern forestry practices, comprising harvesting by clearfelling followed by high-intensity burns and sowing, in dispersed, road-accessed coupes concentrated in the southern half of the SFEFL in the Arve, Picton, Weld and Huon River basins; also major expansion of reservation.

Early 1990s to late 2000s: Continuation and expansion of clearfelling, coupled with further extensive reservation, in keeping with Forest Practices Code (1985) and RFA. Clearance of native forest for plantation establishment, particularly as part of the Intensive Forest Management program following the RFA (on State forest, concentrated in the south-eastern quarter of the SFEFL).

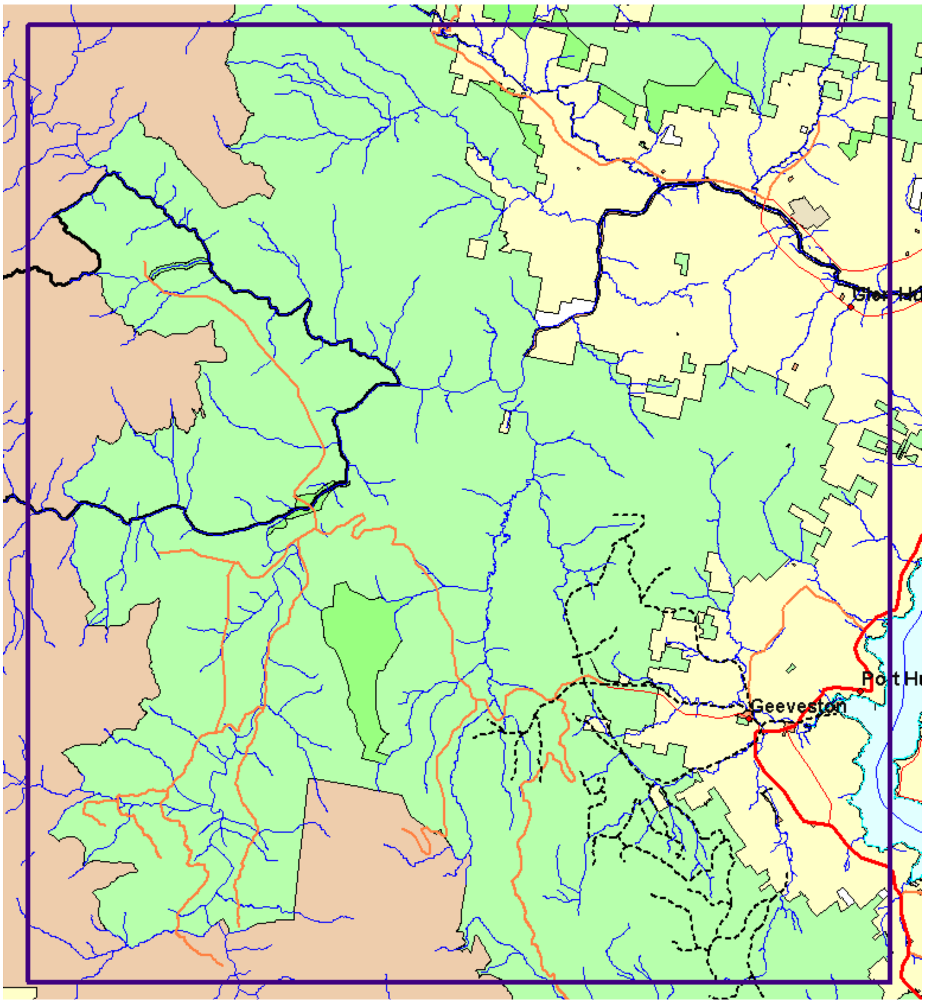


Figure 6. Extent of tramways (dark dashed lines) from early-1900s – mid-1950s logging operations in the Southern Forests Experimental Forest Landscape. Reproduced from Figure 4 in Kostoglou (1995).

Natural disturbance in the form of wildfires (some of them of human origin) has occurred within the SFEFL in 1898, 1906, 1914, 1934 and 1967 (Hickey *et al.* 1999) (Figure 7). The 1898 wildfire, while extensive in south-western Tasmania (Marsden-Smedley 1998) including much of Warra (Hickey *et al.* 1999), did not spread further east into the remainder of the SFEFL. The 1906 and 1914 wildfires affected limited areas of the SFEFL in the south-western portion of Warra (Hickey *et al.* 1999). The 1934 wildfire was extensive throughout the SFEFL, re-burning most of the forests previously burnt in the 1898, 1906 and 1914 wildfires. However, the 1934 wildfire was generally non-stand-replacing within the SFEFL (Hickey *et al.* 1999; Turner et al 2009). The 1967 wildfire was concentrated in the central section of the SFEFL between the Arve and Huon Rivers. Many of the affected stands have been subsequently logged and regenerated using CBS.

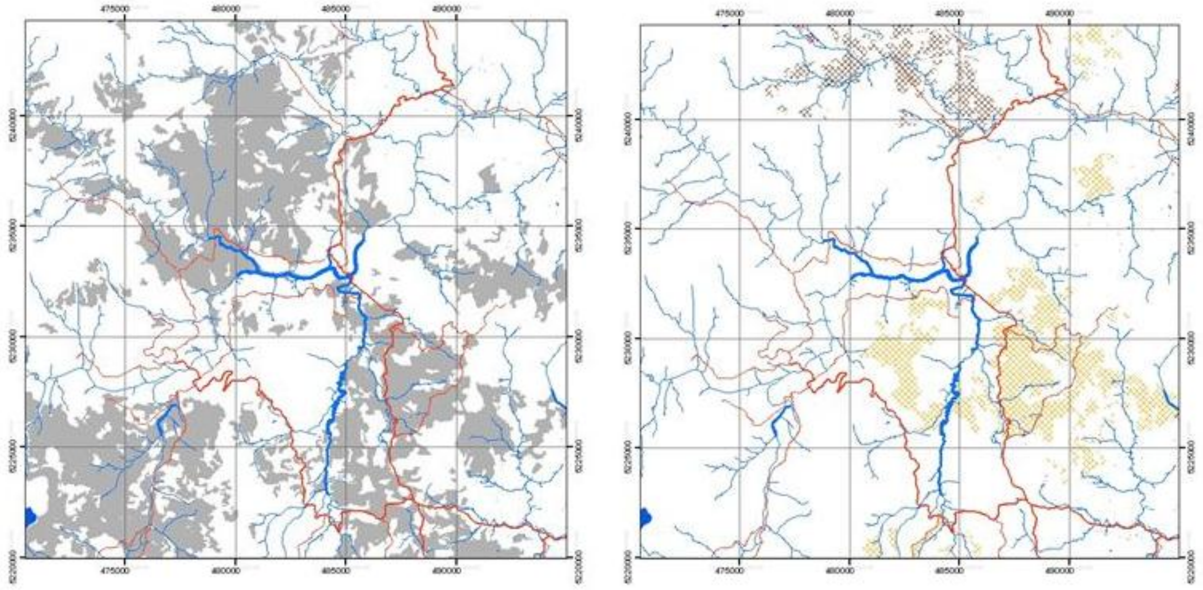


Figure 7. Distribution of the 1934 wildfire (left) and the 1967 wildfire (right) within the SFEFL. Mapping is for the 1934 wildfire is based on inferred boundaries from forest-type mapping from 1947 aerial photography.

Reservation in the SFEFL

The CAR Reserve system consists of both formal reserves (including World Heritage Areas, National Parks and forest reserves), the status of which is conferred by parliament, and informal reserves (e.g. wildlife habitat strips and reserves for threatened species or communities), the status of which is conferred by the land manager, e.g. Forestry Tasmania. Additionally, many areas of State forest outside the CAR Reserve system are excluded by Forestry Tasmania from harvesting for a variety of reasons, most of which relate to compliance with the Forest Practices Code. These include riparian and karst areas, steep slopes and non-commercial stands.

The SFEFL has a strong west-east gradient in reservation levels through the RFA CAR reserves system. The western section of the SFEFL is contiguous with the Tasmanian Wilderness World Heritage Area (Figure 8). Arve Forest Reserve, on the southern boundary of the SFEFL, provides a large contiguous formal reserve surrounded by State production-forest. A predominantly linear network of informal reserves (primarily wildlife habitat strips) extends throughout the State production-forest landscape. Interspersed alongside this network of informal reserves within the production-forest matrix are many small, discrete patches of forest that are excluded from harvesting, mostly as part of compliance with the Forest Practices Code (Figure 8). The eastern and south-eastern sections of the SFEFL extend onto private land where there is little reservation.

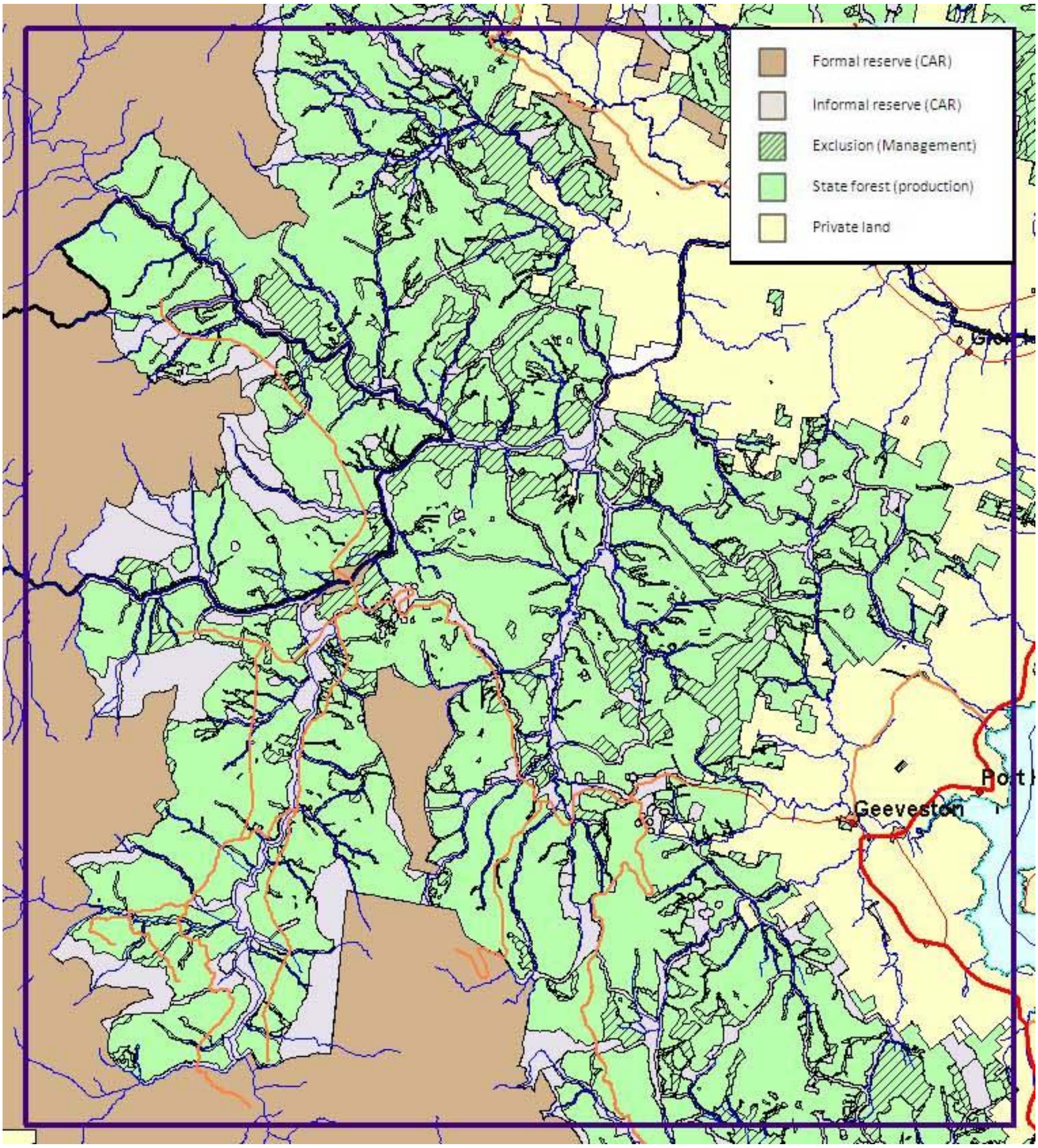


Figure 8. Reserves and protected areas within the Southern Forests Experimental Forest Landscape.

Experimental design and plot selection

A "replicated patch-landscape with control" design (*sensu* McGarigal and Cushman 2002) was used to compare biological responses of focal groups in mature *Eucalyptus obliqua* forest (MAT) with their responses in older (27-49 years-old) silviculturally regenerated forest (SILV). Plots in MAT and in SILV were located to provide a replicated sample for each of several levels of landscape context. Each level of landscape context ('context-class') reflected the intensity of disturbance (reflected by the mix of vegetation groups) surrounding the plot along a notional gradient.

Forestry Tasmania’s Forest PI (photo-interpreted) forest-type mapping and the Department of Primary Industries, Parks, Water and Environment’s (DPIPWE) TASVEG map layer were used to classify the vegetation in the SFEFL into one of ten broad vegetation groups. The PI-types describe the species mix, canopy heights and tree density, which together form a forest class. Selections of the 2005 forest classes (FC2005), based on 2000s aerial photography, were combined to describe each of the broad forest vegetation groups as shown in Table 2. The TASVEG layer was used to classify urban and agricultural areas. A similar classification was used to group forest-types derived from 1947 aerial photography into the broad vegetation groups (Table 2). This classification provided a comparable representation of the landscape prior to the commencement of modern forestry in the study area during the 1960s.

Table 2. Classification used to group forest classes (Forest Class 2005), based on aerial photographs from the 2000s, and PI types, based on aerial photographs from 1947, into broad vegetation-groups. Note: older silvicultural regeneration and thinned silvicultural regeneration were subsequently merged.

Broad vegetation-group		Forest class 2005	Forest-types from 1947 photography
1.	Rainforest	85 - 86	Mature eucalypt density = none, or 'F' AND the string included the term 'M' or 'MR' (myrtle)
2.	Mature eucalypt forest	1 - 17, 22 - 33	Live (i.e. not 'dd E') mature eucalypt density class A, B, C or D
3.	Other native forest	87 - 88	Mature eucalypt density = none, or F AND the string did not include any of the terms 'M' or 'MR', or 'ER', AND the string included the term 'T'
4.	Wildfire regrowth	34 - 45	Mature eucalypt density = none, or F AND the string did not include either of the terms 'M' or 'MR', AND the string included the term 'ER' (regrowth eucalypt)
5.	Older silvicultural regeneration	50 - 65	String included the term 'co' (cut-over)
	Thinned silvicultural regeneration	18 – 21, 46-49	
6.	Young silvicultural regeneration	66 - 84	-
7.	Plantation	89 - 90	-
8.	Native non-forest	Remainder not classified	Mature eucalypt density none, or F AND the string did not include any of the terms 'M' or 'MR', or 'ER', 'T'
9.	Agricultural land	Agriculture / urban from TasVeg	String included the term 'V' (agriculture)

The nine vegetation-groups each represent a point along a continuum of ecological stability / disturbance. Each was therefore given a subjective weighting (ecological stability value) to reflect this (Figure 9). The weightings were informed by the notional time-intervals between disturbance events that generated the particular vegetation-group.

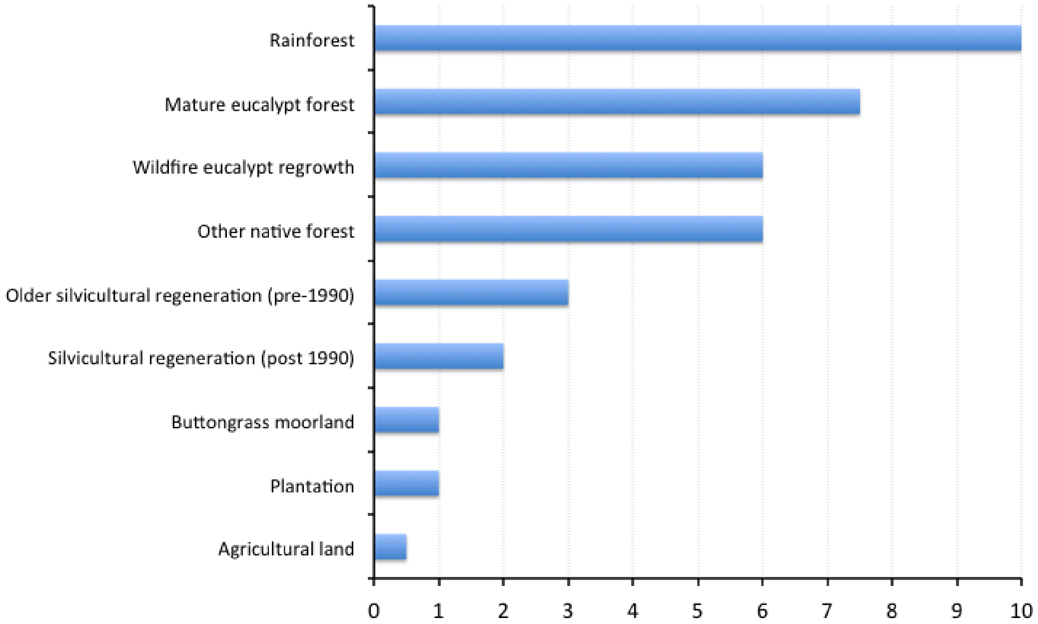


Figure 9. Subjective weightings for the nine vegetation-groups reflecting their position along a continuum of ecological stability / disturbance. Thinned silvicultural regeneration has been merged with older silvicultural regeneration.

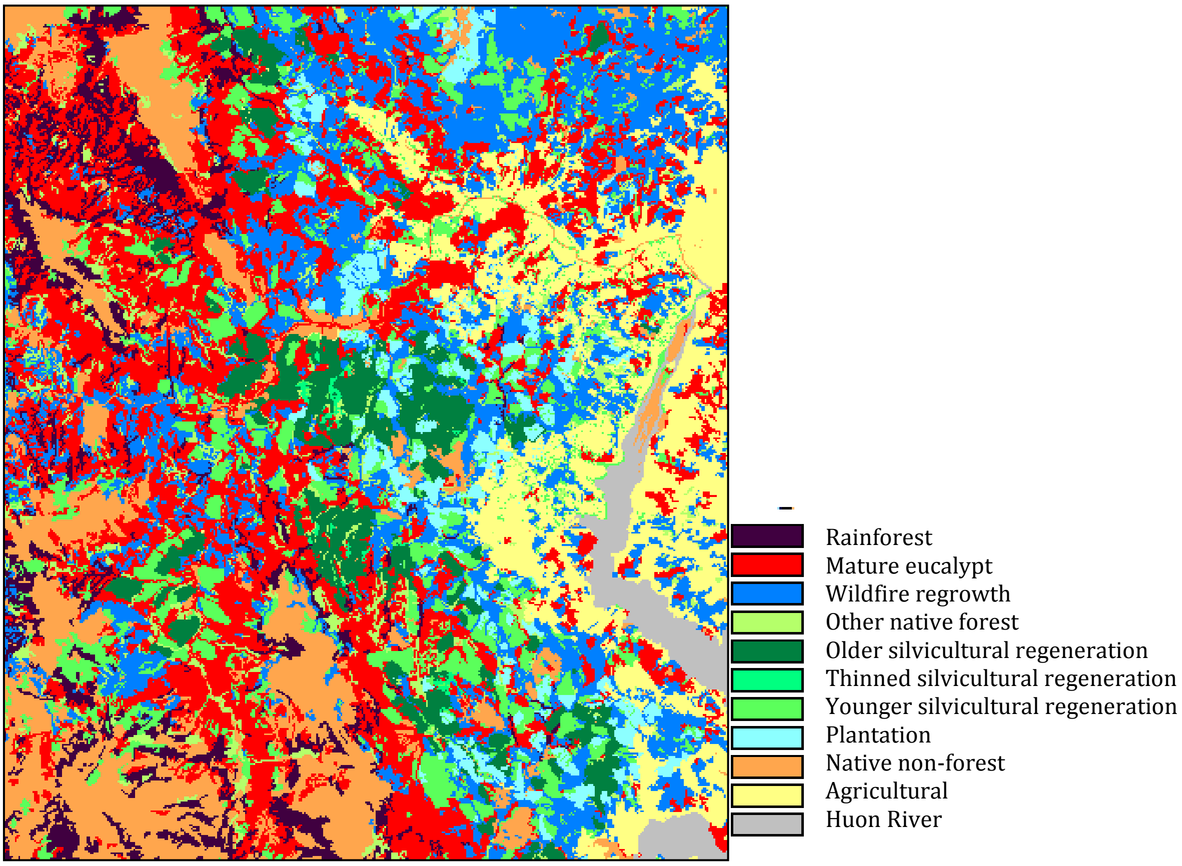


Figure 10. Mapped distribution of ten vegetation-groups in the Southern Forests Experimental Landscape. Note: older silvicultural regeneration and thinned silvicultural regeneration were given the same weighting and were merged prior to subsequent analyses.

The open-source GIS software SAGA© was used to convert the broad vegetation mapping of the SFEFL (Figure 10) to raster format with a 50 x 50 m pixel size. Each pixel was assigned the stability weighting corresponding to its broad vegetation group. Using a moving-window algorithm, the context-score was then calculated by averaging the stability scores of all pixels within the radii 500 m, 1 km and 2 km of each pixel. Context-scores thus calculated were then coalesced into context-classes. This was done by arithmetically splitting the range of context-scores into ten context-classes (1-10) each spanning 10% of the context-score range. The mapped context-classes for the three circular landscape scales are shown in Figure 11.

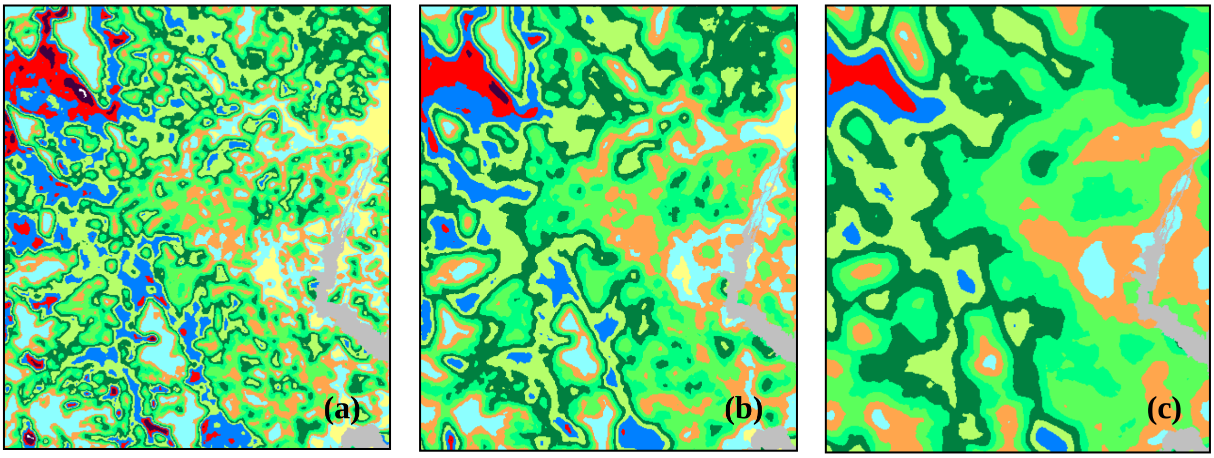


Figure 11. Mapped context-classes calculated for (a) 500 m, (b) 1 km and (c) 2 km circular landscapes around each 50 x 50 m pixel in the SFEFL. Colour-codes for each context-class are shown in Figure 12.

The decision to restrict scale-consistency to the 500 m, 1 km and 2 km scales was made for several reasons. These three encompass the scales considered most appropriate for strategic-level conservation planning: the mid-point scale (1 km) corresponds approximately with Forestry Tasmania's coupe-context planning for a notional group of coupes within a 400 ha patch. Landscape scales below 500 m were considered impractical because as the size of the landscape decreases the surrounding vegetation becomes overwhelmingly dominated by the vegetation-group of the plot at the centre of the circle. At landscape scales larger than 2 km the large size of the landscape dampens the effect of changes in the absolute area of the different vegetation-groups to the context-score: 50 ha change in the area of a forest type produces a 15% shift in proportional area at the 1 km scale but a <1% shift at the 4000 and 8 km scales.

Context scores for each pixel in the study area prior to the commencement of modern forestry (not shown) were calculated in the same way but using vegetation-groups derived from PI forest-type mapping from the 1947 aerial photography. For this spatial data-set, landscape context-class was only calculated based on the 2 km radius circle surrounding each pixel.

The selection of potential study-sites was restricted to those pixels that, for the Forest Class 2005 data-sets, had the same landscape context-class at the 500 m, 1 km and 2 km radius landscape scales, i.e. were three-scale consistent (Figure 12). The three-scale consistent context-class map was overlain with the mapped extent of SILV and MAT. Patches of SILV and MAT coinciding with pixels that were three-scale consistent were identified (Figure 12).

All potential plot locations of scale-consistent patches of MAT and SILV were then highlighted on a series of maps, and prioritised according to the following criteria:

i. Avoid high-altitude sites (>600 m);

ii. Avoid silvicultural regeneration which is towards the young (>1986) or old (<1966) end of the ‘SILV’ spectrum (but older is better than younger);

iii. Avoid forest not dominated by either *E. obliqua*, *E. regnans* or a mixture of these species;

iv. Study-plot centres should avoid being located closer than 75 m from a road, vehicle-track or edge of a strongly contrasting vegetation group. This distance is well beyond the 10-metre edge-affected zone measured in tall eucalypt forests (Westphalen 2003).

v. Vegetation-class patches used for study-plots should be at least 150 m wide at the point where the study-plot is located.

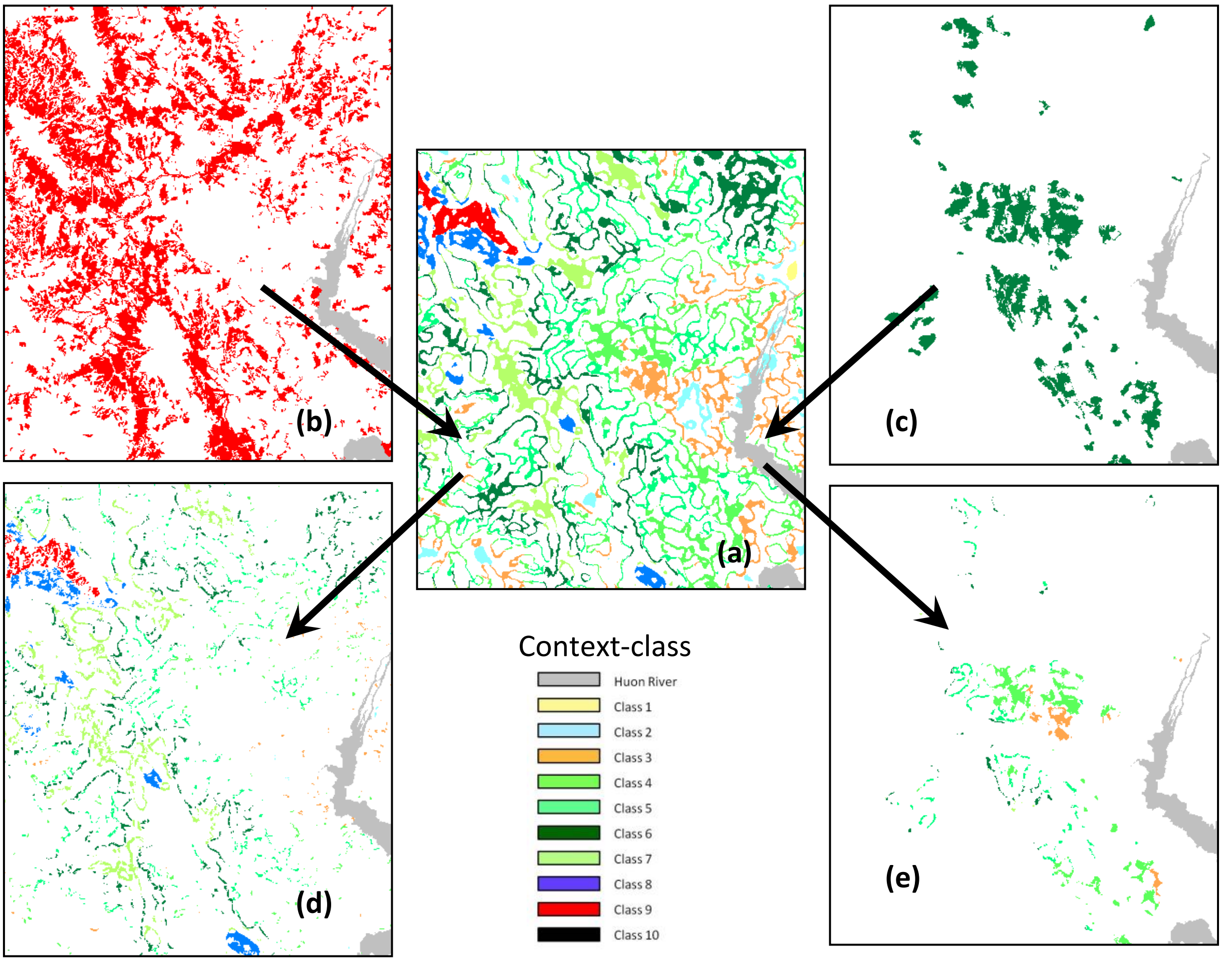


Figure 12. Three-scale consistent landscape context-class mapping of the SFEFL (a) was overlain on the mapped extent of MAT (b) and SILV (c) to identify pixels to screen as potential locations for MAT (d) and SILV (e) plots.

The final experimental design comprised the two vegetation-groups (SILV and MAT), each represented by seven replicate plots across each of four context-classes (classes 3-7). Due to the rarity of mature forests (MAT) in the highly disturbed context class 3, and similarly the rarity of older silvicultural regeneration (SILV) in the relatively undisturbed areas of context class 7 these particular combinations of treatments were not sampled. Seven replicate study plots were assigned to all other combinations of vegetation group and context class. A total of 56 plots therefore represented each of these vegetation-group/context-class combinations. The final list of selected plot-locations is shown in Table 3, and their locations across the study-area are shown on Figure 13. At each selected plot-location, a 50 x 50 m square plot was established following compass-and-chain survey, with the perimeter marked out with flagging tape.

Table 3. Listing of the 56 plots established to provide seven replicates in each of two forest types (mature eucalypt forest and older silvicultural regeneration) and four landscape context-classes.

Plot ID	Context -class	Nearest FT coupe	Easting	Northing	Plot ID	Context-class	Nearest FT coupe	Age 2010 (years)	Easting	Northing
Mature-forest plots					**Older silvicultural regeneration plots**					
M4a	MAT4	AR023E	485675	5222340	S3a	SILV3	AR053E	43	487210	5227450
M4b	MAT4	BB026G	482143	5233484	S3b	SILV3	AR027F	43	485100	5226275
M4c	MAT4	PC035H	472950	5218500	S3c	SILV3	AR047D	43	488550	5226020
M4d	MAT4	AR078G	482906	5231914	S3d	SILV3	AR046B	30	488310	5224200
M4e	MAT4	AR051D	482128	5227908	S3e	SILV3	AR064L	43	488016	5225724
M4f	MAT4	AR085B	485691	5231265	S3f	SILV3	FN032E	43	493626	5226378
M4h	MAT4	FN029C	494429	5227643	S3g	SILV3	AR054J	43	485720	5226022
M5a	MAT5	FN029B	494189	5228296	S4a	SILV4	AR053O	31	486700	5228440
M5b	MAT5	PC039F	472844	5214825	S4b	SILV4	AR075F	44	482522	5230132
M5c	MAT5	FN023A	493581	5229539	S4c	SILV4	AR069F	44	483802	5229390
M5d	MAT5	AR050G	482100	5226300	S4d	SILV4	AR031D	44	484000	5226200
M5e	MAT5	PC040B	471800	5216800	S4e	SILV4	FN032B	43	493004	5226684
M5f	MAT5	PC024B	475421	5226555	S4f	SILV4	AR073D	43	488400	5226900
M5g	MAT5	AR033H	482307	5222468	S4g	SILV4	AR086D	43	487700	5230300
M6a	MAT6	AR031A	483550	5223950	S5a	SILV5	PC037A	27	473811	5217450
M6b	MAT6	BB021A	478420	5235330	S5b	SILV5	PC034G	31	473525	5218962
M6c	MAT6	WR008J	474122	5228070	S5c	SILV5	AR051F	44	483100	5226000
M6d	MAT6	PC009A	477813	5226172	S5d	SILV5	AR012F	44	482647	5222030
M6e	MAT6	PC071D	476200	5216400	S5e	SILV5	PC005C	39	478612	5228408
M6f	MAT6	PC072B	475900	5216500	S5f	SILV5	WR001D	35	477100	5228900
M6g	MAT6	AR041C	481673	5224606	S5g	SILV5	AR034E	41	481235	5222111
M7a	MAT7	PC013D	477465	5223918	S6a	SILV6	AR009C	44	481650	5218700
M7b	MAT7	PC023B	473927	5224955	S6b	SILV6	DN019P	27	478700	5240500
M7c	MAT7	BK001A	472100	5229100	S6c	SILV6	WR007B	38	475857	5229204
M7d	MAT7	BB020B	479170	5238940	S6d	SILV6	AR034G	33	480530	5221824
M7e	MAT7	WR017D	473050	5237675	S6e	SILV6	AR048H	30	480843	5226064
M7f	MAT7	BB021E	478805	5236619	S6f	SILV6	AR050G	27	481869	5225824
M7g	MAT7	PC013E	478198	5224383	S6g	SILV6	DN017G	49	478479	5241830

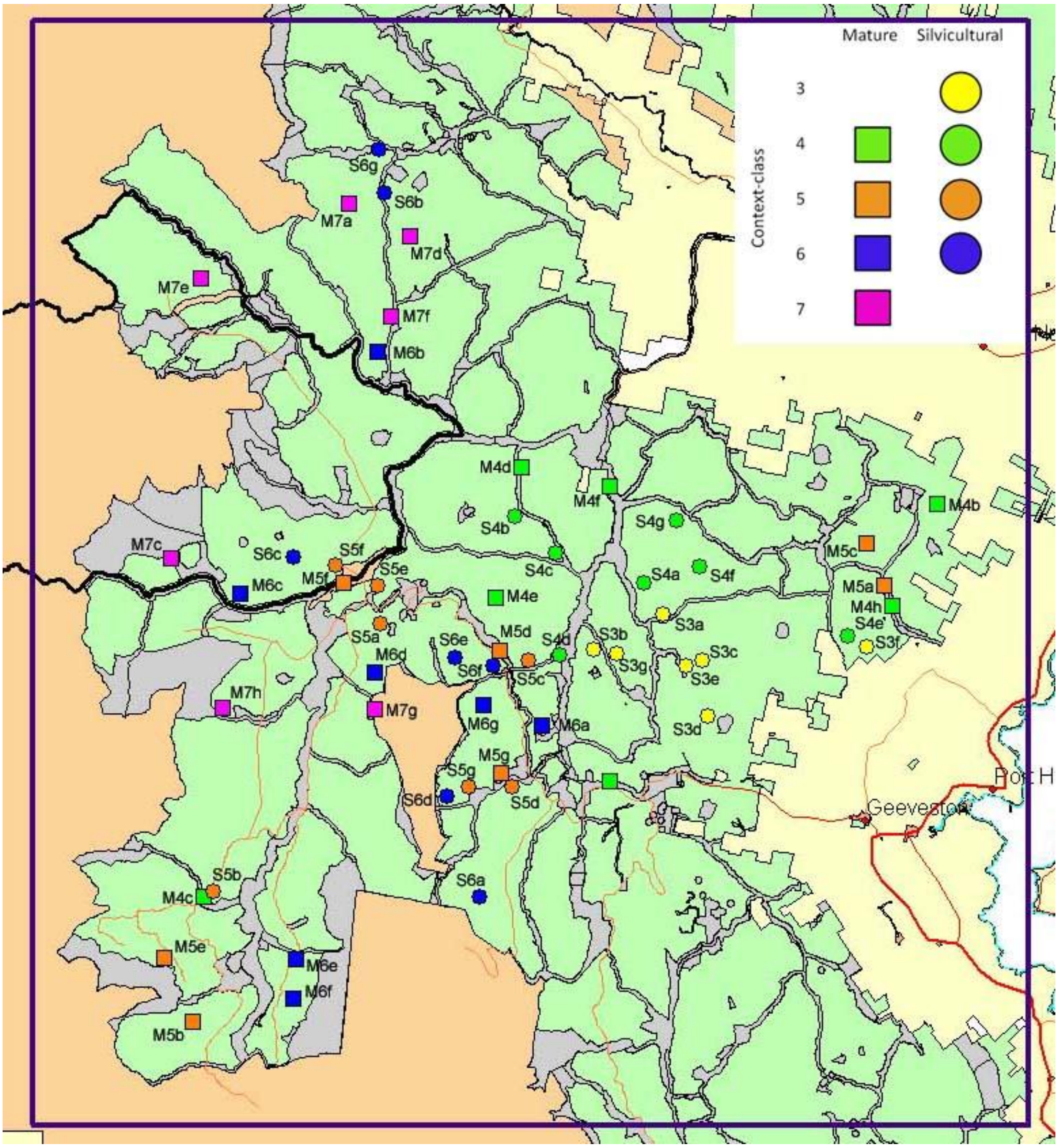


Figure 13. Location of sample plots in mature-eucalypt forest (M) and older silvicultural regeneration (S). Numerals (3-7) indicate context-class and lower-case letters (a-g) indicate replicate. Orange-shaded areas are World Heritage area, National Parks and Forest Reserves; green is State production forest; grey are informal reserves on State forest; cream is private land.

The area of the SFEFL occupied by each context-class showed a normal distribution, peaking between context-classes 6 and 7 (Figure 14). The experimental design, requiring seven replicates of mature eucalypt forest and seven of older silvicultural regeneration in each scale-consistent context-class, restricted sampling to just three context-classes (4-6). However, context-classes 4-6 were representative of only 64.5% of the total area of the SFEFL, so in addition, each forest type sampled an additional context-class: context-class 7 in mature eucalypt forests and context-class 3 in older silvicultural regeneration. The four context-classes then sampled by the mature-forest plots were representative of 81.5% of the total area of the SFEFL, while the four sampled then by the silvicultural plots were representative of 72% of the area of the SFEFL.

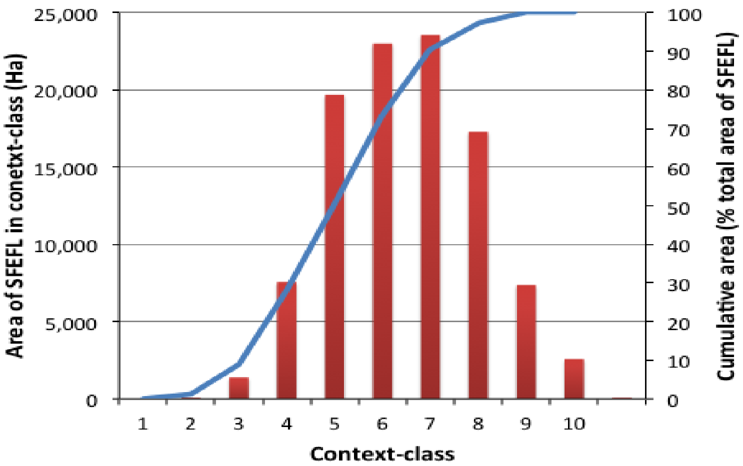


Figure 14. Total area (red columns) and cumulative percentage area (blue line) of each context-class (based on 1-km landscape scale analysis) within the SFEFL.

Surveying and sampling the three focal groups

Birds

Each of the 56 plots was visited on 16 occasions during the spring – early autumn period in 2009-10 and 2010-11 by the same observer (AH). The plots were surveyed using the method described in Hingston and Grove (2010). The 56 plots were visited according to a different sequence on each of the 16 survey cycles to ensure the observations across all of the plots had comparable seasonal distributions. Surveys were carried out between sunrise and sunset on days with fine weather and little wind (<Beaufort scale 3). Each plot was surveyed four times before 10:00 h, four times between 10:00 h and 13:00 h, four times between 13:00 h and 16:00 h, and four times after 16:00 h. No site was surveyed more than once per day. Five-minute point counts were done at each corner of each 50 x 50 metre plot, so that each sample-occasion comprised a twenty-minute period of observation (sight and/or sound). The identities of all birds seen or heard within 25 m horizontally of each point were recorded. Species nomenclature follows that of Christidis and Boles (2008), and habitat preference (generalist, open forests and woodlands, dense forest) based on descriptions in databases of Tasmanian Parks and Wildlife Service (www.parks.tas.gov.au/index.aspx?base=3049) or Birdlife Australia (www.birdlife.org.au/bird-profile). Each species observation made at a plot corner on a survey visit was restricted to a presence/absence record because of difficulty determining the numbers of individuals in dense undergrowth and tall trees. Hence, measures of abundance refer to the total number of species recorded from the four corners during each visit to the plot, treating the corners as non-independent subsamples. If a bird was flushed from within 25 m of a plot corner as the observer approached that point, the bird was included in the data-set and the 5-min survey commenced immediately. Species that were flying more than 20 m above the vegetation were excluded from analyses unless they were aerial feeders or raptors.

Beetles

A pilot study conducted at the commencement of the project (Forster, 2009) determined that triangular window intercept traps (TWITs) (Figure 15a) provided the optimum trapping technique for flighted saproxylic beetles in tall *E. obliqua* forest. A rain diverter was mounted above the collection bottle of each trap to minimise dilution of the ethanol preservative (Figure 15b). A TWIT was installed near each corner of each of the 56 plots (total 224 traps) in early summer 2009-10. The position of the TWIT near the plot corner was adjusted to provide as open a flight-line for flying insects as possible.

Figure 15. Transparent window intercept trap (a) with a water diverter installed above the collection bottle (b).

Once all traps were installed the collection bottles were charged with 100 ml of 95% ethanol and left to sample beetles passively for a three-month period (February – April 2010). The collection bottles were changed mid-way through the three-month sampling period and removed at the end of the sampling period. Upon changing or removal the collection bottles were topped-up with 95% ethanol, if required, before being stored in a cool room at 3°C until the captured beetle specimens were ready to be removed for identification and pinning (June-December 2011). The TWITs were run for a second three-month period during the summer (December – March) of 2010-2011.

A pitfall trap to sample ground-active beetles was installed near each corner of each plot in early summer (December) 2010 using the method described in Bashford *et al.* (2001). This involved coring a 15 cm deep hole into the soil using a 9 cm diameter auger and inserting a 15 cm length of 9 cm diameter PVC sewer pipe. A 425 ml plastic food container was suspended inside the PVC pipe and charged with 100 ml of propylene glycol as a preservative. A 12 cm diameter plastic food container lid was suspended approximately 3 cm above each trap using three wooden skewers to protect the traps from rainfall and disturbance by birds and mammals.

The pitfall traps were left to sample beetles for a three-month period (December 2010 – March 2011). Each trap was serviced mid-way through the collection period to transfer the collected samples into plastic bottles and recharge the containers with fresh preservative solution. The pitfall traps were removed at the end of the three-month collection period. Samples collected at the mid-point and end of the sample period were stored in a cool room at 3°C.

Only the samples taken from the four TWITs from each plot during the second six-week period of the first summer-autumn were processed. Processing involved removing, pinning and identifying all beetle taxa and adding their records (taxon x number of specimens separately by plot) to an in-house invertebrate biodiversity database. Identification was done to the species-level for all named taxa, while unnamed taxa were grouped into morphospecies. A taxonomic expert among the authors (LF) verified the identification of each taxon and morphospecies with reference to specimens held in the Tasmanian Forest Insect Collection (TFIC). Once the identity was verified, all specimens were archived in the TFIC.

The long time taken to process the large number of specimens (≈90,000) captured by the TWITs during the three-month sampling period in the first summer-autumn precluded processing of specimens captured in the TWITs and pitfall traps during the other sampling periods, but these have been retained for potential future analysis.

Vascular plants

In each of the 56 plots, all plants observed (JB) while traversing through and around the 50 x 50 m plot were used to compile a whole-plot plant census. Vascular plant nomenclature followed Buchanan (2009). Six 10 x 10 m subplots were selected from each of the 56 plots for detailed floristic assessment. The subplots were selected using a method of non-replacement random sampling subject to two conditions:

(i) since adjoining subplots share a high proportion of the same individual trees, subplots were excluded if they shared a 10 m boundary with a previously selected subplot;

(ii) to ensure that the vegetation sampling included some of the local area sampled for beetles and birds at the four plot corners, the final subplot sampling design was only accepted if at least two corner regions were sampled by at least one subplot (a corner region being defined as the 20 by 20 m corner of the 50 by 50 m plot).

Percentage foliage cover (PFC) was estimated using all six sub-plots at 14 of the plots; in five of the six sub-plots at 38 plots; and in four of the six sub-plots in four of the plots. A presence-absence species list was recorded in those sub-plots where PFC was not estimated.

Within each of the 56 plots, tree basal area was measured using the Bitterlich-stick method (Mueller-Dombois and Ellenberg 1974) from randomly-selected corners of four subplots within the plot and from the plot centre. These data were averaged to produce an estimate of the average basal area for the plot in m^2/ha.

Deriving independent variables

A total of 400 independent variables in eight broad groups was developed and screened for usefulness in potentially explaining variation in the focal groups (Table 4). Six of the groups measured attributes at the local scale of the plot and two groups measured landscapes attributes at a range of scales surrounding the plots. The scales used were 31.25 m, 62.5 m, 125 m, 250 m, 500 m, 1 km, 2 km, 4 km and 8 km radii.

Geographic and topographic variables

Ten geographic and topographic metrics were collated (Table 5). The easting and northing grid co-ordinates (GDA 94, MGA 86 zone 55) of the four corners (A, B, C, D) for each plot were measured by GPS, either hand-held (Garmin Etrex™) or Trimble GPS with an external antenna that was later differentially corrected (using Hobart as the base station). Approximately 60% of the corner co-ordinates were measured by differentially corrected GPS. Compass bearings between corners A-B and A-D were also measured using a Suunto compass. The co-ordinates of the four corner measurements for each plot, together with the A-B and A-D bearings, were imported into ARCGIS (version 9.3) and converted to polygons: the centroid of each polygon (= plot centre) was calculated using the “geographic field calculator” tool.

Table 4. List of variable groups showing the number of variables that were measured.

Variable group	Number of variables in group
1. Geography and topography (plot)	10
2. Climate (plot)	32
3. Geology and soils (plot)	13
4. Coarse woody debris (plot)	24
5. Floristic composition (plot)	10
6. Fire history (plot)	3
7. Roads and streams (landscape)	
• density in landscape	72
• distance to nearest	8
8. Vegetation groups (landscape)	
• proportion of area in landscape	180
• distance to nearest patch	20
• heterogeneity in landscape	28
Total	400

The remaining eight geographic variables were derived from a statewide 25 m digital elevation model (DEM) using ARCGIS. The altitude of the centre of each plot was extracted from the DEM using the ARCGIS “extract value” tool. Aspect of each plot was obtained using the “extract value tool” after calculating an aspect raster from the DEM. Two additional aspect metrics were derived from the calculated plot aspect: (i) degrees from true north (0-180°); and (i) westerly aspect = 270° ± 45° (0,1 value). Slope of each plot was obtained using the “extract value” tool after calculating a slope raster from the DEM. Similarly plan curvature and profile curvature of each plot were obtained using the extract value tool after calculating the plan and profile curvature rasters, respectively, from the DEM. Each plot was then classified as one of four topographic features: planar, ridge, channel, pit.

Table 5. List of ten measured variables in the geographic / topographic group.

1. Plot centre easting (metres east)	2. Plot centre northing (metres north)
3. Altitude (metres)	4. Aspect (degrees)
5. Aspect (degrees from true north)	6. Westerly aspect (270±45°)
7. Slope (degrees)	8. Plan curvature
9. Profile curvature	10. Topographic feature

Climatic variables

A suite of climatic variables for each plot was extracted in ARCGIS using the extract value tool from a statewide coverage (developed by the Landscape Logic project - http:/www.landscapelogic.com.au) of climatic variables predicted using the ESOCLIM$^{©}$ module of ANUCLIM$^{©}$ Version 5.2 (Houlder *et al.* 2000) from a 25 m digital elevation model. The full suite of 32 extracted climatic variables is listed in Table 6.

Table 6. List of 32 derived climatic variables in the climate variable group.

Temperature:
1. Average of mean weekly
2. Diurnal range (average of weekly diurnal ranges)
3. Temperature range (average max – annual min)
4. Isothermality (diurnal range / annual temperature range
5. Seasonality (coefficient of variation - mean temperatures)
6. Mean temperature of the wettest quarter
7. Mean temperature of the driest quarter
8. Mean maximum temperature of the warmest month
9. Mean minimum temperature of the coolest month

Rainfall
10. Total annual rainfall
11. Seasonality (coefficient of variation)
12. Total rainfall of the warmest quarter
13. Total rainfall of the coolest quarter
14. Total rainfall of the wettest month
15. Total rainfall of the driest month
16. Total rainfall of the warmest quarter
17. Total rainfall if the coolest quarter

Radiation
18. Mean annual radiation
19. Mean radiation of the highest month
20. Mean radiation in the lowest month
21. Mean radiation of the warmest quarter
22. Mean radiation of the coolest quarter
23. Mean radiation of the wettest quarter
24. Mean radiation of the driest quarter

Moisture
25. Mean annual moisture
26. Moisture seasonality (coefficient of variation)
27. Mean moisture of the driest month
28. Mean moisture of the wettest month
29. Mean moisture of the warmest quarter
30. Mean moisture of the coolest quarter
31. Mean moisture of the wettest quarter
32. Mean moisture of the driest quarter

Geological and soil variables

Four metrics describing the underlying geology and the soil type were generated (Table 7). The full geological description for each plot was extracted from the digital 1:250,000 geology map of Tasmania. The geological period and a simple descriptor of the underlying geology of each plot were derived from the full geological description. The soil at each plot was extracted from the digital 1:250,000 Land Systems map of Tasmania.

A further nine metrics describing the chemical properties of the surface soil at each plot were generated (Table 7). Soil samples were collected at each plot from each of four of the 10 x 10 m subplots in which plant cover estimates were made. At each of these subplots four non-purposefully located sites were sampled to 10 cm depth using a garden trowel after first removing the surface litter layer. The four soil samples from each sub-plot were bulked and initially placed in clean zip-lock plastic bags before transferring as soon as possible into paper bags for air-drying. Dried soils from each subplot were ground and sieved using a 2 mm sieve and tweezers to remove leaf litter, roots, rocks and seed, charcoal etc. Equal quantities of soil from each of the four subplots per plot were bulked together for analysis. A Palintest™ soil testing kit (www.palintest.com.au) was used to test for standard soil nutrients (aluminium, ammonia, calcium, copper, iron, magnesium, manganese and potassium), pH and conductivity. Nitrogen and phosphorus were also tested but the concentrations observed were below the detectable limits of the test procedure. Each test involved first making a soil solution in distilled water. The pH and conductivity were tested using an electronic pH and conductivity meter/probe (respectively). For soil nutrient testing, a filtered extract of the soil solution was made using the appropriate chemical extractant (magnesium acetate, potassium chloride, ammonium chloride or disodium EDTA). The required chemicals for colorimetric nutrient analysis were then added to a sample of the extract appropriately diluted, which resulted in the extract changing colour. A calibrated photometer unit was used to compare the colours of the pure extract with the test sample, providing an output displayed in terms of weight by volume of the test mineral.

Table 7. List of measured variables in the geological and soils group.

Geological	
1. Full geological description	2. Geological period of bedrock
3. Simple geological descriptor	4. Soil group
Soil chemical properties (0-10 cm)	
1. Aluminium (ppm)	2. Ammonium (ppm)
3. Calcium (ppm)	4. Copper (ppm)
5. Iron (ppm)	6. Magnesium (ppm)
7. Potassium (ppm)	8. pH
9. Conductivity	

Coarse woody debris variables

A slope-corrected, line-intersect transect along the perimeter of each 50 x 50 m plot was employed to measure coarse woody debris (CWD). Surveys restricted measurement to pieces of CWD ≥30 cm in diameter at the point of contact with the transect. Diameter of the CWD at the point of contact with the transect was measured with a diameter tape, employing either a circumferential measurement or the average of two diameter measurements (one at the widest point and the other perpendicular to that point). The decay stage of each piece of CWD was determined according to the classification of Grove *et al.* (2011). The tree species that generated the CWD was determined for each piece based on characteristics of stem and bark (when present) and with reference to extant trees present in the plot (e.g. to differentiate *E. obliqua* and *E. regnans*). Each piece of CWD was further categorised as one of stem, branch, stump or root.

The contribution to total volume per hectare (v) made by each piece of CWD was estimated using the formula developed by van Wagner (1968):

$$v = \frac{\pi^2}{8 \times L} \times d^2$$

where L is the horizontal transect length (after correcting for average slope of each side of the 50 x 50 m plot) and d is the diameter of the piece of CWD. Total CWD volume per hectare for each plot, and the volume of components of the CWD pool (decay class, diameter class in 30 cm intervals, species, and origin as stem or branch), were calculated by summation. A total of 24 metrics describing CWD were generated (Table 8).

Table 8. Summary list of variables used describe coarse woody debris.

Host species	Diameter class	Decay class
1. Proportion of total volume not from eucalypt species. 2. Origin (branch / stem)	Volume: 3. 30-60 cm 4. 61-90 cm 5. 91-120 cm 6. 121-150 cm 7. >150 cm 8. Small (≤90 cm) 9. Average diameter 10. Total volume Number of pieces: 11. 30-60 cm 12. 61-90 cm 13. 91-120 cm 14. 121-150 cm 15. >150 cm 16. Small (≤90 cm)	Volume: 17. I 18. II 19. III 20. IV 21. V 22. Recent addition (I+II) 23. Mid-aged (III) 24. Legacy (III+IV)

Variables describing floristic composition

Floristic surveys described previously were used to generate 10 metrics describing the vegetation. Species cover-abundance data obtained from the detailed sub-plot surveys, and augmented by presence-absence records (absence was assigned a cover of 0.01%) of other species within the sub-plots not sampled for detailed percentage cover estimates, were used for subsequent analyses using the multivariate statistical software package PC-ORD™ Ver. 5 (McCune and Mefford 2006).

A non-metric multidimensional scaling (NMS) ordination of the species cover-abundance data was carried out and the first three NMS axes, which in total explained 87% of variation in the dataset, were extracted. Mean plant species richness of each plot was calculated as the sum of the total number of species recorded in each sub-plot, divided by the number of sub-plots sampled. A cluster analysis set to default options in PC-ORD (Euclidean distance and Wards Method as the group linkage method) was used to classify the plots into plant communities. Four discrete plant communities resulted - termed thamnic, callidendrous, *Pomaderris* and *Monotoca* based on the species composition of the dominant understorey species.

Shannon's diversity index (H') was calculated using the formula:

$$H' = -\sum_{i}^{S} p_i \log p_i$$

where, p_i is the relative abundance of each species calculated as the abundance of a given species as a proportion of the sum of all species abundances within the plot. Only sub-plots scored for percentage foliar cover were used to calculate abundance. Species that were only recorded in the presence-absence sub-plots were added to the dataset after being given a mean cover estimate of 0.01%.

The Sørensen distance measure (also known as the Bray-Curtis dissimilarity measure) was calculated to provide a measure of the dissimilarities within and between plots. Samples were standardised to equal sample totals by expressing the cover of a species as a proportion of the total cover of all species in a plot.

Two metrics were generated recording the percentage cover of litter and of logs in the sampled sub-plots (same sub-plots used to measure cover-abundance) in each of the 56 plots.

Variables describing fire and logging history

Three variables describing fire and logging history of each plot were generated:

(i) time since last fire (or logging) as of 2010;

(ii) estimated time since last fire as of 1947;

(iii)estimated minimum number of fires since 1850.

Time since last fire (or logging) was estimated by overlaying FC2005 PI-type mapping with Forestry Tasmania's digital layer of the mapped extent of wildfires. The estimated time since last fire as of 1947 was estimated on the basis of the PI-type mapping from 1947 photography and supported by the digital wildfire extent layer. The minimum number of wildfires since 1850 was estimated from the series of PI-type maps generated from aerial photography from 1947.

Road and stream variables

Statewide digital map layers of roads and drainage (sourced from the most recent DPIPWE coverages) provided the basis for calculating a suite of metrics describing the density of roads and streams in various scales of landscapes around each plot and as the distance from each plot to the nearest road and stream. Road and drainage (stream-class) classifications were as defined in Tasmania's Forest Practices Code (Forest Practices Authority 2003). Five road classes and four stream classes were recognised (Table 9).

Table 9. Summary of stream and road classifications as defined in the Tasmanian Forest Practices Code (Forest Practices Authority 2000). NB. Class 3 and 4 roads are not differentiated on Forestry Tasmania's road-class database.

Class	Rivers and streams	Roads
1	Rivers, lakes, artificial storages (other than farm dams) and tidal waters	All weather primary road in large network carrying in excess of 2500 tonnes/week
2	Creeks and streams draining catchments > 100 ha	All weather significant feeder road carrying between 1000-2500 tonnes/week
3	Water courses (mostly flowing year-round) draining catchments between 50-100 ha	All weather minor (spur) road carrying 1000 tonnes/week
4	All other watercourses carrying water for part of the year	Minor (spur road) carrying up to 1000 tonnes / week
5		Temporary track for dry weather cartage

Density metrics were generated using ARCGIS to measure the total length of stream and of road of the specified class-range within circular areas of nine different radii ranging from 31.25 m to 8 km centred on each plot and expressed as metres of stream / road per hectare. Distance from each plot to nearest stream / road of a specified class was calculated using the "near analysis" tool in ARCGIS. A total of 72 stream / road density metrics and eight distance to nearest stream /road metrics were generated (Table 10).

Table 10. Summary of the number of density and "distance to nearest" metrics generated for streams and roads. [1] Stream / road classes aggregated as follows: class 1; classes 1 and 2, classes 1-3 (streams only), classes 1-4, classes 1-5 (roads only).

	Density	Distance to nearest
Streams	36 (9 landscape scales x 4[1] stream classes)	4 stream classes
Roads	36 (9 landscape scales x 4[1] road classes)	4 road classes

Vegetation-group variables

The area of each of the nine broad vegetation-groups (described previously) as a proportion of total area in the surrounding landscapes (31.25 m – 8 km) was calculated for each of the 56 plots. This group of variables was termed "vegetation proportion". ARCGIS was used to sum the area of all mapped patches of the nine vegetation-groups within radii of 31.25 m, 62.5 m, 125 m, 250 m, 500 m, 1 km, 2 km, 4 km and 8 km around each of the plots. In addition, area summations were made for:

(i) four different combinations of subsets of the nine vegetation-groups;

(ii) the area of the mature vegetation-groups that were within CAR reserves (by overlaying the June 2010 version of DPIPWE's Reserve Layer); and

(iii) the area of mature eucalypt forest excluding 50 m perimeter buffers (all edges with differing vegetation-groups and only hard edges).

A total of 180 metrics was generated based on the proportional abundance of 20 different combinations of the vegetation-groups at each of nine landscape scales (Table 11).

Table 11. List of 20 variables derived from vegetation groups used to generate "proportion of area in the surrounding landscape" and "distance to nearest" metrics.

Broad vegetation groups		
1. Agricultural and native non-forest	2. Agricultural and plantation	3. Plantation
4. Silvicultural - young	5. Silvicultural -old	6. Other native forest
7. Wildfire regrowth eucalypt	8. Mature eucalypt	9. Rainforest
Mature in CAR reserves		
10. Mature in CAR Reserve (excluding plot)	11. Mature in CAR Reserve (including plot)	12. Mature + rainforest in CAR Reserve
13. Mature + rainforest + wildfire regrowth in CAR Reserve		
Mature combinations		
14. Mature (including plot)	15. Mature (excluding plot)	16. Couped-up mature
17. Mature + rainforest	18. Mature + rainforest + wildfire regrowth	
Non-dissected mature		
19. Core mature (50 m edge buffer)	20. Mature not separated by a stream, road or hard vegetation edge	

Metrics measuring the distance from each plot to the nearest patch of a particular vegetation-group were generated using the "near analysis" tool in ARCGIS. Distances were measured for the same 20 combinations of vegetation-group shown in Table 12. This group of variables was termed "vegetation distance".

Measures of heterogeneity in the vegetation-groups in the landscape at seven radii (125 m – 8 km) surrounding each of the 56 plots were calculated. This was done by creating separate matrices of vegetation-group x proportional abundance for each of the seven spatial scales and using the row and column summary tool in PC-ORD (Version 5) to calculate four diversity parameters:

S = Richness of vegetation-groups (number of non-zero vegetation-groups) around the plot;
E = Evenness of non-zero vegetation-groups around the plot = H/ln(S);
H =Diversity of vegetation-groups around the plot (Shannon index of information content);
D = Simpson's index of vegetation diversity around the plot.

This process generated 28 metrics grouped under the term “vegetation heterogeneity”.

Data analysis

Testing for potentially confounding gradients

The analysis was carried out in two stages. In the first stage the aim was to identify which of the independent metrics had significant parallel gradients or significant contrasts with the gradient of disturbance-intensity.

Principal components analysis was used to attempt to reduce the number of independent variables tested. The analysis was confined to the plot-level variables, which were aggregated into their respective variable groups as outlined in the methods used to derive those variables. Analysis of variance (ANOVA) was used to test the significance of differences in each of the independent variables between MAT and SILV plots and among the three landscape context-classes sampled by both MAT and SILV plots. Where there was heterogeneity in the residuals the Kruskal-Wallis ANOVA of ranks was used. Least significant difference range tests were used, *post-hoc*, to detect significant differences among group means. In cases where the Kruskal-Wallis test was used, differences in medians among groups were determined by examining box-and-whisker plots with median notches.

In the second stage, the aim was to identify which of the independent metrics had a significant relationship with the abundance of species from within the three focal groups (individually and aggregated to the focal group level). Those variables that showed significant relationships with species abundance AND had parallel gradients or significant contrasts with the disturbance-intensity gradient were those most likely to need to be controlled to detect species responses to the disturbance gradient.

The *Random Forests* routine within the R-environment was used to conduct an unsupervised screening of the independent variables (including additional variables generated from principal components analyses) to detect a subset of variables that were most useful in predicting species response in each focal group.

Random Forests models predicting species abundance (at the individual species level and at the focal-group level) were generated separately for MAT and SILV plots. For each dependent variable tested, 2000 trees were generated (*ntree* = 2000). The graphical output plotting the change in model power (pseudo-R^2) with the successive removal of independent variables was examined for each species. For all models yielding a maximum pseudo-R^2 of 40% or more, the independent variables chosen in the final model (in order of importance) were collated. The collated list of independent variables was then tabulated after grouping each of the variables into one of 11 broad categories (detailed in Appendix 2). Further grouping by landscape scale (62.5 m – 8 km) was carried out for the subset of collated independent variables that measured attributes of the surrounding 62.5 m – 8 km landscapes.

Testing the response of focal groups

The aims here were to: (i) measure the magnitude of changes in the abundance, species-richness and assemblage composition of the focal groups in response to harvesting; and (ii) measure changes in the abundance, species-richness and assemblage composition of the three focal groups in relation to the gradient of disturbance-intensity (within and between forest types).

Analysis was carried out at two levels for each of the three focal groups - the focal-group level and the individual species level. At the focal-group level, four univariate response variables were used: total abundance (total number of observations or specimens); total number of species (species-richness); total number of rare species; and number of rare species as a proportion of the total number of species. An additional six groups were created for birds by aggregating the avifauna into three habitat groups – open-forest specialists, generalist and dense-forest specialists (as detailed earlier in the methods) – and generating abundance and species-richness variables. A matrix of species x abundance in each of the 56 plots was also constructed for each of the three focal groups for multivariate analyses, to test the effects of forest type and context-class on assemblage composition. Species-level analysis was based on univariate response variables recording the abundance of each species in each plot, and was restricted to the common species – those that occurred on seven or more of the 56 plots. A total of 28, 254 and 52 univariate response variables of species abundance were generated for birds, beetles and vascular plants respectively.

Total abundance (bird observations, beetle specimens, percentage plant cover) and species-richness of each focal group were computed for each of the 56 plots by summation from the raw survey data. Additional variables were constructed to measure the richness of rare species (number of rare species; and rare species as a proportion of the total number of species): a species was designated as rare if it occurred on fewer than seven of the 56 plots.

The program PC-ORD© (McCune and Mefford 2006) was used for multivariate analyses, including non-metric multidimensional scaling (NMS), non-parametric multivariate analysis of variance and indicator species analysis. For multivariate ANOVA, the *Permanova* routine (Anderson 2001) was used to conduct a two-way factorial analysis (forest type as Factor 1; context-class as Factor 2) of non-transformed data using the Bray–Curtis distance measure and 4,999 randomisations. For indicator species analysis, the *IndVal* routine (Dufrệne and Legendre 1997) was implemented, using non-transformed data. Linear least squares regressions were used to examine the relationships between the NMS axis scores for each of the three focal groups with independent variables identified as having significant relationships with species abundance and the disturbance gradient.

Analysis of covariance, using the Multifactor ANOVA procedure in *Statgraphics*© (Statistical Graphics Corporation, 1996) was used to test differences in each of the univariate response variables at the focal-group level. Four factors were used: forest type (MAT versus SILV); context-class (overall); context-class within MAT; and context-class within SILV. The ANOVAs of forest type and context-class (overall) were restricted to the three context-classes (4-6) shared by the MAT and SILV plots. The ANOVAs of context-class within a forest type used all four context-classes spanned by each of MAT and SILV. ANOVAs were first attempted using untransformed data. Where necessary, log-transformation or rank-transformation was used to stabilise variances. Independent variables identified in the initial screening as having significant relationships with the abundance of individual species or the disturbance gradient were tested for significance as covariates in ANCOVA models.

Detecting the spatial scales of responses to the proportion of forest types

The open-source program Focus© (Holland *et al.* 2004) was used to calculate correlations for the linear regressions of abundance / species-richness measures with four attributes of the surrounding landscape (proportion of mature eucalypt forest, proportion of older silvicultural regeneration, density of all roads, vegetation-group heterogeneity [Simpson's Index]) at landscape scales of between 31.25 m – 8 km radius. This program repeatedly subsamples from the 28 plots in MAT and 28 in SILV to create unique combinations of plots that are all spatially independent (i.e. there is no overlap of the landscape surrounding each plot). This was necessary because, as the scale of the landscape widened, an increasing number of plots had sections of their landscape overlapping those of other plots, leading to pseudo-replication. For each abundance / species-richness measure tested, Focus attempted to generate 50 regressions with the amount of mature forest in the surrounding landscape at the specified spatial scale. Each regression represented a unique subset of up to 18 spatially independent plots sub-sampled from the 28 plots available in each of MAT and SILV. For landscape scales larger than 1 km, increasingly fewer plots satisfying the criterion of spatial independence were available to subsample. There were too few spatially independent plots available at the 8 km scale to calculate meaningful relationships between abundance / species-richness and proportion of forest types in that landscape. At the 2 and 4 km scales, the number of spatially independent plots available to subsample restricted the number of plots used to calculate regressions to 9-13 and 5-6, respectively.

Spatial analyses were conducted using four landscape-scaled explanatory variables: density of roads (all classes); heterogeneity of vegetation-groups (Simpson's Index); proportion of older silvicultural regeneration; and proportion of mature forest. Two sets of analyses were conducted for each focal group: (i) comparison of the scales of responses in richness and abundance; and (ii) a taxonomic hierarchical analysis comparing the scales of responses when focal groups were aggregated at the focal-group, habitat and species (within habitat group) levels. Species chosen for the hierarchical analysis were those that produced Random Forests models with good explanatory power (pseudo-$R^2 \geq 40\%$) and included landscape variables in their models.

Testing for threshold levels in the amount of mature eucalypt forest in the surrounding landscape

The aim was to detect threshold amounts of, or proximity to, mature eucalypt forest below which the abundance or species-richness of elements within the three focal groups in silvicultural regeneration suddenly changed. This was carried out in two stages. First, regressions of abundance and species-richness with the independent variables (amount of mature eucalypt forest in the surrounding 62.5 – 4 km landscape; distance to nearest patch of mature eucalypt forest / rainforest) were done using the SIMPLE REGRESSION procedure within Statgraphics© (Statistical Graphics Corporation 1996). The *Comparison of Alternative Models* option was used to select the form of model that gave the highest R^2 value.

Those combinations of the abundance / species-richness with the independent variables that were statistically significant, and distinctly non-linear, proceeded to the second stage of analysis. This was done using the COMPARISON OF REGRESSION LINES procedure within Statgraphics©. This procedure constructs a broken-stick with separate linear segments above and below a user-specified break-point (of the independent variable). For each combination of dependent and independent variables a range of broken-stick models was generated by specifying break-points spanning the range of the independent variable.

Variance-ratio tests of the residual mean square from the broken-stick and linear models were carried out to determine if a broken-stick model was significantly better in describing the data than the corresponding linear model (as described in Parkes *et al.* 2002). The calculated variance ratios were compared against the F-distribution to determine their statistical significance. The variance-ratio approach identifies the putative break-point of the component segments of the broken-stick model as the value that minimises the residual mean square of the model. A second approach to identify the optimum break-point was also taken by comparing the significance of the difference (as T-values) in the slopes of the two linear segments of the broken-stick model across the observed range of break-points.

Results

Gradients within the Southern Forests Experimental Forest Landscape

The experimental aim of the context-class stratification of the SFEFL was to capture a gradient of disturbance-intensity that was minimally confounded by other gradients. Detailed results of tests to detect differences among context-classes in the 400 metrics are presented in Appendix 2.

Differences among context-classes were dominated by variables describing anthropogenic and natural disturbance (Table 12). However, there were significant differences in other groups suggesting context-class occasionally captured gradients other than disturbance-intensity. The geographic group had two variables that differed significantly among context-classes - the east-west position (easting) of plots; and slope. East-west position differed significantly among context-classes overall ($F_{2,39}$=6.8; P=0.003; 4>5, 6), among context-classes within MAT ($F_{3,24}$=3.04; P<0.048; 4>6, 7) and among context-classes within SILV ($F_{3,24}$=16.5; P<0.001; 3, 4>5, 6). Thus the more intensively disturbed parts of the landscape (context-classes 3 and 4) occupy significantly more easterly positions than plots in the less disturbed parts of the landscape (context-classes 5-7). Slope differed significantly among context-classes ($F_{4,51}$=2.58; P=0.048; 3, 4 < 7 and 3<5), but only when plot type was ignored. The difference reflects a trend for slopes to be greater in plots located in progressively less disturbed landscapes.

The climate group had a high proportion of variables that differed significantly among context-classes (Table 12). Because of high correlations among many of the climate variables principal components analysis was able to describe 95.6% of variation in the 32 variables in the first three principal component axes (Table 13). Only axis 1 differed significantly among context-classes although differences among context-classes in axis 3 values almost reached statistical significance. Plots in the most intensively disturbed parts of the landscape (context-class 4) have higher summer radiation, lower summer moisture and higher moisture seasonality than plots in the less disturbed parts of the landscape (context-classes 5 and 6). The differences among context-classes in axis 1 values remained after accounting for the co-variance of geographic position (east-west and north-south) and altitude of the plots.

Table 12. Number and proportion of metrics within nine variable groups that differed significantly among context-classes.

Variable group	Metrics tested	Metrics differing significantly among context-classes	Proportion of metrics differing significantly among context-classes (%)
Geographic / topographic			
Geography and topography	10	2	20
Climate	32	23	72
Streams			
- Density in landscape	45	8	18
- Distance to nearest	5	0	0
Total for geographic / topographic	92	33	36
Natural processes			
Geology and soils	13	2	15
Floristic composition	10	0	0
Coarse woody debris	23	10	43
Total for natural processes	48	12	26
Anthropogenic / natural disturbance			
Fire history	3	2	67
Roads			
- Density in landscape	36	13	36
- Distance to nearest	4	0	0
Vegetation-groups			
- Proportion of area in landscape	189	107	57
- Distance to nearest patch	21	18	86
- Heterogeneity in landscape	28	15	54
Total for anthropogenic / natural disturbances	281	154	55

Table 13. Summary of analysis of variance testing for differences among context-classes in the three principal component axes describing climate variables. Proportion of the variation explained by each axis is shown in parentheses. A description of how the climatic attributes described by the axes vary in response to increasing axis values is given in italicised text.

Principal component axis	Differences among context-classes
Axis 1 (69%): *decreasing radiation / increasing moisture during the warmer periods; decreasing moisture seasonality*	$F_{2,39}$=3.82; P=0.031 4 < 5, 6
Axis 2 (22%): *increasing temperatures*	$F_{2,39}$=2.44; P=0.10
Axis 3 (4.6%): *increasing winter temperatures and decreasing temperature seasonality and diurnal range.*	Kruskal-Wallis=4.96; P=0.056 4 < 6

The density of streams (reflected in all stream classes) at landscape scales ≥ 2 km was significantly higher (16-25%) for plots in the more intensively disturbed parts of the SFEFL (represented by context-classes 3-4) than plots in the less intensively disturbed parts of the SFEFL (context-classes 5-7).

Only two variables in the geology and soils group differed significantly among context-classes. Soils in the lower context-classes (3-4) had lower aluminium content (reflecting higher soil fertility) that the higher context-classes (5-7). Chromosol (texture-contrast) soils occurred significantly more frequently in the more intensively disturbed part of SFEFL whereas ferrosols (gradational) soils occurred more frequently in the higher context-classes. This division of soils types is consistent with the gradient of increasing rainfall with increasing context-class (http://www. soil.org.au/soil_types.htm accessed 11/6/12).

Coarse woody debris showed consistent patterns separating the more intensively disturbed parts of the SFEFL (context-class 3-4) from the less disturbed (context-classes 5-7). Plots in the more intensively disturbed parts of the SFEFL had lower volumes and fewer pieces of large diameter CWD; lower average CWD diameter; lower volumes of decay-class 3 CWD; and lower volumes of "new additions" CWD than plots in the less disturbed parts of the SFEFL. These differences in CWD were strongly associated with past fire history: a disproportionate number of SILV plots in the more intensively disturbed parts of the landscape (context-classes 3-4) had experienced two fires since 1850, whereas a disproportionate number of SILV plots in less disturbed parts (context-classes 5-7) had experienced one fire. In MAT plots the association between CWD and past fire history was ambiguous.

The anthropogenic / natural disturbance variables showed a consistent pattern - variables linked to anthropogenic disturbance showed the opposite gradient with context-class to variables linked with natural disturbance. Context-class depicted a clear gradient when the variables representing proportion of vegetation-groups in the surrounding landscape were aggregated into those associated with anthropogenic disturbance and those associated with natural disturbance (Figure 16). Road density only showed significant differences among context-classes at relatively wide spatial scales (≥ 2 km), whereas variables measuring the proportion of a vegetation-group in the surrounding landscape tended to differ among context-classes across broad landscape scales (31.25 m – 8 km).

There was also a time-since-disturbance gradient embedded within the gradient of disturbance-intensity described by context-class. Plots in less disturbed parts of the landscape (context-classes 5-7 in 2010) had uniformly high context scores based on forest type mapping derived from 1947 aerial photography (Figure 17): forestry had yet to move into those parts of the SFEFL that contained plots in context-classes 5-7. By contrast, plots in the more intensively managed parts of the landscape (context-classes 3 and 4) had already shown significantly ($F_{4,51} = 4.46$; mse = 1.066; $P = 0.0036$) lower context-scores in 1947. This presumably reflects disturbance resulting from past wildfires and forestry operations along tramways in eastern parts of the SFEFL during the first half of the 20th century, although it may also be that forest in this part of the SFEFL had historically low levels of maturity anyway for other reasons. The differences shown in Figure 17 for context-scores in the 1 km landscape around plots were also reflected in the 500 m and 2 km landscapes around plots (results not shown).

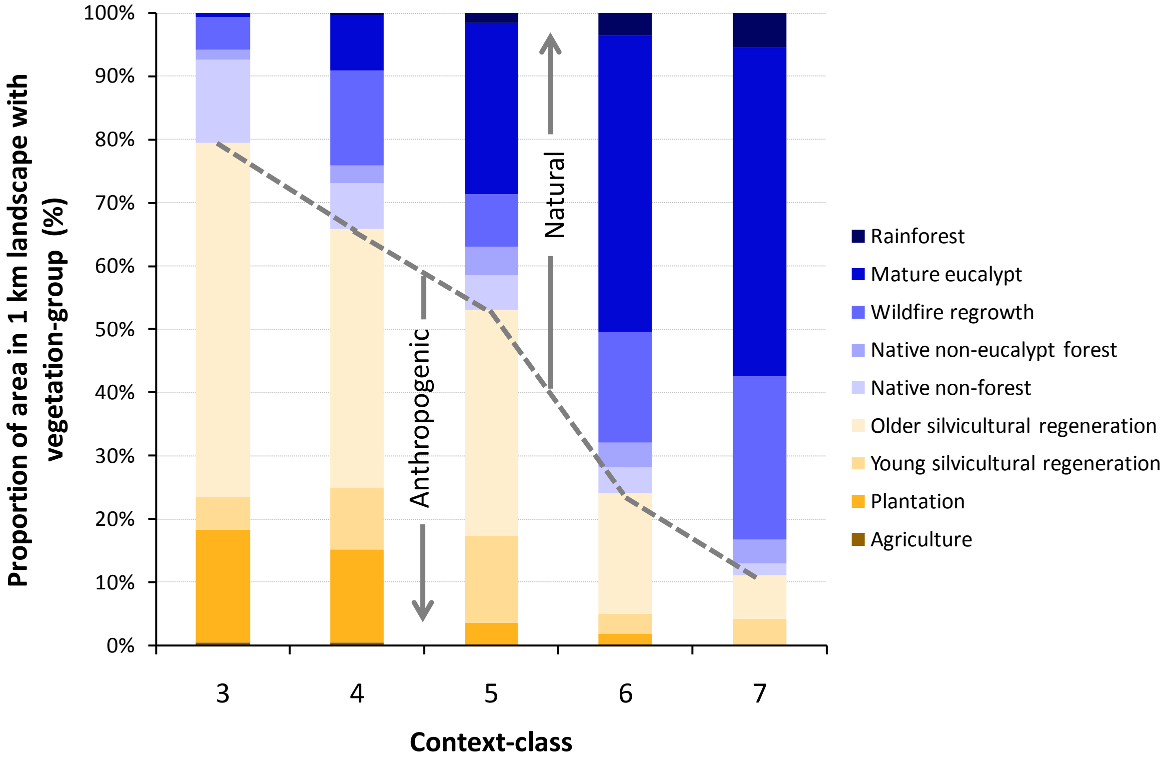


Figure 16. Average proportion of 1 km radius landscapes around plots, partitioned by context-class, that are occupied by each of nine vegetation-groups. The vegetation-groups have been aggregated into those originating from anthropogenic disturbance and those originating from natural disturbance regimes.

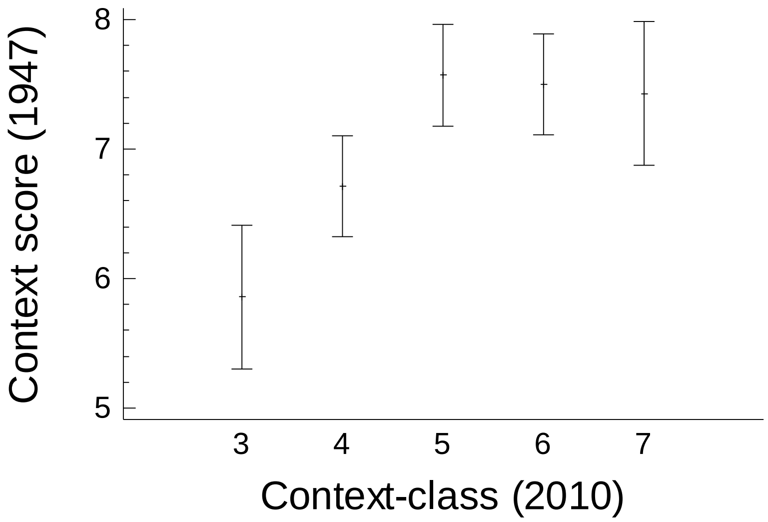


Figure 17. Change in context scores of 1 km landscape surrounding MAT and SILV plots between 1947 and 2010. Context scores (1947) are based on photo-interpreted forest-type mapping from 1947 aerial photography. Context-class (2010) is based on 2005 forest class mapping from 2000s aerial photography.

Species-level responses to variables describing local- and landscape-level attributes

The previous section established that the experimental layout did capture some gradients other than disturbance-intensity. The aim here was to see which independent variables were influencing the abundance of species within the three focal groups. In particular, we wanted to identify those that also differed significantly along the gradient of disturbance-intensity.

All three focal groups.

Random Forests models exceeding the pseudo-R^2 benchmark of 40% arose for a much higher proportion of the common beetle and plant species than for birds. This pattern occurred in both MAT and SILV plots. While only a small number of species-level models for birds exceeded the 40% benchmark, a high proportion of the group-level variables for all three focal groups yielded models exceeding the 40% benchmark (Table 14).

Table 14. Number Random Forests models with pseudo-R^2 values of ≥40% in the three focal groups. Values in parentheses are number of species yielding models with pseudo-$R^2 \geq 40\%$ as a percentage of all common species in the focal group.

	Birds	Beetles	Vascular plants
Plots in MAT			
Group-level	2	1	1
Species-level	2 (7)	60 (23.5)	13 (25)
Plots in SILV			
Group-level	4	0	1
Species-level	2 (7)	33 (12.9)	19 (36.5)

Birds.

In models predicting the abundance of bird species, variables describing the density of roads in the surrounding landscape and the proportion of vegetation-groups in the surrounding landscape (vegetation proportion) appeared most commonly, in both MAT and SILV models (Figure 18). In SILV, models predicting the abundance and richness of birds were dominated by landscape-level attributes. In MAT, plot-level attributes were also important predictors.

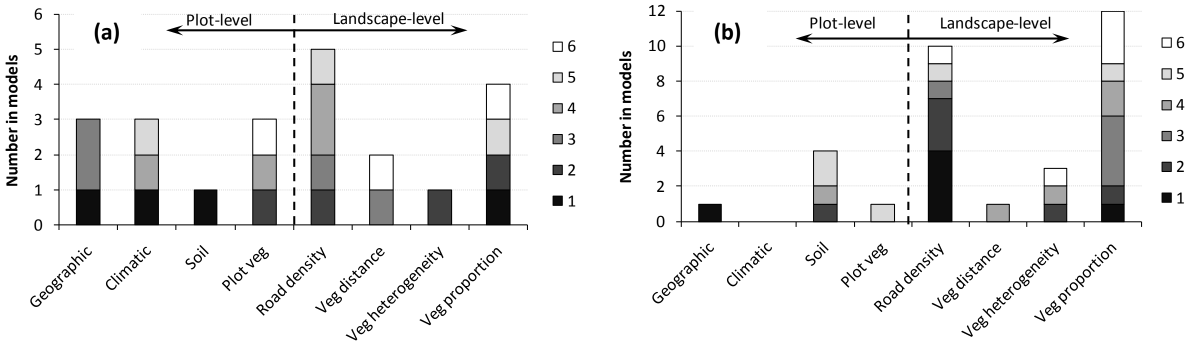


Figure 18. Number of independent variables (aggregated into variable groups) in each of six ranked importance-groupings based on the order of their inclusion in Random Forests models predicting the abundance and richness of birds in plots of (a) mature eucalypt forest and of (b) older silvicultural regeneration. Variable groups describing plot-level attributes and those describing landscape-level attributes are indicated.

The most common independent variable from the road density group in models of species abundance was the density of roads (all classes) in the surrounding landscape, which acted either positively or negatively in equal measure (Table 15). The most common independent variable from the vegetation proportion group was the proportion of SILV in the surrounding landscape (Table 14). In most models, species abundance showed a negative relationship with the proportion of SILV in the surrounding landscape. Altitude and temperature, which are strongly correlated (r=-0.80, P<0.001), were the geographic / climatic variables most often included in models and acted positively or negatively on bird abundance in equal measure.

Table 15. Independent variables, listed by variable group, that appeared most commonly in models predicting the abundance of birds, either as a negative or positive factor.

Variable group	Proportion of group (%)	Relationship with abundance	
		Negative	Positive
Road density			
Density of roads - all classes	47	3	4
Proportion of vegetation-groups			
Proportion of SILV in surrounding landscape	56	7	2
Geographic			
Altitude	100	1	2
Climatic			
Temperature	67	1	1

Beetles.

Landscape-level attributes dominated models predicting the abundance of beetle species in SILV, while plot-level attributes were relatively more common in species abundance models in MAT (Figure 19). Variables describing the proportion of vegetation-groups and the density of roads were the dominant landscape-level groups, while CWD and vegetation-type ("plot veg") were the dominant plot-level groups.

The most common independent variable from the vegetation proportion group in models of species abundance was the proportion of MAT in the surrounding landscape, primarily as a positive correlate (Table 16). The proportion of SILV in the surrounding landscape was also common in models, usually as a negative correlate with species abundance. The two road density variables that included smaller roads (class 3 or smaller) appeared in beetle abundance models with similar frequency (Table 16). Species abundance showed both positive and negative trends with road density, with neither dominating.

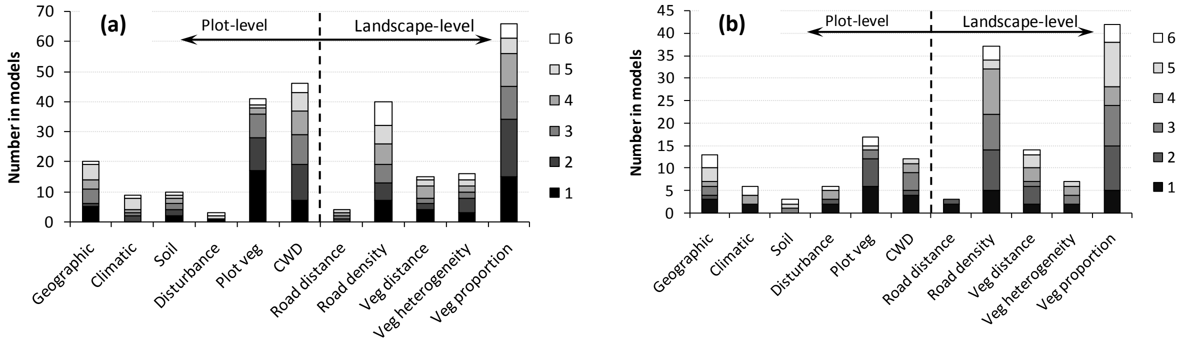


Figure 19. Number of independent variables (aggregated into variable groups) in each of six importance groupings based on the order of their inclusion in Random Forest models predicting the abundance of beetles in plots of (a) mature eucalypt forest and of (b) older silvicultural regeneration. Variable groups describing plot-level attributes and those describing landscape-level attributes are indicated.

Table 16. Most common independent variables in each of the three variable groups that appeared most frequently in Random Forests models predicting the abundance of beetles. The number of occasions the independent variable had negative or positive relationships with beetle abundance are shown.

Variable group	Proportion of variable group in models (%)	Relationship with abundance	
		Negative	Positive
Proportion of vegetation-groups			
Proportion of mature eucalypt forest	57	20	42
Proportion of older silvicultural regeneration	20	19	3
Road density			
Density class 1-3 roads	44	12	22
Density all road classes	35	16	11
CWD			
Mean CWD diameter	10	1	5
Number of pieces 90-120 cm diameter	10	1	5
Plot vegetation			
Vegetation NMS – Axis 3	33	7	12
Vegetation NMS – Axis 2	17	6	4

A large number of CWD variables appeared in models, but with no one variable from the group clearly dominating. Mean CWD diameter and the number of CWD pieces in the 90-120 cm range appeared most frequently in models, but together only represented 20% of the CWD variables appearing in models (Table 16). Species abundances primarily showed positive trends with these two CWD variables, and with the other CWD variables more generally. Plot-level vegetation variables appearing commonly in models were dominated by two of the NMS axes measuring species assemblage composition. Axis 2 describes the continuum in sclerophyllous understorey from fertile (negative) to infertile (positive) soils, with beetle abundance trending positively and negatively with NMS axis 2 in roughly equal measure. Axis 3 describes the continuum in species dominance from sclerophyllous elements (negative) to rainforest elements (positive). Beetle abundance most commonly showed positive relationships with NMS axis 3 (Table 17).

Vascular plants.

Landscape-level attributes, particularly the proportion of vegetation-groups in the surrounding landscape, contributed most of the variables to models predicting the cover-abundance of vascular plant species (Figure 20). Plot-level attributes appeared more commonly in species abundance models for SILV than for MAT.

The most common independent variable from the vegetation proportion group in models of species abundance was the proportion of MAT in the surrounding landscape, with an equal mix of positive and negative relationships with abundance (Table 17). Time since last fire was the most common variable from the disturbance group selected in models. Species abundance showed a positive relationship with time since last fire in all models (Table 17). The aluminium content of the topsoil was the most common variable from the soils group, showing positive and negative relationships with plant species abundance in equal measure.

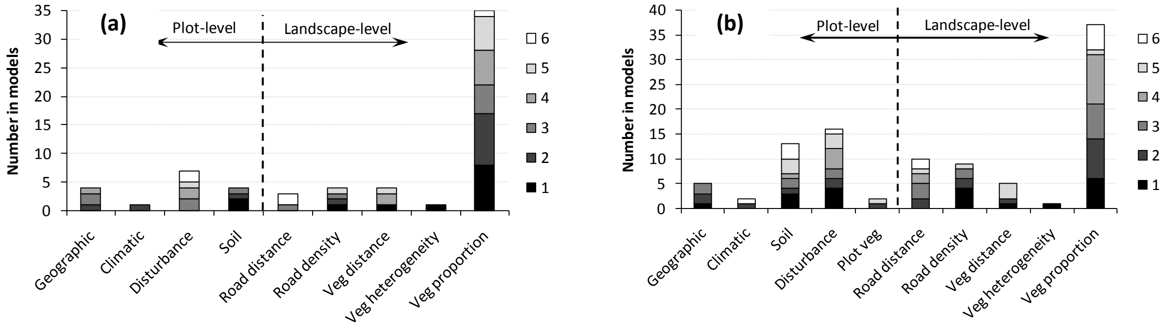


Figure 20. Number of independent variables (aggregated into variable groups) in each of six ranked importance-groupings based on the order of their inclusion in Random Forests models predicting the abundance of vascular plants in plots of mature eucalypt forest (MAT) and of older silvicultural regeneration (SILV). Variable groups describing plot-level attributes and those describing landscape-level attributes are indicated.

Table 17. Most common independent variables in each of the three variable groups that appeared most frequently in Random Forests models predicting the abundance of vascular plants. The number of occasions the independent variable had negative or positive relationships with plant cover-abundance are shown.

Variable group	Proportion of variable group (%)	Relationship with abundance	
		Negative	Positive
Proportion of vegetation-groups			
Proportion of mature eucalypt forest	66	12	11
Disturbance			
Years since fire	35	0	8
Soils			
Aluminium	50	1	1

Focal-group responses to forest type

Birds.

Birds were the least diverse of the three groups surveyed in the SFEFL, with only 44 species recorded, of which 28 were common species recorded on seven or more plots. Of the 44 species, 36 (82%) were found in both MAT and SILV plots, six (13.5%) were found only in MAT plots and two (4.5%) were found only in SILV plots (Figure 21). Thus birds were more diverse in the MAT plots than in the SILV plots. This was reflected in significant differences in bird species richness between MAT and SILV plots being detected overall, and in each of the three habitat groups (Table 18). The differences were strongest for species favouring dense-forest habitats. A total of 3,133 bird observations were made: 1,989 (63.5%) were from MAT plots and 1,144 (36.5%) were from SILV plots. This difference in abundance between MAT and SILV plots was statistically significant and was reflected in all three habitat-based groupings of birds, but most strongly in species classified as habitat generalists (Table 18). Common species provided 98.2% of the total observations made.

Species assemblages differed significantly between MAT and SILV plots (Table 18) with a clear separation between plots of the two groups in the scatterplot of axis 1 and 2 of the NMS ordination (Figure 22). The dense-forest birds formed a tight cluster, for all but two species (lyrebird and strong-billed honeyeater) in the species ordination (Figure 23). Indicator species analysis provided further evidence of MAT plots having a richer and more abundant avifauna than SILV plots with 14 species affiliated with MAT plots, while none were affiliated with SILV plots.

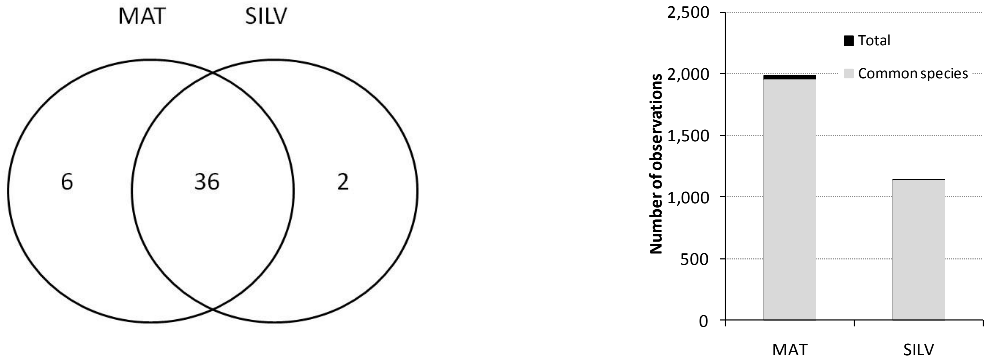


Figure 21. Venn diagram showing the number of bird species in MAT and SILV plots. Bar charts show bird observations in total, and of "common species" (present in 7 or more plots), in MAT and SILV plots.

Table 18. Significance of differences between plot types (MAT versus SILV) in abundance, richness and assemblage composition for birds. Analyses were restricted to the three context-classes (4-6) that overlapped for MAT and SILV plots. [1.] Habitat group classification (Appendix 4) – analysis restricted to common species only.

Measure	All birds	Open-forest species	Generalist species	Dense-forest species
Species-richness	$F_{1,41}$=22.1; P<0.001; M > S	$F_{1,41}$=8.25; P<0.01; M>S	$F_{1,41}$=9.30; P<0.01; M>S	$F_{1,41}$=17.8; P<0.001; M>S
Abundance	$F_{1,41}$=46.9, P<0.001; M > S	$F_{1,41}$ = 7.7; P<0.01; M>S	$F_{1,41}$=20.1; P<0.001, M>S	$F_{1,41}$ = 11.5; P<0.01; M>S
Assemblage composition	PERMANOVA: $F_{1,41}$ = 8.05, P=0.0002			
Indicator species	MAT=14 spp SILV=0 spp			

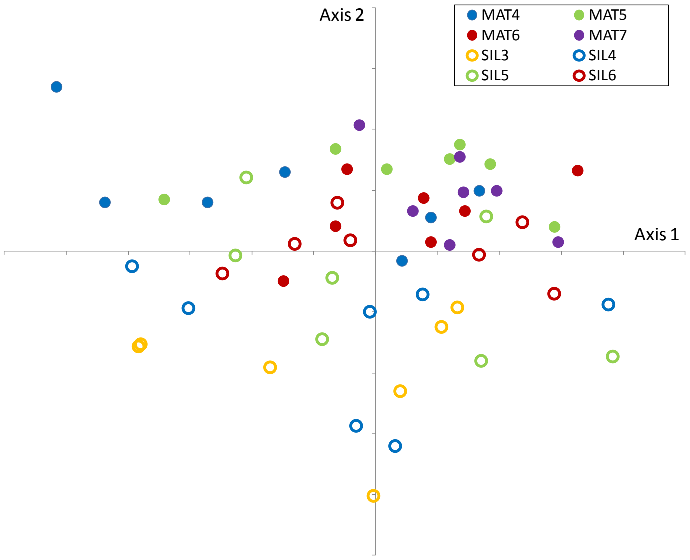


Figure 22. Scatterplot of axis 1 and 2 NMS ordination scores of bird assemblage composition in the 56 plots with points colour-coded according to treatment combination (type x context-class). Stress for a 2-dimensional solution = 19.32.

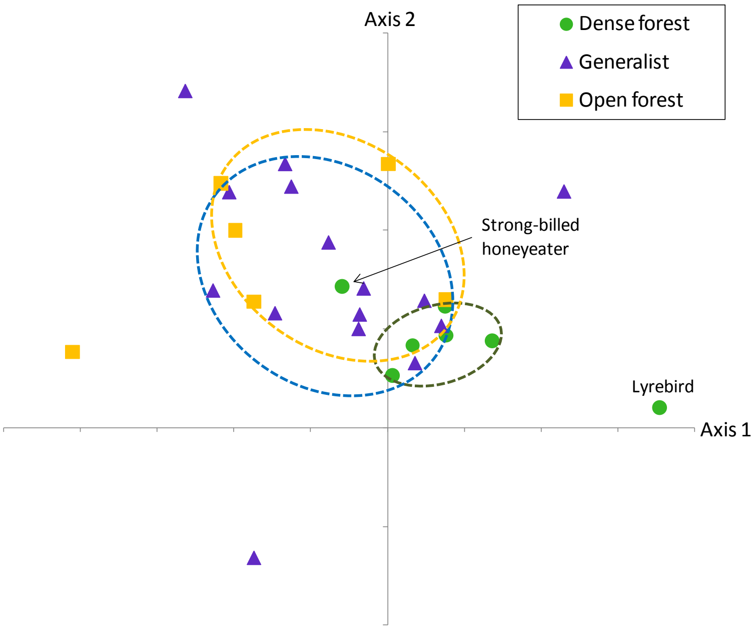


Figure 23. Scatter plot of two axis NMS ordination bird species scores with points coded according to habitat group.

Geographic, climatic and soils variables were the most often selected plot-level attributes in models to predict the abundance of birds using unsupervised variable selection with Random Forests. North-south position (northing) was moderately correlated (r=0.34, P<0.01) with axis1 of the bird NMS ordination. Three climate variables – temperature PCA axis 2, rainfall PCA axis 1 and radiation PCA axis 1 – were all negatively correlated (r=-0.27 to 0.29; P<0.05) with axis 1 of the bird NMS ordination but each was also strongly correlated with northing. Soil PCA axis 1 (representing general fertility – high calcium and magnesium, high pH and low aluminium) and east-west position (easting) were each moderately negatively correlated (r=-0.42, P=0.0014) with axis 2 of the bird NMS ordination. Despite these significant correlations, these plot-level attributes accounted for only about 10% of the variation in bird assemblage composition (axes 1 and 2 of NMS).

Beetles

Beetles were the most diverse of the three groups surveyed in the SFEFL, with a total of 619 species recorded, of which 254 were “common” species that were recorded in seven or more plots. Of the 619 species, 384 (62%) were found in both MAT and SILV plots, 117 (18%) species were found only in MAT plots and 118 (18%) species were found only in SILV plots (Figure 24). Thus MAT and SILV plots had comparable richness of beetles, which was reflected in the lack of any statistically significant differences between MAT and SILV in any of the species richness measures. A total of 85,740 specimens were trapped: 48,592 (56.7%) in MAT plots and 37,148 (43.3%) in SILV plots (Figure 24). These differences in abundance were not significantly different. Common species provided 98.5% of the specimens trapped.

Beetle assemblage composition did differ significantly between MAT and SILV plots (PERMANOVA: $F_{2,36}$=1.8; P=0.042) although the differences were much weaker than shown by the birds. NMS ordination scores tend to cluster the MAT plots more tightly than the SILV plots (Figure 25). Despite the small differences in the abundance, richness and assemblage composition of beetles between MAT and SILV plots, indicator species analysis still detected 28 species as indicators of MAT but only 2 species as indicators of SILV.

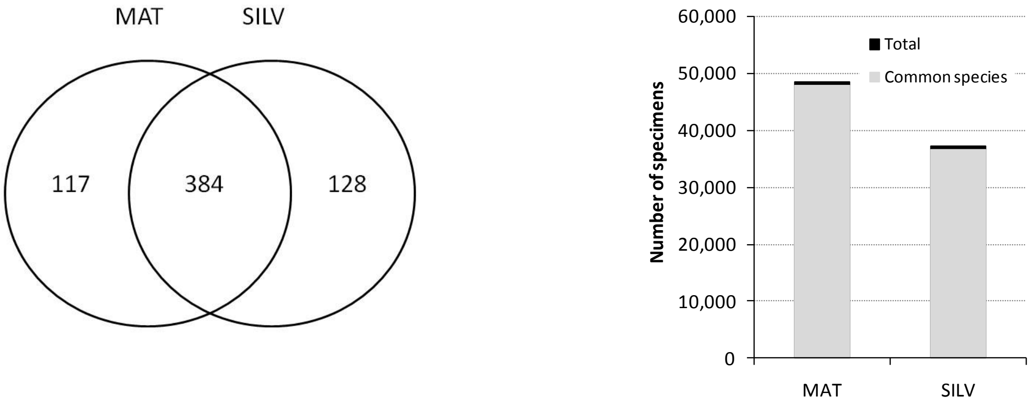


Figure 24. Venn diagrams showing the number of species of beetles in MAT and SILV plots. Bar charts show beetle specimens, in total and of "common species" (present in 7 or more plots), in MAT and SILV plots.

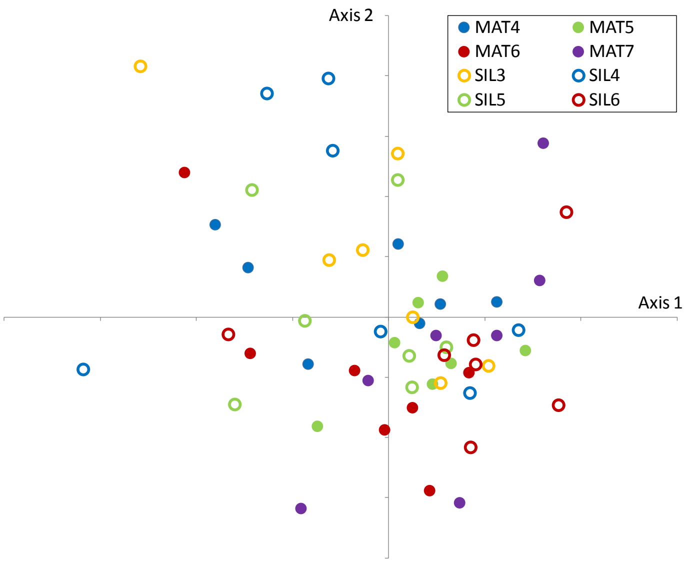


Figure 25. Scatterplot of axis 1 and 2 NMS ordination scores of beetle assemblage composition in the 56 plots with points colour-coded according to treatment combination (type x context-class). Stress for a 2-dimensional solution = 16.21.

A high proportion of Random Forests models, developed to predict the abundance of beetle species using unsupervised variable selection, incorporated plot-based attributes. The groups appearing the most in models were geographic (dominated by altitude), plot vegetation (mixture of variables) and CWD (mixture of variables). These were tested in linear regression models with the two NMS axes from the beetle ordination. Altitude, temperature (PCA axis 1), moisture (moisture PCA axis 1) and total volume of CWD were each moderately strongly correlated with axis 1: altitude positively ($r=0.59$, $P<0.0001$) (Figure 26); temperature PCA 1 negatively ($r=-0.59$, $P<0.0001$); moisture PCA 1 positively ($r=0.47$, $P<0.0001$); and total CWD volume positively ($r=0.34$, $P=0.011$). Altitude, temperature PCA 1 and moisture PCA 1 were each significantly correlated with each other and the relationship of any one of them with beetle NMS axis 1 accounted for the variation due to the other two. However, the significant correlation between beetle NMS axis 1 and CWD remained after accounting for the variation due to altitude (Figure 26). This was reflected in both CWD volume ($T=3.82$, $P=0.0004$) and altitude ($T=6.16$, $P<0.00001$) being significant in a multiple least-squares linear regression model with beetle NMS axis 1:

$$\text{Beetle NMS axis 1} = -0.1087 + 0.00074(\text{CWD Vol}) + 0.0028(\text{Altitude}) \qquad R^2=46.5\%$$

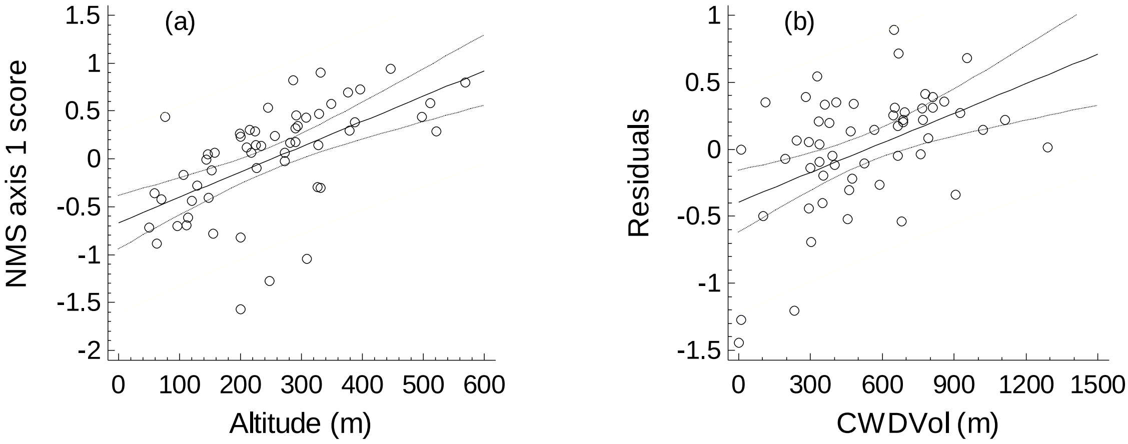


Figure 26. Scatterplots of: (a) axis 1 NMS score of beetle ordination with altitude; (b) residuals from (a) with total volume of CWD. Fitted least-square linear regression models are shown

Axis 2 of the NMS ordination of the beetle assemblages was most strongly correlated (r=0.42, P=0.0012) with axis 1 of the soil PCA (Figure 27). CWD volume and the landscape variables – distance to mature and mature within 500, 1000 or 2 km - also showed moderate correlations with beetle NMS axis 2 (r=0.32 to 0.38). Distance to mature forest explained the most additional variation in beetle NMS axis 2 when included in the multiple least squares linear regression model with soil PCA axis 1. However, the model only explained 24.7% of the variation in beetle NMS axis 2.

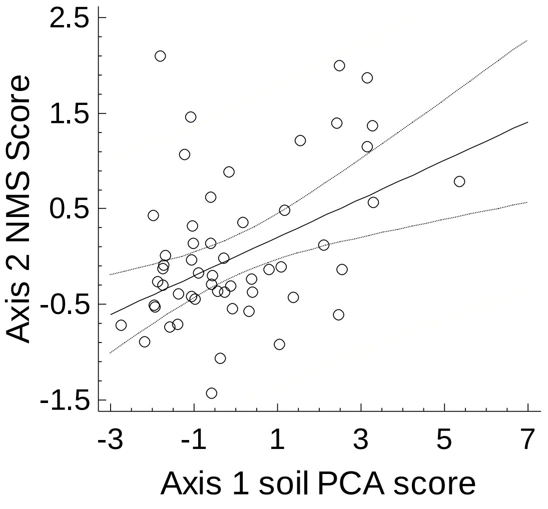


Figure 27. Scatterplot of axis 2 NMS score of beetle ordination with axis 1 score of the soil PCA. Fitter linear least square regression model is shown.

Vascular plants

Vascular plants were moderately diverse in the SFEFL, with 107 species recorded, of which 52 were common species present on seven or more plots. Of those 107 species, 75 (70%) were found in both MAT and SILV plots, 17 (16%) were found only in MAT plots and 15

(14%) were found only in SILV plots (Figure 28). Thus MAT plots had marginally greater richness of vascular plants than SILV. This difference in richness almost reached statistical significance ($F_{1,40}$=3.96; MSE=39.42; P = 0.053). Differences in cover-abundance of vascular plants between MAT and SILV plots were not statistically significant

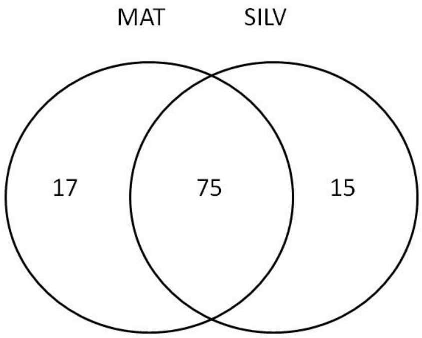


Figure 28. Venn diagrams showing the number of species of vascular plants in MAT and SILV plots.

Despite the lack of differences in cover-abundance and species-richness of vascular plants between MAT and SILV plots there was a significant difference in the assemblage composition between the two groups (PERMANOVA: $F_{1,36}$=3.40; MSE=2.64; P=0.0052). Indicator species analysis found that 13 species were significantly associated with MAT plots but only three species with SILV plots.

The differences in assemblage composition were subtle when the scatterplot of NMS axis 1 and 2 ordination scores for the plots were grouped according to plot type x context-class (Figure 29a). However, when the points were identified on the basis of community type (based on cluster analysis as described in methods) there was a clear aggregation of the plots in the ordination space (Figure 29b). Axis one separated callidendrous and thamnic-horizontal understoreys from *Monotoca* and *Pomaderris* sclerophyll understoreys. Axis two separated the callidendrous and *Pomaderris* sclerophyll understoreys from thamnic-horizontal and *Monotoca* sclerophyll understoreys. The x-y scatterplot of the axis 1 and 2 NMS ordination scores for the species showed the strong clustering of rainforest species as listed in Jarman *et al.* 1999 (Figure 30).

The results from the NMS ordination for the plots clearly show the two key drivers of plant assemblages in the SFEFL – disturbance and soil fertility – both of which were included in a high proportion of Random Forests models predicting the abundance of vascular plant species. Axis one scores were significantly negatively correlated with time since last fire ($F_{1,54}$=29.9, MSE=0.313; P<0.001): time since last fire accounted for more than one third of the variation in Axis one score (R^2=35.6%) (Figure 31a). Axis two scores were significantly negatively correlated ($F_{1,54}$=15.19, MSE=0.43; P<0.001) with PCA axis one from the PCA of soil chemical properties: soil PCA axis one accounted for 22% of the variation in NMS axis two (Figure 31b). High values of soil PCA axis 1 represented higher fertility soils with high concentrations of calcium, magnesium and high soil pH values. Low PCA axis 1 values were associated with low fertility soils containing high concentrations of aluminium.

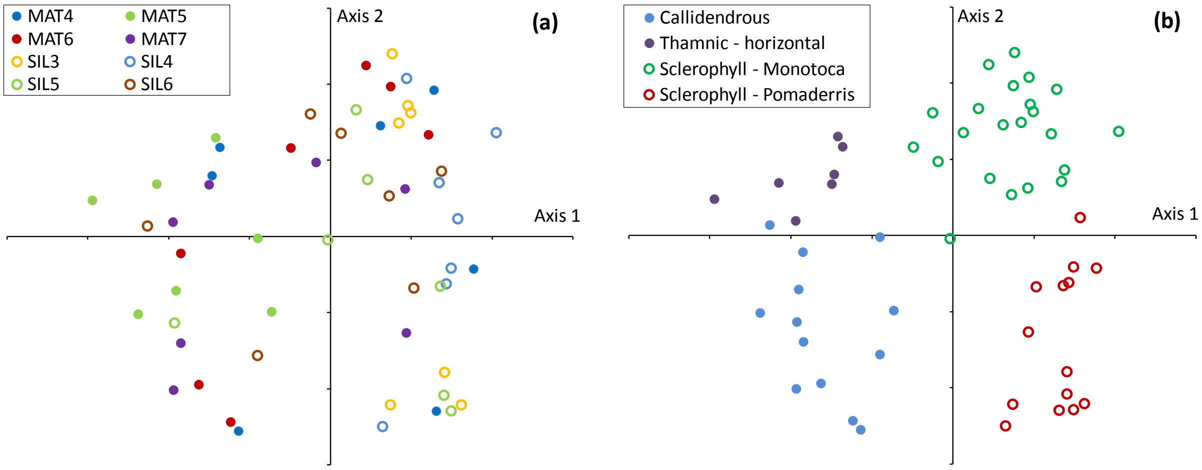


Figure 29. Scatterplot of axis 1 and 2 NMS ordination scores of the assemblage composition of vascular plants in the 56 SFEFL plots. Stress for a 2-dimensional solution = 15.94. Points have been partitioned according to: (a) treatment combination (type x context-class); (b) vegetation community based on cluster analysis.

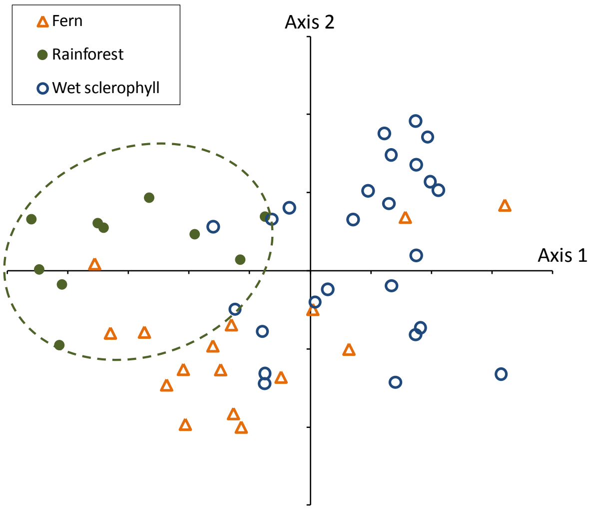


Figure 30. Scatterplot of axis 1 and 2 scores from the species matrix from the NMS ordination of vascular plants in the 56 SFEFL plots. Points have been colour-coded according to the stratification of species into one of three groups – rainforest species, wet sclerophyll species or ferns.

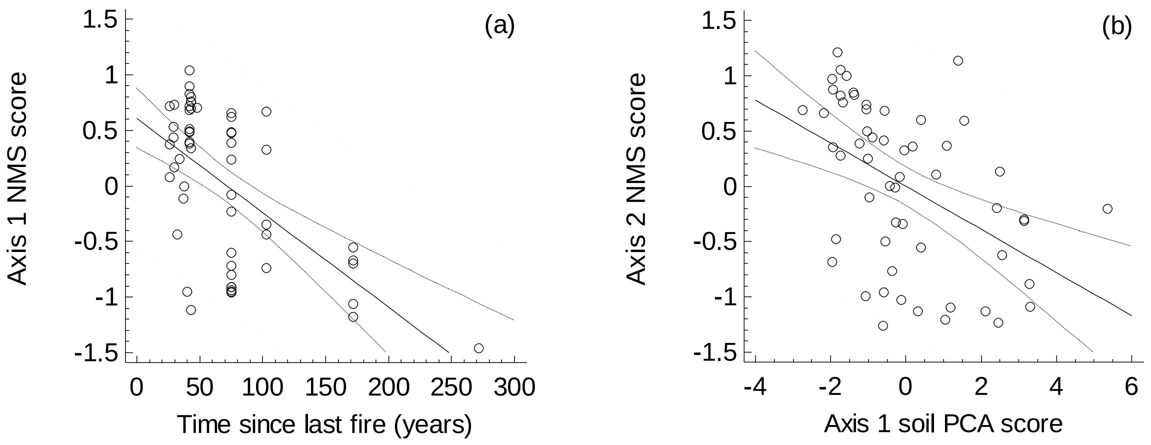


Figure 31. Scatterplots of: (a) axis 1 score of plant NMS ordination and time since last fire; (b) axis 2 score of plant NMS ordination and axis 1 score of soil PCA. Fitted linear least squares regression models are shown.

Focal-group responses to landscape context-class

Birds.

There were no overall effects of context-class on total bird abundance and species richness, although the abundance of species preferring dense forests did show a significant difference among plots in different context-classes: context-class 4 had a lower abundance of dense-forest species than context-classes 5 and 6 (Table 19). There was no effect of context-class within MAT plots for any measure of abundance or richness (Table 18). However, in SILV plots there was a significant effect of context-class on the abundance of birds, which was reflected in a trend of increasing abundance with increasing context-class (Figure 32). This was due entirely to differences in the abundance of species preferring dense forests. A two-way ANOVA on bird abundance detected a significant interaction between context-class and forest type ($F_{2,35}$=5.1, P=0.012), reflecting the contrasting relationships between bird abundance and context-class in MAT and SILV plots. Total species richness in SILV plots (but not richness of rare species) also increased with increasing context-class; however, the differences only reached statistical significance for those species preferring dense forest. The relatively small differences in abundance and richness of birds were reflected in only a small, although significant, difference in assemblage composition among context-classes (Table 19).

Table 19. Significance of differences among context-classes overall, among context-classes within MAT, and among context-classes within SILV, in abundance, species richness and assemblage composition of birds, beetles and vascular plants. Results followed by * showed significant (P<0.05) covariance with position east-west (easting) in the model. Results followed by $^\sharp$ showed significant (P<0.05) covariance with soil PCA axis 1 in the model. Results followed by § showed significant (P<0.05) covariance with time since last fire in the model. $^{1.}$ Rank-transformed data.

	Overall	Within MAT	Within SILV
Abundance:			
Birds (overall)	n.s.	n.s.	$F_{3,24}$=5.3; P<0.01; 3, 4 < 6
• generalist species	n.s.	n.s.	n.s.
• open-forest species	n.s.*	n.s.*	n.s.
• dense-forest species	$F_{2,35}$=6.2^1; P<0.01; 4<5-6	n.s.*	$F_{3,27}$=10.7, P<0.001; 3,4<5<6
Beetles (All)	n.s.$^\sharp$	n.s.	n.s.
Vascular plants (all)	n.s.	n.s.	n.s.
• rainforest species	$F_{2,38}$=3.16; P=0.054§; 4<5, 6	n.s.	$F_{3,24}$=8.37^1,P<0.001,3,4<5,6
Species richness			
Birds (overall)	n.s.	n.s.	n.s.
• generalist species	n.s.	n.s.	n.s.
• open-forest species	n.s.*	n.s.*	n.s.
• dense-forest species	n.s.	n.s.	$F_{3,27}$=4.6; P<0.05; 3<5,6
Beetles (All)	n.s.	n.s.	n.s.
Vascular plants (all)	n.s.	n.s.	n.s.
• Rainforest species	$F_{2,38}$=8.47; P<0.001§; 4<5, 6	n.s.	$F_{2,23}$=15.4^1, P<0.001$^\sharp$, 3,4<5,6
Rare species richness			
Birds	n.s.	n.s.	n.s.
Beetles	n.s.	n.s.	n.s.
Vascular plants	K-W=6.3; P<0.05; 4 > 5	$F_{3,27}$=3.77; P<0.05; 4 > 5, 7	n.s.
Rare / total species			
Birds	n.s.	n.s.	n.s.
Beetles	n.s.	n.s.	n.s.
Vascular plants	K-W=9.2; P<0.05; 4 > 5	$F_{3,27}$=4.60; P<0.01; 4 > 5, 7	n.s.
Assemblage composition			
Birds	$F_{2,36}$=2.03; P=0.017; 4≠6	n.s.	$F_{3,24}$=2.31; P<0.01 3, 4≠6 | 3≠5
Beetles	$F_{2,36}$=1.91; P<0.01; 4≠6	$F_{3,24}$=1.34 P=0.09; 4≠7	$F_{3,24}$=1.39 P=0.097; 3≠6
Vascular plants	$F_{2,36}$=1.94, p<0.05; 4 ≠ 5	n.s.	n.s.

Given the significant correlations of east-west and north-south position with NMS scores of bird assemblage composition (reported in previous section) those two variables were included as covariates in ANCOVA models. Only the abundance and richness of open-forest birds and abundance of dense-forest birds had significant, or nearly so, covariate terms in the models, each due to east-west position. However, there was no overlap in the models for both the covariate and context-class being significant: the covariate term was not significant in the context-class within SILV model, where differences among context-classes were highly significant (for the dense-forest habitat group). Conversely, differences among context-classes were not significant in MAT plots while the covariate term was significant.

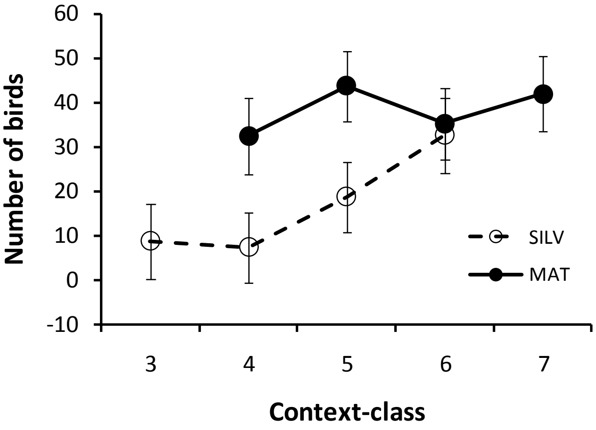


Figure 32. Differences in the least-squares mean number of dense-forest birds (rank-transformed and adjusted for covariate – east-west position) among context-classes within SILV and MAT plots. Error bars indicate 95% LSD intervals.

Beetles.

The abundance of beetles differed significantly among context-classes overall ($F_{2,39}$=3.9 [log-transformed]; $P<0.05$; 4 < 6). However, given the several significant relationships between beetle assemblage composition with plot-level variables (altitude, CWD volume, soil PCA axis 1), analysis of covariance was also checked. While neither altitude nor CWD volume were significant as covariates in the ANCOVA model, soil PCA axis 1 score was ($F_{1,38}$=7.7; $P<0.01$). Once the covariance between beetle abundance and soil PCA axis 1 score was removed the differences in beetle abundance among context classes was no longer significant.

Beetle assemblage composition also differed significant among context-classes overall ($F_{2,36}$=1.91; $P<0.01$): plots in context-class 4 had a significantly different assemblage composition than plots in context-class 6. This reflected plots in context-class 6 having a significantly lower NMS axis-2 score than plots in context-class 4. Soil PCA axis 1 score was a significant covariate in the ANCOVA model ($F_{1,38}$=9.08; $P<0.01$). Once the covariance between NMS axis-2 score with soil PCA axis-1 score was removed the differences in NMS axis-2 scores among context-classes were no longer significant

Beetle abundance and assemblage composition in both MAT and SILV showed no significant differences among context-classes (Table 19). Likewise there were no significant differences in species-richness among context-classes overall, among context-classes within MAT and among context-classes within SILV (Table 19).

Vascular plants.

The cover-abundance and the total species richness of vascular plants did not differ among context-classes overall, or among context-classes within MAT or within SILV (Table 19). This was reflected in a lack of significant difference in assemblage composition among context-classes in both MAT and SILV.

Given the strong clustering of rainforest species in the NMS ordination for species, the abundance and richness of rainforest species, as a group, was analysed to test for differences among context-classes, overall (Table 19). Differences in cover of rainforest plants approached, but did not reach, statistical significance among context-classes (Table 19). Time since last fire was a significant ($F_{1,38}$=24.5, P<0.001) covariate but its inclusion in the model made little difference to the significance of the context-class effect. There were, however, significant differences in the species-richness of rainforest plants among context-classes, overall (Table 19): plots in the most intensively disturbed parts of the landscape (context-class 4) had significantly lower species-richness of rainforest plants than plots in less disturbed parts of the landscape (context-classes 5 and 6). While time since last fire was a significant covariate in the model ($F_{1,38}$=7.76, P<0.01), the significant differences among context-classes remained after controlling for time since last fire. There were no significant differences among context-classes in either cover or richness of rainforest plants in MAT plots (Table 19). By contrast, there were highly significant differences among context-classes in both cover and richness of rainforest plants in SILV plots (Table 18): Plots in the more intensively disturbed parts of the landscape (context-classes 3 and 4) had significantly lower cover and richness of rainforest plants than plots in the less disturbed parts of the landscape (context-classes 5 and 6). Soil PCA axis 1 score was a significant covariate in the species-richness model, but its inclusion in the model made little difference to the significance of differences among context-classes.

Significant differences were detected in the richness of rare species (and rare species as a proportion of the total species richness) among context-classes overall: there was a greater richness of rare species in context-class 4 than in context-class 5 (Table 19). This result was mirrored in the MAT plots, but not in the SILV plots.

All three focal groups.

Among the three focal groups only birds and rainforest plants showed significant differences in total abundance and species richness among forest types within context-classes (Figure 33). For all bird species, for species favouring dense forest, and for generalist species, both abundance and species richness were significantly greater in MAT than in SILV plots in context-classes 4 and 5, but not in context-class 6. Bird species favouring open forest did not differ significantly in abundance or species richness between MAT and SILV plots in any of the context-classes. For all habitat-based bird groupings, the differences in both abundance and species richness between MAT and SILV declined with increasing context-class.

Beetles showed no significant differences between MAT and SILV plots in abundance or species-richness for any of the context-classes, and there were no consistent patterns in those differences with context-class.

Vascular plants overall showed no significant differences between MAT and SILV plots in either cover or species richness for any of the context-classes. However, for the subset of rainforest plants both cover and species-richness differed significantly between MAT and SILV plots in context-class 5 (Figure 33). Differences between MAT and SILV plots in the cover of rainforest plants peaked in context-class 5, while differences in species-richness of rainforest plants between MAT and SILV tended to decline with increasing context-class.

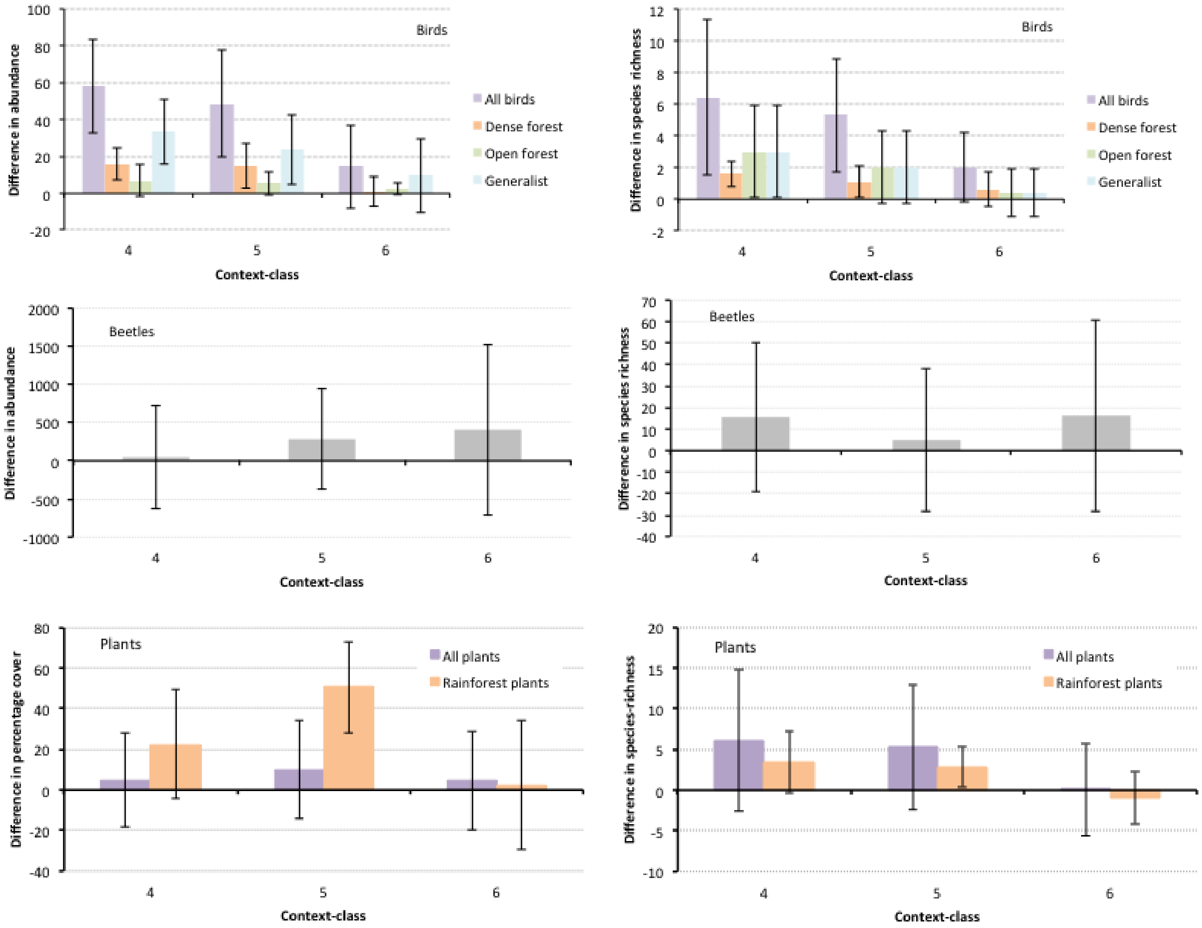


Figure 33. Mean difference (with 95% confidence intervals) between MAT and SILV plots (within context-classes) in abundance and species richness of birds, beetles and vascular plants. Positive values for difference reflect MAT>SILV.

Response of individual species to forest type and context-class

All three focal groups.

Significant differences in the abundance of individual species between MAT and SILV were detected at rates matching the results from the Indicator Species Analysis (ISA) for each of the three focal groups (compare Table 20 with Table 19). For both birds and plants, a high proportion (75% and 86%, respectively) of the species detected as significant indicators of either MAT or SILV using ISA were also detected as significantly different (or nearly so) between MAT and SILV in the ANOVAs (Appendices 3 and 5). In contrast, there was poor agreement between the results of the ISA and the ANOVAs for beetles: only one species detected as a significant indicator of MAT or SILV was also detected as significantly different between MAT and SILV using ANOVA.

Birds.

There were few bird species showing significant differences in abundance among context-classes. This reflects the lack of significant difference in the total abundance of birds with context-class (Table20). Bird abundances at the species-level showed contrasting relationships with context-class in MAT and SILV. This result is consistent with the significant interaction in total bird abundance between forest type and context-class (Figure 28). In MAT plots, more of the species differing significantly among context-classes showed a negative trend in abundance with increasing context-class (Table 20, Appendix 3). In SILV plots, virtually all of the species differing significantly with context-class showed a positive trend in abundance with increasing context-class (Table 20, Appendix 3). This was mirrored in the trends of species-level abundance with context-class overall: all of the species differing significantly in abundance among context-classes (overall) showed a positive trend of abundance with increasing context-class.

Table 20. Number of species of birds, beetles and vascular plants showing significant differences (or nearly so - 0.05<P<0.1 - in parentheses) in abundance between plot types (MAT and SILV), among context-classes independent of plot type, and among context-classes within MAT and within SILV. +ve and –ve denote positive and negative relationships respectively; ∩ and ∪ symbols denote humped and u-shaped relationships respectively.

	MAT vs SILV	Context-class (overall)	Context-class within MAT	Context-class within SILV
Birds (28 common spp)	M>S: 11(5) S>M: 0	+ve: 2(2) ∩∪: 0(1) -ve: 0(1)	+ve: 1(1) ~: 1 (0) -ve: 2(1)	+ve: 2(3) ~: 1 -ve: 0
Beetles (254 common spp)	M>S: 14 (8) S>M: 5	+ve: 14(14) ∩∪: 12(11) -ve: 3(2)	+ve: 6(7) ~: 3(5) -ve: 3(2)	+ve 8(7) ~: 12(14) -ve: 3(3)
Vascular plants (52 common spp)	M>S: 8(2) S>M: 2(2)	+ve: 0 ∩∪: 8(6) -ve: 0	+ve: 0 ~: 1(7) -ve: 0	+ve: 6(1) ∩: 1 -ve: 0(1)

Beetles.

While the number of significant, species-level relationships in abundance with context-class was greatest for beetles, the number of significant relationships as a proportion of the total number of common species was comparable with the other two groups. The majority of significant differences in abundance among context-classes reflected a positive or non-linear trend in species abundance with increasing context-class. This pattern was consistent across the three context-class strata examined. In the context-class (overall) stratum, species showing a positive trend in abundance with context-class predominated. This mirrored the result obtained for total beetle abundance among context-class overall (Table 20). In the context-class (overall) stratum, species showing a "∪" trend with context-class occurred in similar numbers to those showing a "∩" trend with context-class, effectively cancelling their combined effect on overall beetle abundance. There was no dominating trend in abundance with context-class in those species showing significant differences in abundance among context-classes in either MAT or SILV. This was consistent with the lack of any significant difference in total beetle abundance in these two strata (Table 19).

Vascular plants.

The cover-abundances of vascular plant species that differed significantly (or nearly so) among context-classes trended differently with context-class in SILV compared to MAT and differently compared to context-class overall. The cover-abundance of species differing significantly among context-classes in SILV almost universally showed a positive trend with increasing context-class (Table 20). All of the species showing a positive trend with context-class in SILV were rainforest species (Appendix 5). By contrast, the cover-abundance of species differing significantly among context-classes in MAT, and context-classes overall, did not trend either positively or negatively with context-class. The pattern of changes in cover-abundance with context-class was clearest in context-class overall, and was reflected in either a maximum or minimum in cover-abundance at context-class 5. Species showing a maximum in cover abundance at context-class 5 were rainforest trees and ferns, while those with a minimum in cover-abundance at context-class 5 were species favoured by disturbance (Appendix 5).

Identifying disturbance-sensitive species

Disturbance-sensitive species were identified by three methods:

i) In Random Forests models, a species showed a positive response to the amount of MAT in the surrounding landscape or a negative response to either road density or the amount of SILV in the surrounding landscape;

ii) A species showed significant differences in abundance among context-classes (overall) and showed a trend of increasing abundance with increasing context-class;

iii) A species showed significant differences in abundance among context-classes within MAT, or within SILV, and showed a trend of increasing abundance with increasing context-class.

These methods identified five bird species, 38 beetle species and 13 vascular plant species as being sensitive to disturbance (Table 21).

Three of the five bird species identified as disturbance-sensitive (scrubtit, Tasmanian scrubwren and Tasmanian thornbill) are known to prefer dense-forest habitats, while the the others (grey shrikethrush and golden whistler) are generalists. All but two of the plant species identified as disturbance-sensitive were rainforest species.

Table 21. Number of species of birds, beetles and vascular plants identified as sensitive to disturbance by each of three methods.

Method for selecting species	Birds	Beetles	Plants
Random Forests	1	23	9
Context-class (overall)	2	12	-
Context-class with MAT or within SILV	3	15	6
Total (one or more method)	5	38	13

By comparison with the dense-forest birds and rainforest plants, which occupied a distinct space in their respective NMS ordination (Figures 23 and 30), the group of beetles identified as disturbance-sensitive did not occupy discrete space in the NMS ordination (Figure 34). There is insufficient knowledge of the ecology of Tasmanian beetles to relate their identified disturbance-sensitivity to their ecological / habitat traits. The majority (60%) of the species determined to be disturbance-sensitive are recorded as facultatively saproxylic in the database of the Tasmanian Forest Insect Collection (www.tfic.net.au). This was 50% higher than the proportion expected by chance and represented a significant departure from independent assortment ($\chi^2_3 = 7.85$, $P<0.05$). One of the disturbance-sensitive beetle species, *Prostomis atkinsoni* – an obligately saproxylic species – is known to prefer logs containing brown rot, which mainly develops in large eucalypt logs generated from mature trees. This species is one of several that are the focus of a population genetics study currently being conducted in the SFEFL.

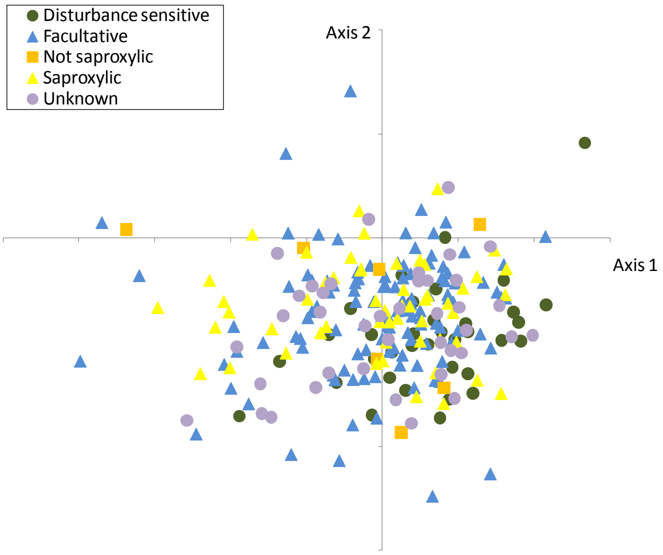


Figure 34. Scatterplot of axis 1 and 2 scores from the species matrix from the NMS ordination of beetles in the 56 SFEFL plots. Points have been colour-coded according to the stratification of species into one of five groups reflecting saproxylicity (including facultative) and sensitivity to disturbance.

Unsurprisingly the subset of disturbance-sensitive beetles shows significant differences in both abundance (except in SILV plots) and species-richness among context-classes (Table 21). However, differences in abundance among plots in different context-classes were confounded by plot-level attributes – CWD volume and soil PCA axis-1 score in MAT and SILV plots, respectively. Once these two factors were controlled for differences in abundance of disturbance-sensitive beetles among MAT plots and SILV plots in different context-classes became non-significant (Table 22).

Table 22. Results of analysis of variance testing for the significance of differences in the abundance and richness of disturbance-sensitive beetle species among context-classes; and analysis of covariance testing for those differences after controlling for the indicated covariate (type I sum of squares used for F-tests). $^{1.}$ Log-transformed data.

Measure	Context-class stratum		
	Overall	Within MAT	Within SILV
ANOVA model			
Abundance^1	$F_{2,39} = 8.5$***	$F_{3,24} = 3.8$*	$F_{3,24} = 2.4^{ns}$
Richness	$F_{2,39} = 15.9$***	$F_{3,24} = 9.4$***	$F_{3,24} = 6.5$**
ANCOVA model			
Abundance^1	Soil PCA: $F_{1,37}=25.4$*** CWD Vol: $F_{1,37}=4.8$* Context: $F_{2,37}=3.2^{ns}$	CWD Vol: $F_{1,23}=13.4$*** Context: $F_{3,23}=1.5^{n.s.}$	Soil PCA: $F_{1,23}=13.9$*** Context: $F_{3,23}=1.2^{ns}$
Species-richness	MAT500: $F_{1,38}=37.8$*** Context: $F_{2,38}=1.9^{ns}$	Road(all)1000: $F_{1,21}=9.4$** CWD Vol: $F_{1,21}=15.3$*** MAT1000: $F_{1,21}=5.3$* Context: $F_{3,21}=0.9^{ns}$	MAT500: $F_{1,23}=19.9$*** Context: $F_{3,23}=0.3^{ns}$

Differences in the species-richness of disturbance-sensitive beetles among the different context-classes were strongly confounded with the amount of mature forest in the surrounding landscape in both MAT and SILV (Table 22). Within MAT, the total volume of CWD and the density of roads (all classes) in the 1 km landscape were also significant co-variates (Table 22). Together, these three covariates (mature eucalypt forest in the 1 km landscape, CWD volume and density of roads in the 1 km landscape) strongly differentiate MAT plots in context-class 4 from the higher context-classes.

Detecting the spatial scales of responses to landscape measures by the focal groups

Birds

Correlations in bird abundance with each of the three landscape measures (road density, proportion of vegetation-groups and vegetation-group heterogeneity) showed a consistent pattern in relation to landscape scale. That pattern is shown for the correlation in abundance with the proportion of mature eucalypt forest in the surrounding landscape (Figure 35). In MAT plots, generalist species showed a peak negative correlation with surrounding forest types at small spatial scales and weak correlations with surrounding forest types at wide spatial scales. All levels of the hierarchy (individual species within the habitat group → all species within the habitat group → all birds) showed the same pattern indicating that the overall response for bird abundance in mature eucalypt plots was dominated by the response of the generalist species. In SILV, the patterns in correlations were inconsistent among the generalists hierarchy. The dense-forest species showed the reverse pattern. For this group, correlations showed inconsistent patterns with surrounding forest types among hierarchies in MAT plots, but in SILV all levels of the hierarchy showed a strong positive correlation with the proportion of mature eucalypt forest in the surrounding landscape at small spatial scales. Correlations remained high into wider landscape scales. Thus in SILV, the overall response in bird abundance to the proportion of forest types in the surrounding landscape was dominated by the response of dense-forest species.

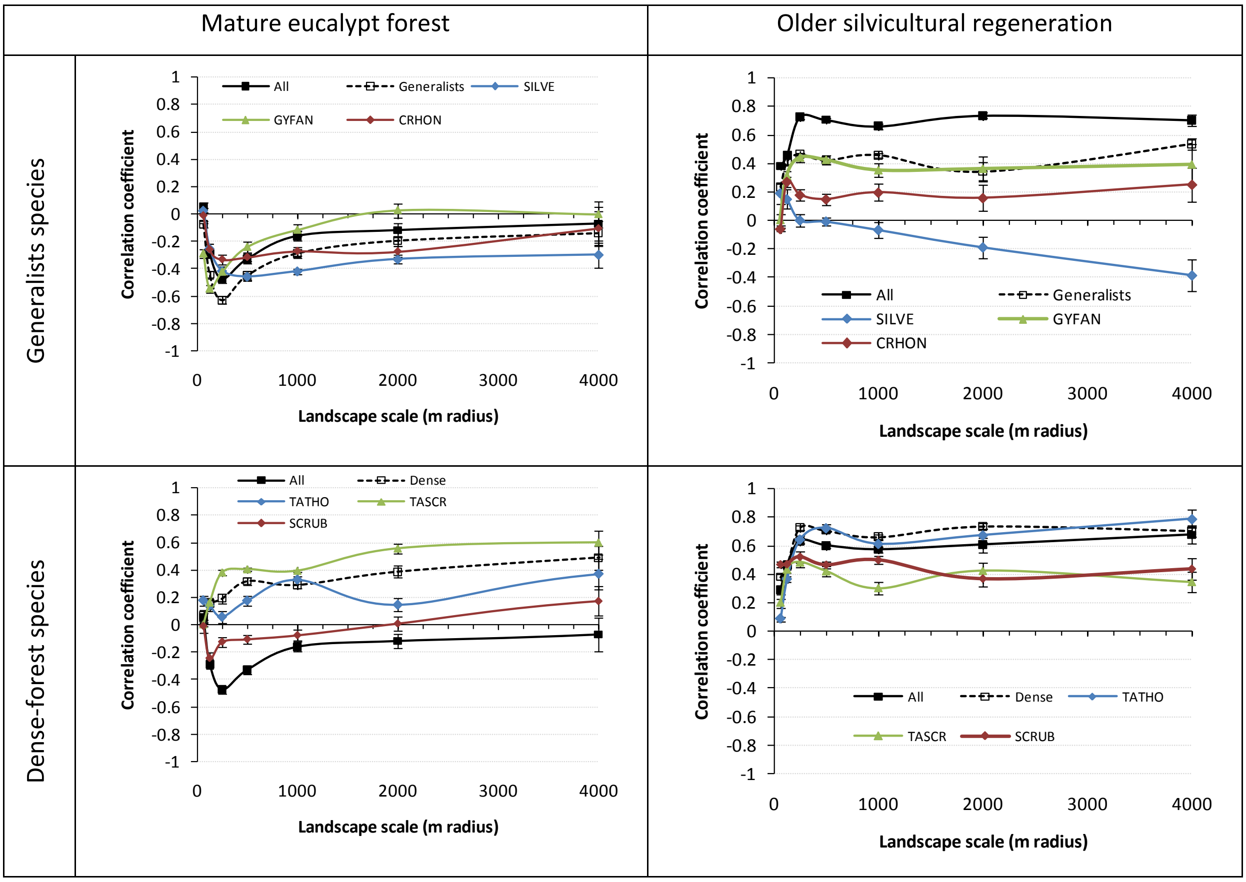


Figure 35. Correlation coefficients of the regressions of bird abundance with the proportion of mature eucalypt forests at spatial scales between 62.5 m – 4 km. Pairs of graphs in each row show a partitioning of correlations x spatial scale by an hierarchical arrangement for birds: all bird species > habitat group (generalists, dense forest) > species within the habitat group. The three generalist species are: silvereye (SILVE), grey fantail (GYFAN) and crescent honeyeater (CRHON). The three dense-forest species are: Tasmanian thornbill (TATHO), Tasmanian scrubwren (TASCR) and scrubtit (SCRUB). Results are presented separately for plots in MAT and plots in SILV.

Beetles

All beetle groups showed a similar pattern of correlations in abundance and richness in MAT plots with the amount of mature eucalypt forests in the surrounding landscapes across the range of landscape scales (Figure 36). The correlations were stronger for abundance than richness, with a peak positive correlation with the amount of mature forest within the 1 km radius landscape. In SILV plots, only disturbance-sensitive species showed moderate correlations with the amount of mature forest in the surrounding landscape (Figure 36). The positive correlations of both abundance and richness of disturbance-sensitive species with the amount of mature eucalypt forest in the surrounding landscape rose sharply at the 250 m landscape scale and remained high thereafter with increasing landscape scale. The correlations in abundance and richness with road density (all road classes) across the range of landscape scales were comparable in magnitude, but in opposite directions to the amount of mature eucalypt forest in the landscape (data not shown).

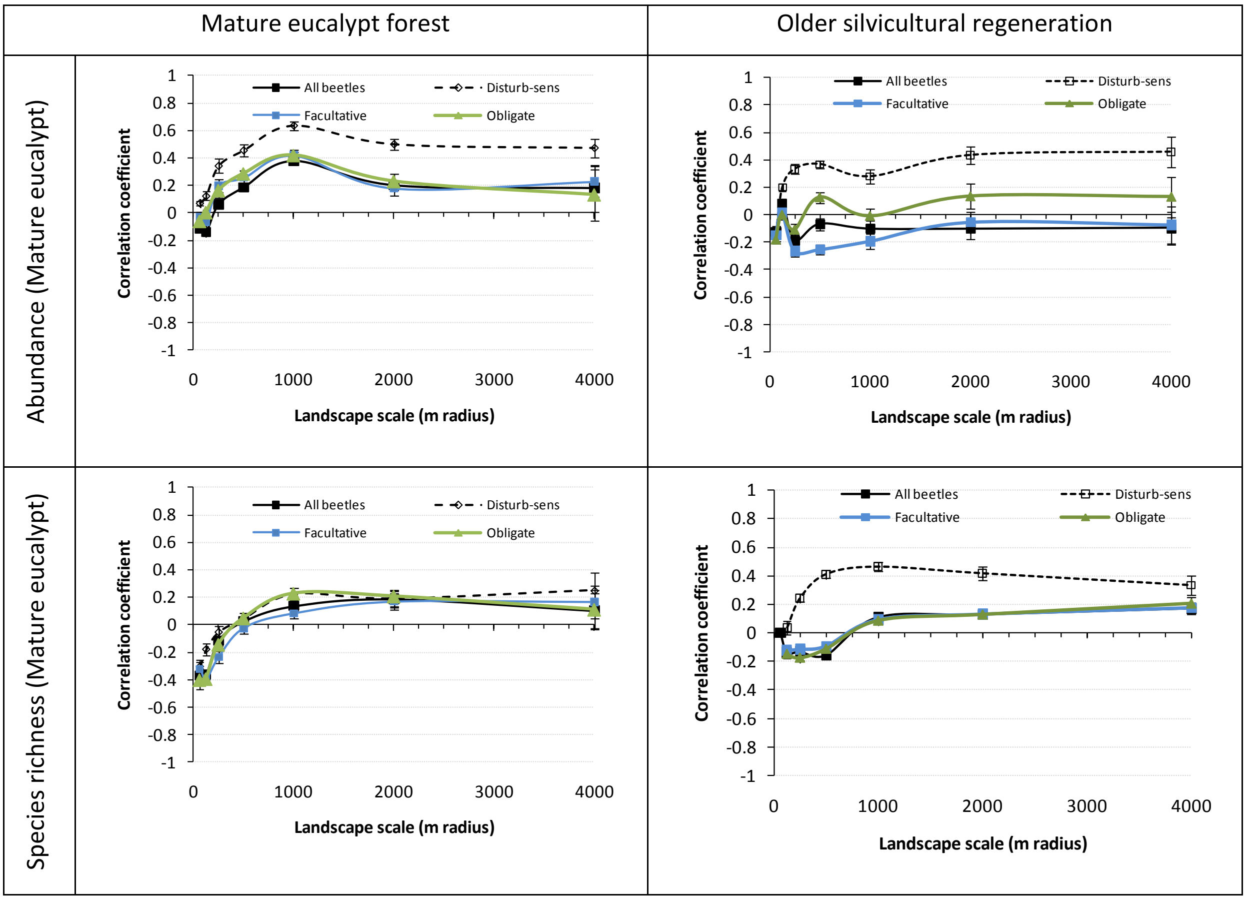


Figure 36. Correlation coefficients of the regressions of abundance and species-richness of beetle groups with the proportion of mature eucalypt forests in the surrounding landscape of spatial scales between 62.5 m – 4 km. Results are presented separately for plots in mature eucalypt forest and plots in older silvicultural regeneration.

Vascular plants

The cover-abundance of the three wet sclerophyll species showed no consistent patterns in correlation with any of the three landscape measures in either MAT plots or SILV (Figure 37). Likewise, the cover-abundance of disturbance-sensitive rainforest species in MAT plots showed no consistent pattern in correlations with either the amount of mature forest or the heterogeneity of vegetation-groups in the surrounding landscape. The cover-abundance of rainforest species did, however, show a positive correlation with road density in the surrounding landscape at small (125-250 m) spatial scales (results not shown). In SILV all rainforest species showed a sharp rise in their correlation with each of the three landscape measures commencing at small spatial scales and persisting into wider landscape scales (Figure 37). The responses shown by the individual rainforest species were amplified in the disturbance-sensitive group (as defined in the previous section and comprising rainforest species).

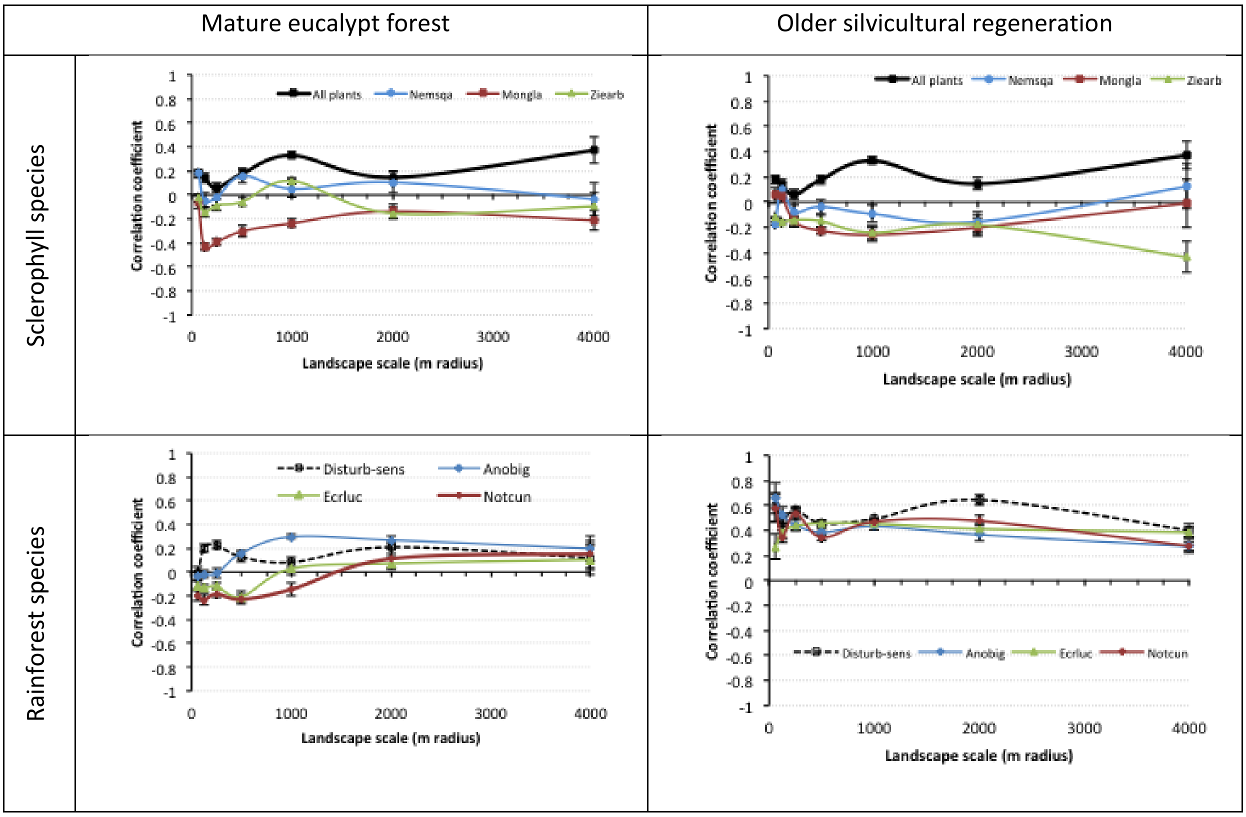


Figure 37. Correlation coefficients of the regressions of cover-abundance of plant species with the proportion of mature eucalypt forests at spatial scales between 62.5 m – 4 km. Pairs of graphs in each row show a partitioning of correlations x spatial scale x forest type (mature eucalypt forest and older silvicultural regeneration. The top row shows the relationship for three wet sclerophyll species and all plants, the lower row shows the relationship for three rainforest species and disturbance-sensitive species overall. The three wet sclerophyll species are: *Nematolepis squamea* (Nemsqa), *Monotoca glauca* (Mongla) and *Zieria arborescens* (Ziearb). The three rainforest species are: *Anodopetalum biglandulosum* (Anobig), *Eucryphia lucida* (Eucluc) and *Nothofagus cunninghamii* (Notcun).

Testing for threshold effects in responses of focal groups

The strong correlations for dense-forest birds, rainforest plant and disturbance-sensitive beetles with the amount of mature eucalypt forest in the landscape surrounding SILV plots were explored further. Exploration was carried out using abundance for dense-forest birds, and richness for rainforest plants and disturbance-sensitive beetles. The logic of this is that, for birds and plants, these measures showed strongest correlations with the amount of mature eucalypt forest in the surrounding landscape for their respective groups (Figure 38). Richness was chosen for disturbance-sensitive beetles because that measure was not confounded with plot attributes (differences in disturbance-sensitive beetle abundance in SILV plots among context-classes were confounded with soil PCA axis-1 and CWD volume).

Did the spatial patterns shown by disturbance-sensitive rainforest plants, beetles and dense-forest birds simply represent a landscape context effect, or was there some other mechanism causing the spatial response to the amount of mature eucalypt forest in the landscape surrounding the sample plots? The disturbance-sensitive subsets of the three focal groups were each moderately positively correlated with one and other (Figure 39). This indicates they each might be responding to the same cues or with each other.

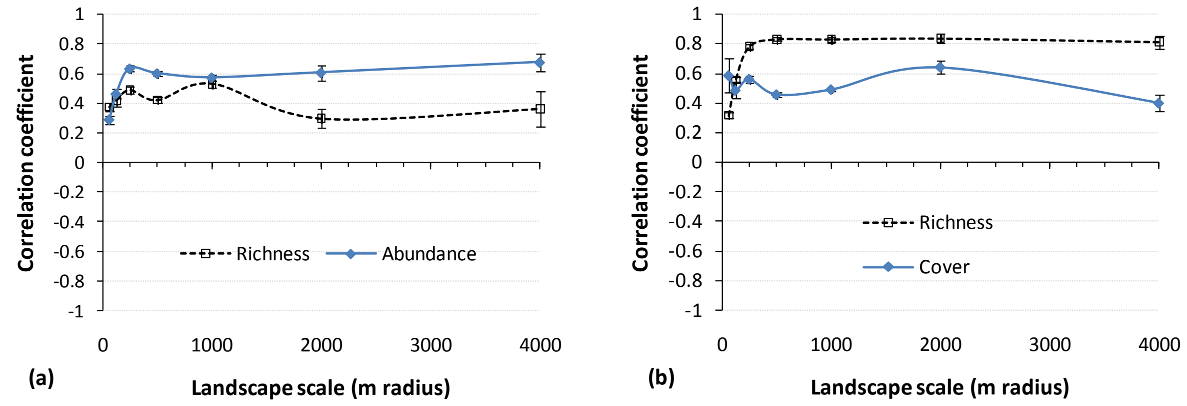
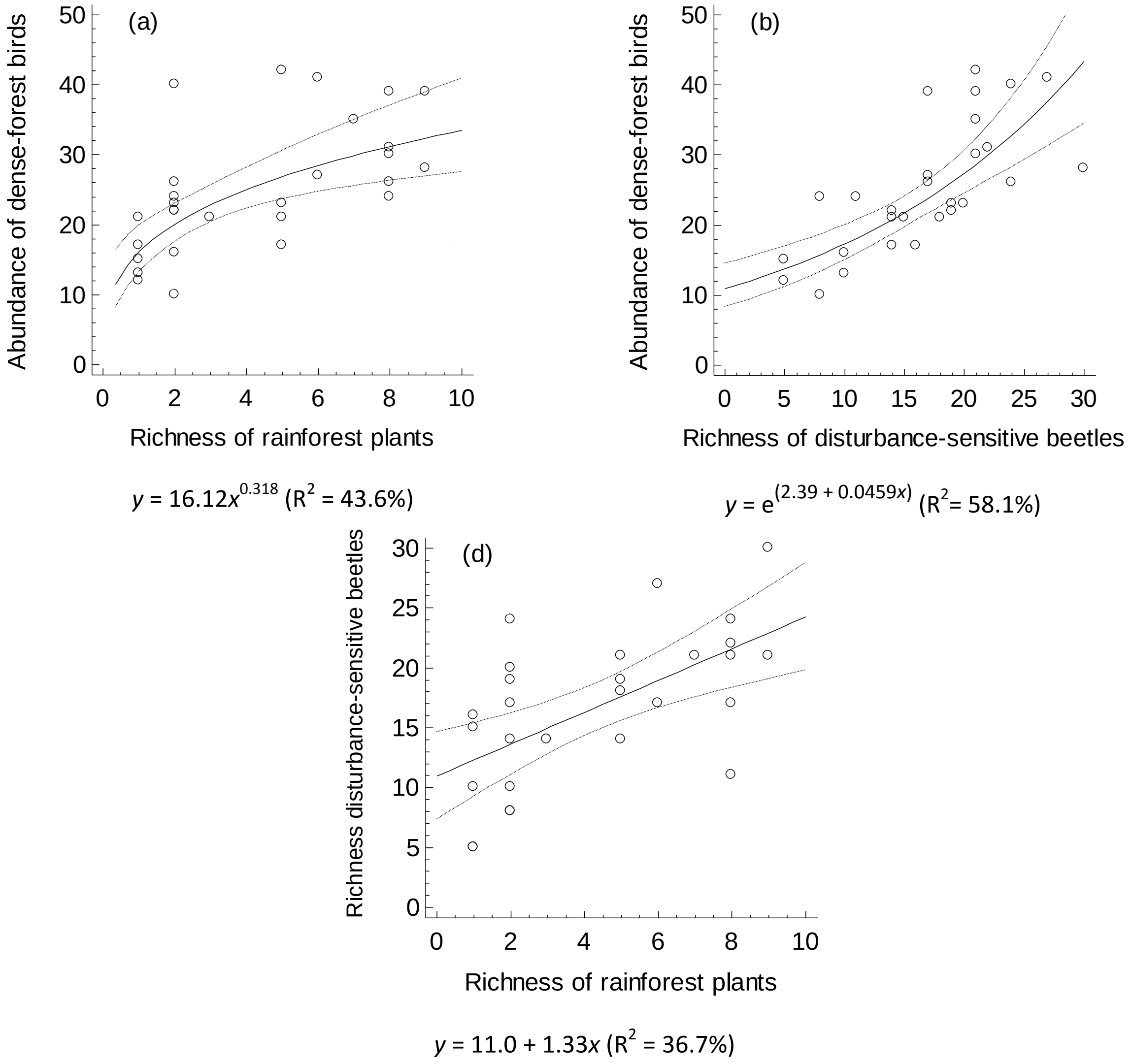


Figure 38. Comparison of the strength of correlations of species-richness and abundance / cover measures with the amount of mature eucalypt forest in the surrounding 125 m – 4 km landscapes. Relationships are shown for (a) dense forest birds and (b) rainforest plants.



$y = 16.12x^{0.318}$ ($R^2 = 43.6\%$)

$y = e^{(2.39 + 0.0459x)}$ ($R^2 = 58.1\%$)

$y = 11.0 + 1.33x$ ($R^2 = 36.7\%$)

Figure 39. Linear regressions for combination of the abundance of dense-forest birds; the species-richness of rainforest plants; and, the species-richness of disturbance-sensitive beetles in SILV plots.

Given that many of the rainforest species making up the disturbance-sensitive plant group have previously been found to recolonise disturbed areas from intact edges (Tabor *et al.* 2007), the relationships with distance to nearest patch of mature eucalypt forest or rainforest were tested. All disturbance-sensitive subsets of the three focal groups showed strong negative, non-linear correlations with distance to the nearest patch of mature eucalypt forest or rainforest (Figure 40).

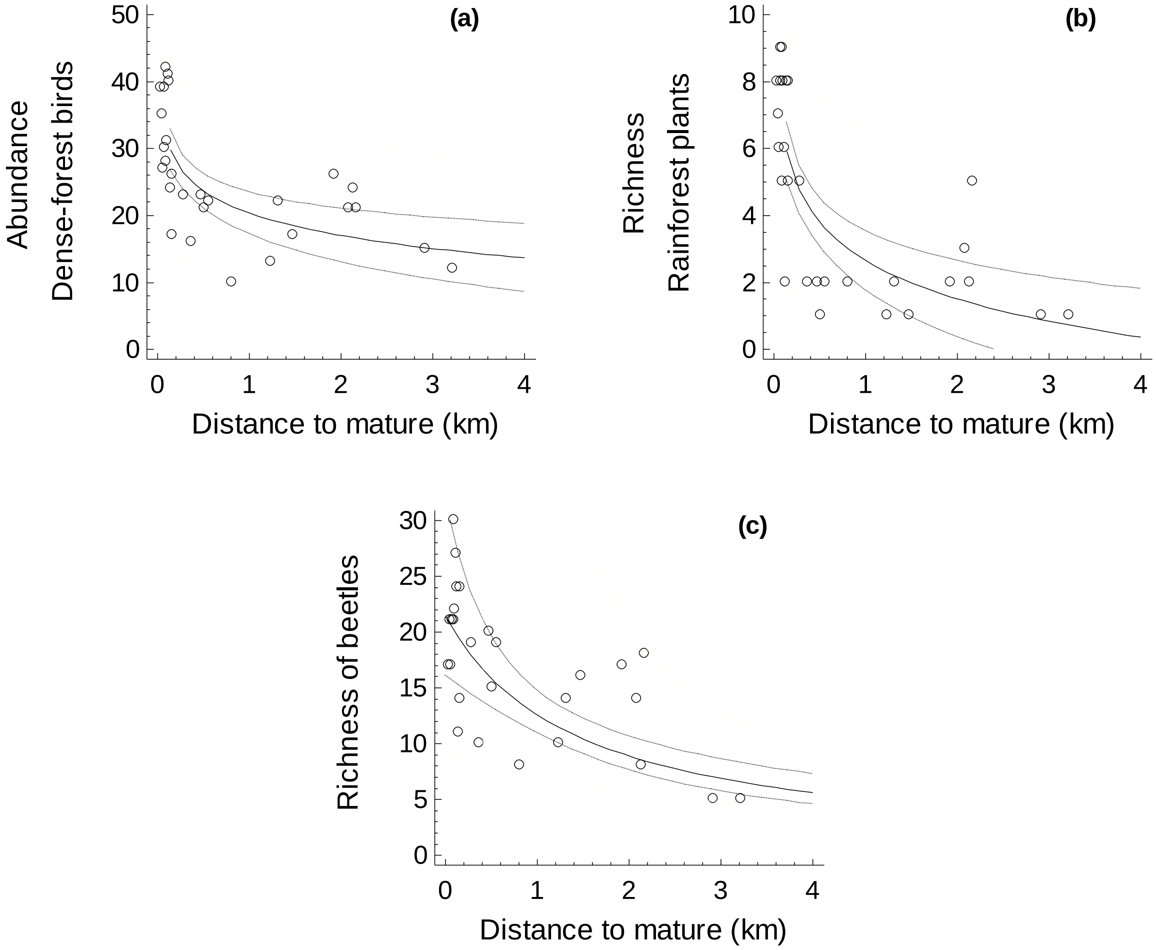


Figure 40. (a) Regressions of (a) abundance of dense-forest birds; (b) species-richness of rainforest plants; (c) disturbance sensitive beetle species in SILV with distance to the nearest patch of mature eucalypt forest or rainforest. Bird and plant data are best described by logarithmic models: (a) $y = 63.7 – 5.6*\mathrm{Ln}(x)$ ($r = -0.69$; $P<0.0001$); (b) $y = 14.6 – 1.67*\mathrm{Ln}(x)$ ($r = 0.78$; $P<0.0001$); while beetle data is best described by a reciprocal-y model (c) $y = 1/(0.047 + 0.328x$ ($r = 0.73$; $P<0.0001$))

Distance to the nearest patch of mature eucalypt forest or rainforest was strongly correlated with the proportion of mature eucalypt forest in the surrounding landscape, with the strength of correlation increasing with increasing landscape scale across the range 125 m – 4 km. The relationship between distance to mature and the proportion of mature eucalypt forest in the surrounding landscape was distinctly non-linear with a reciprocal-Y model best fitting the data at small scale (125 – 250 m); a logarithmic model best fitting the data between 500 m – 2 km scales; and an exponential model at the 4 km scale. Broken-stick models provided an equivalent or better fit (than logarithmic or exponential models) of the relationship between distance to mature and proportion of mature eucalypt in the landscape at the 1 - 4 km scales. At these scales broken-stick models provided a significant improvement over linear models (based on variance ratio of the residual mean squares from the broken-stick and linear regressions). In each case, broken-stick models provided an improvement over exponential or logarithmic models (Figure 41).

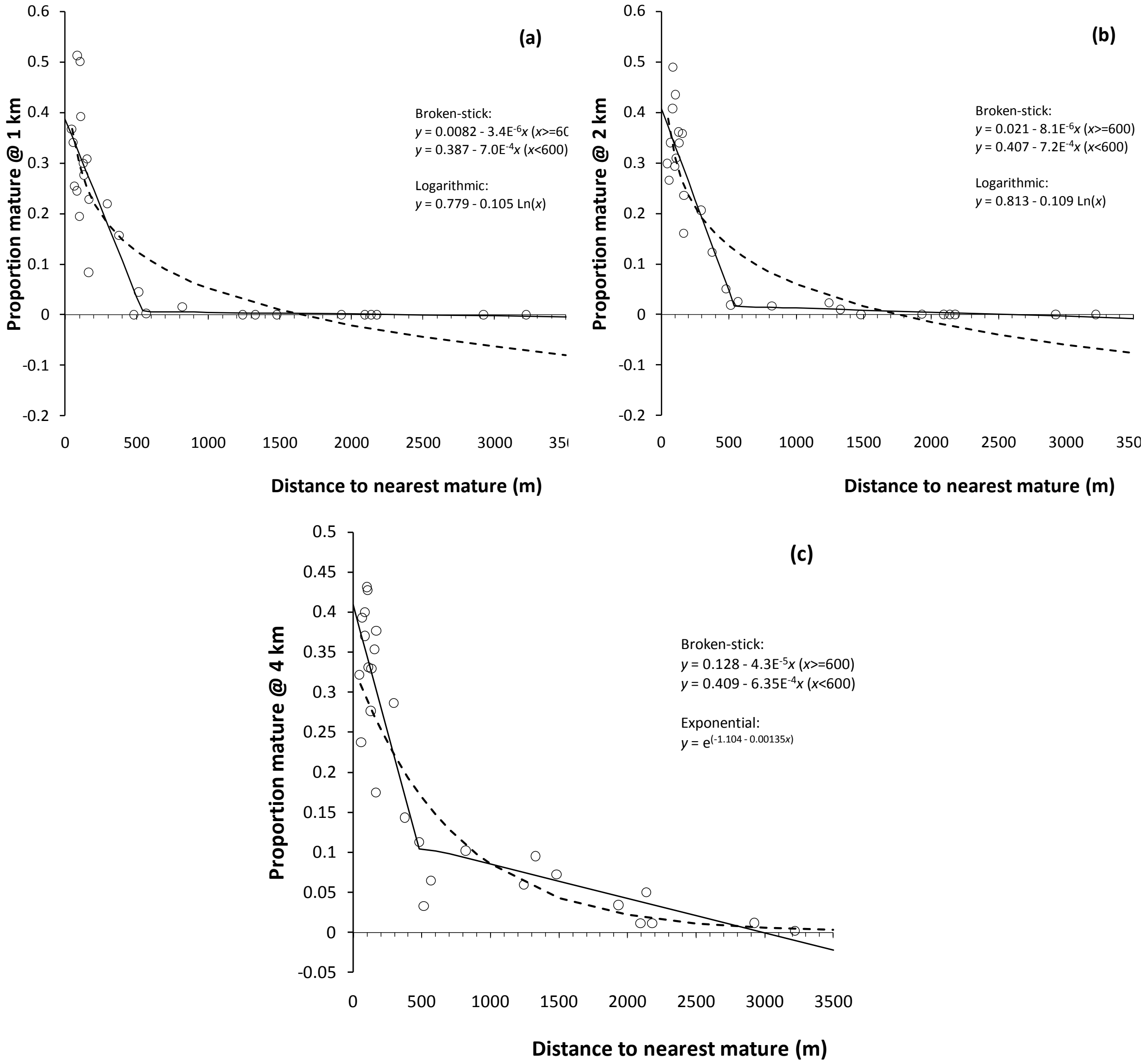


Figure 41. Scatter plots of the distance from plots of older silvicultural regeneration to the nearest patch of mature forest and the proportion of mature eucalypt forest in the surrounding (a) 1 km , (b) 2 km and (c) 4 km landscapes. Fitted broken-stick (solid line) and exponential or logarithmic (dashed line) models are shown.

The strong correlations across broad landscape scales shown by the subset of disturbance-sensitive species of the three focal groups with the amount of mature eucalypt forest in the landscape might be explained by distance to the nearest patch of mature forest. This was confirmed when the residuals from the regressions of (a) bird abundance; (b) rainforest species-richness; (c) disturbance-sensitive beetle richness with distance to closest patch of mature forest were regressed against amount of mature eucalypt forest in the surrounding landscape: residuals showed no significant correlation with amount of mature eucalypt forest in the surrounding landscape (Table 23).

Table 23. Correlation coefficients of regressions of four dependent variables with the amount of mature eucalypt forest in the surrounding 250 m – 4 km landscapes. Dependent variables were the abundance of dense-forest birds; the species-richness of rainforest plants; the species-richness of disturbance-sensitive beetles; and the residuals from their regressions with distance to the closest patch of mature eucalypt forest / rainforest. Results were based on regression models giving best fit: (√x) represents $y = a - bx^{0.5}$ and (x) represents $y = a + bx$.

Dependent variable	250 m	500 m	1 km	2 km	4 km	Significance-level
Abundance (birds)	0.77 (√x)	0.73 (√x)	0.68 (x)	0.68 (x)	0.71 (x)	All <0.0001
Residuals	0.25 (√x)	0.20 (x)	0.11 (x)	0.07 (x)	0.08 (x)	All n.s.
Richness (plants)	0.82 (√x)	0.84 (√x)	0.84 (x)	0.84 (x)	0.83 (x)	All <0.0001
Residuals	0.10 (x)	0.17 (x)	0.15 (x)	0.10 (x)	0.19 (x)	All n.s.
Richness (beetles)	0.63 (√x)	0.67 (x)	0.64 (x)	0.66 (√x)	0.66 (√x)	All <0.0001
Residuals	0.08 (x)	0.10 (x)	-0.11(√x)	-0.11(√x)	-0.09 (√x)	All n.s.

Testing for threshold values of distance to mature forests (eucalypt and rainforest) and proportion of mature eucalypt forest in the surrounding landscapes was performed for the disturbance-sensitive subset from the three focal groups. There was no evidence that a broken-stick model provided a better fit than a linear model for the regressions of four response variables (abundance of dense-forest birds, species-richness of rainforest plants, cover of rainforest plants and species-richness of disturbance-sensitive beetles) with the amount of mature eucalypt forest in the surrounding landscape. The results for a fifth potential independent variable – species-richness of dense-forest birds – are not shown because neither linear nor broken-stick models yielded significant regression models. F-tests of the residual mean squares from the linear and broken-stick models showed they did not significantly differ from each other for any threshold value (in the range 0.1 – 0.4) of the proportion of mature eucalypt forest in the surrounding 500 m – 2 km landscapes (Table 24).

Broken-stick models did provide significantly better fits than linear models for the relationship of the three response variables (abundance of dense-forest birds, cover of rainforest plants and species-richness of rainforest plants in older silvicultural regeneration) with distance to the nearest patch of mature forest (Table 25). A broken-stick model did not provide a significantly better fit than a linear model for the relationship between the species-richness of disturbance-sensitive beetles with distance to mature forest.

Table 24. Residual means squares from linear and broken-stick regression models of four dependent variables (the abundance of dense-forest birds - Birds; the species-richness of rainforest plants – Plants (richness), the cover of rainforest plants – Plants (cover), and the richness of disturbance-sensitive beetles (Beetles)) with the proportion of mature eucalypt forests in the 500 – 4 km landscapes surrounding older silvicultural regeneration plots. Four break-point values (0.1 – 0.4) of the proportion of mature eucalypt forests in the surrounding landscape were tested in the broken-stick models. The F-test is based on the variance ratio of the residual mean square from the linear and broken-stick model.

Landscape scale	Dependent variable	Linear model	Broken-stick model (break-point indicated)			
			<0.1	<0.2	<0.3	<0.4
500	Birds	44.38	36.68 $F_{24,26}$=1.21; P=0.32	36.68 $F_{24,26}$=1.21; P=0.32	57.63 $F_{24,26}$=0.77; P=0. 74	58.99 $F_{24,26}$=0.75; P=0. 76
	Plants (richness)	2.64	2.63 $F_{24,26}$=1.0; P=0.49	2.63 $F_{24,26}$=1.0; P=0.49	2.58 $F_{24,26}$=1.02; P=0.48	2.67 $F_{24,26}$=0.99; P=0.51
	Plants (cover)	259	275 $F_{24,26}$=1.0; P=0.49	275 $F_{24,26}$=1.0; P=0.49	256 $F_{24,26}$=1.0; P=0.48	273 $F_{24,26}$=0.99; P=0.51
	Beetles	22.9	23.7 $F_{24,26}$=0.97; P=0.53	23.7 $F_{24,26}$=0.97; P=0.53	22.8 $F_{24,26}$=1.0; P=0.49	22.6 $F_{24,26}$=1.0; P=0.48
1000	Birds	49.68	53.57 $F_{24,26}$=0.93; P=0.57	46.73 $F_{24,26}$=1.06; P=0.44	42.21 $F_{24,26}$=0.98; P=0. 52	43.94 $F_{24,26}$=0.97; P=0.53
	Plants (richness)	2.53	2.69 $F_{24,26}$=0.94; P=0.56	2.52 $F_{24,26}$=1.0; P=0.49	2.58 $F_{24,26}$=0.98; P=0.52	2.61 $F_{24,26}$=0.97; P=0.53
	Plants (cover)	250	270 $F_{24,26}$=0.93; P=0.56	260 $F_{24,26}$=0.96; P=0.49	267 $F_{24,26}$=0.94; P=0.52	263 $F_{24,26}$=0.97; P=0.53
	Beetles	24.9	26.9 $F_{24,26}$=0.92; P=0.57	26.3 $F_{24,26}$=0.95; P=0.55	22.5 $F_{24,26}$=1.1; P=0.40	25.1 $F_{24,26}$=0.99; P=0.51
2000	Birds	40.92	44.15 $F_{24,26}$=0.92; P=0.57	36.46 $F_{24,26}$=1.12; P=0.39	38.78 $F_{24,26}$=1.06; P=0. 45	38.74 $F_{24,26}$=1.06; P=0. 44
	Plants (richness)	2.50	2.61 $F_{24,26}$=0.96; P=0.54	2.56 $F_{24,26}$=0.98; P=0.52	2.51 $F_{24,26}$=1.0; P=0.50	2.57 $F_{24,26}$=0.97; P=0.52
	Plants (cover)	253	272 $F_{24,26}$=0.96; P=0.54	270 $F_{24,26}$=0.98; P=0.52	267 $F_{24,26}$=0.95; P=0.55	270 $F_{24,26}$=0.94; P=0.56
	Beetles	23.9	24.2 $F_{24,26}$=0.99; P=0.51	24.9 $F_{24,26}$=0.96; P=0.54	25.8 $F_{24,26}$=0.93; P=0.57	25.6 $F_{24,26}$=0.93; P=0.57
4000	Birds	43.24	44.83 $F_{24,26}$=0.96; P=0.53	36.79 $F_{24,26}$=1.18; P=0.34	45.36 $F_{24,26}$=0.95; P=0. 54	42.86 $F_{24,26}$=1.0; P=0. 49
	Plants (richness)	2.50	2.74 $F_{24,26}$=0.91; P=0.59	2.78 $F_{24,26}$=0.9; P=0.60	2.98 $F_{24,26}$=0.84; P=0.67	2.57 $F_{24,26}$=0.97; P=0.53
	Plants (cover)	253	269 $F_{24,26}$=0.94; P=0.56	268 $F_{24,26}$=0.94; P=0.56	227 $F_{24,26}$=1.11; P=0.39	251 $F_{24,26}$=1.01; P=0.49
	Beetles	23.9	25.4 $F_{24,26}$=0.94; P=0.56	24.9 $F_{24,26}$=0.96; P=0.54	24.7 $F_{24,26}$=0.97; P=0.53	23.5 $F_{24,26}$=1.02; P=0.48

The break-points corresponding to the most significant improvement of the broken-stick model (lowest residual mean square) relative to the linear model were150 m, 100 m, 300 m and 150 m for the abundance of dense-forest birds; cover of rainforest plants; species-richness of rainforest plants; and species-richness of disturbance-sensitive beetles respectively (Table 25). However, higher break-points are suggested if the criterion for identifying the optimum break-point is to maximise the significance of the differences in slopes (maximise the T-value of the differences in slopes) between the two segments of the broken-stick model. On that criterion, the suggested break-points are 400 m, 150 m, 600 m and 150 m for the abundance of dense-forest birds; cover of rainforest plants; species-richness of rainforest plants; and species-richness of disturbance-sensitive beetles respectively (Figure 42). These break-points still produce broken-stick models that are significantly better than linear models for the cover and species-richness of rainforest plants but not for the abundance of dense-forest birds (although the difference does approach statistical significance), or the species-richness of disturbance-sensitive beetles.

Table 25. Residual means squares (RMS) from linear and broken-stick (B-S) regression models of four dependent variables (the abundance of dense-forest birds, cover of rainforest plants, species-richness of rainforest plants and species-richness of disturbance-sensitive beetles) with the distance to the nearest patch of mature forest. The F-ratio and associated probability-level (P<0.05 denoted by an asterisk) based on the residual mean square from the linear model and broken-stick model at the indicated break-point are shown in parentheses. Results for which the probability value was <0.05 are shown in bold.

Break-point value (m to nearest mature)	Abundance of dense-forest birds	Cover of rainforest plants	Species-richness of rainforest plants	Species-richness of disturbance-sensitive beetles
100 m	56.37 (1.04ns)	**123.06 (2.36*)**	4.71 (1.13ns)	25.5 (0.94ns)
150 m	**27.18 (2.15*)**	**126.38 (2.30*)**		17.8 (1.35ns)
200 m	36.61 (1.59ns)	155.86 (1.87ns)	2.83 (1.88ns)	24.1 (1.00ns)
300 m	37.1 (1.57ns)	202.45 (1.44ns)	**2.49 (2.14*)**	23.8 (1.01ns)
400 m	36.48 (1.60ns)		**2.56 (2.08*)**	23.4 (1.03ns)
500 m	39.95 (1.46ns)		**2.58 (2.06*)**	
600 m	41.44 (1.41ns)		**2.61 (2.04*)**	
900 m			3.03 (1.76ns)	
Linear RMS	58.36	290.8	5.32	24.0

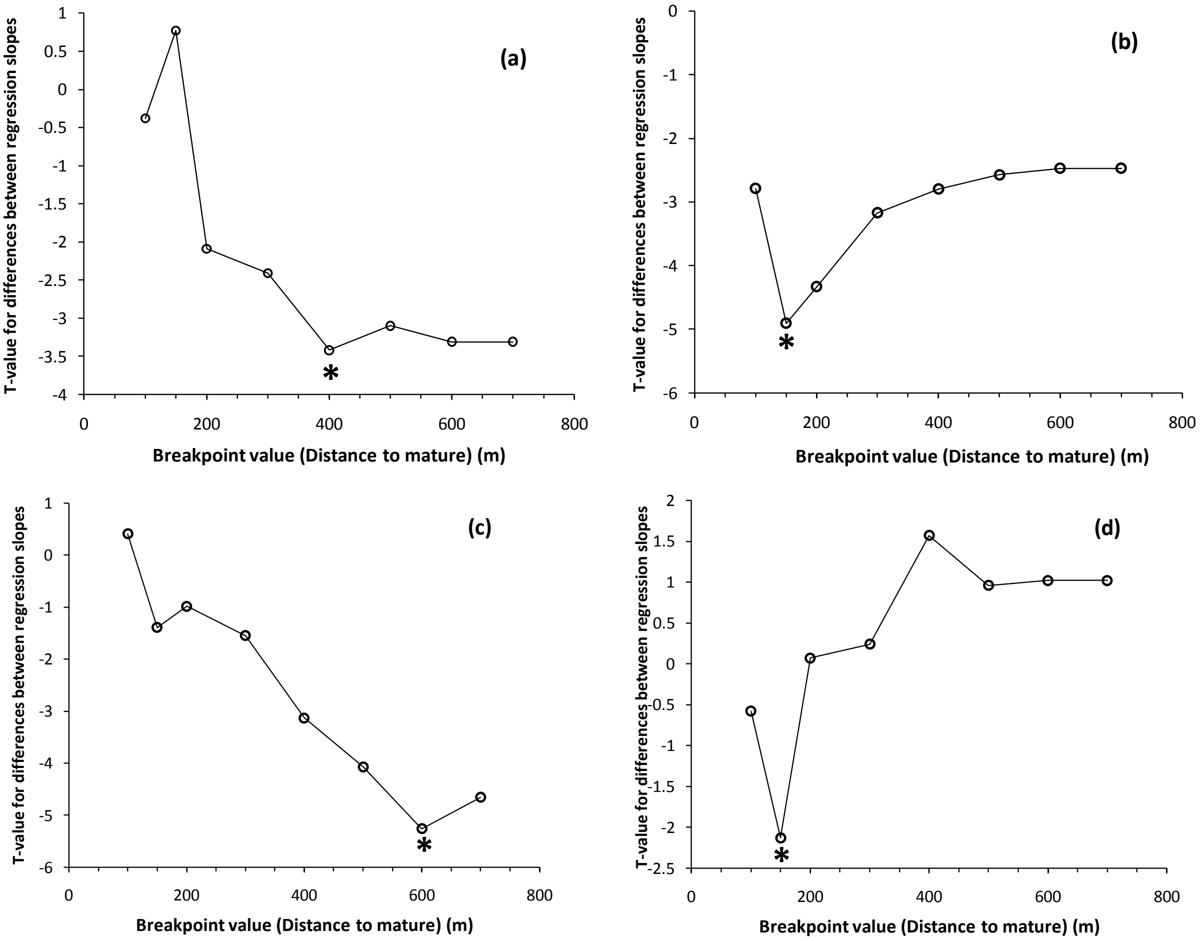


Figure 42. T-values of the difference between slope coefficients of the two segments of broken-stick regressions at varying values of the breakpoint (largest absolute t-value indicated with an asterisk) for the regressions of: (a) abundance of dense-forest birds; (b) cover of rainforest plants; (c) species-richness of rainforest plants; and (d) species-richness of disturbance-sensitive beetles in plots of older silvicultural regeneration with distance to mature forest.

The change in break-points depending on minimising residual mean squares or maximising the significance of difference in slopes between the two regression segments was particularly marked for the models of the abundance of dense forest birds with distance to mature forest. The lower break-point based on minimising residual mean square resulted in a model that provided a strong fit for the segment above the break-point but poorly fitted the segment below the break-point (Figure 43a). The fitted model suggests that at close distances (below the break-point) there is a sharp increase in the abundance of dense forest birds in older silvicultural regeneration with increasing distance from mature forest – a result that runs contrary to the strong preference of dense forest birds with mature forest. The alternative break-point based on maximising the significance of difference between the two segments of the model predicts a strong increase in abundance of dense forest birds with decreasing distance to mature forest once older silvicultural regeneration is within 400 m of mature forest (Figure 43b). This relationship is ecologically more acceptable, as it agrees with the strong preference for mature eucalypt forest shown by dense forest birds. Even though the improvement of the fit (relative to the linear model) of the broken-stick model using a 400 m break-point drops below statistical significance (Table 26) the model still provides a substantial improvement over the linear model - R^2 for linear and broken-stick models were 32.8% and 56.4%, respectively. The fitted broken-stick regression models for the three dependent variables that produced models significantly better than their corresponding linear model are shown in Figure 44.

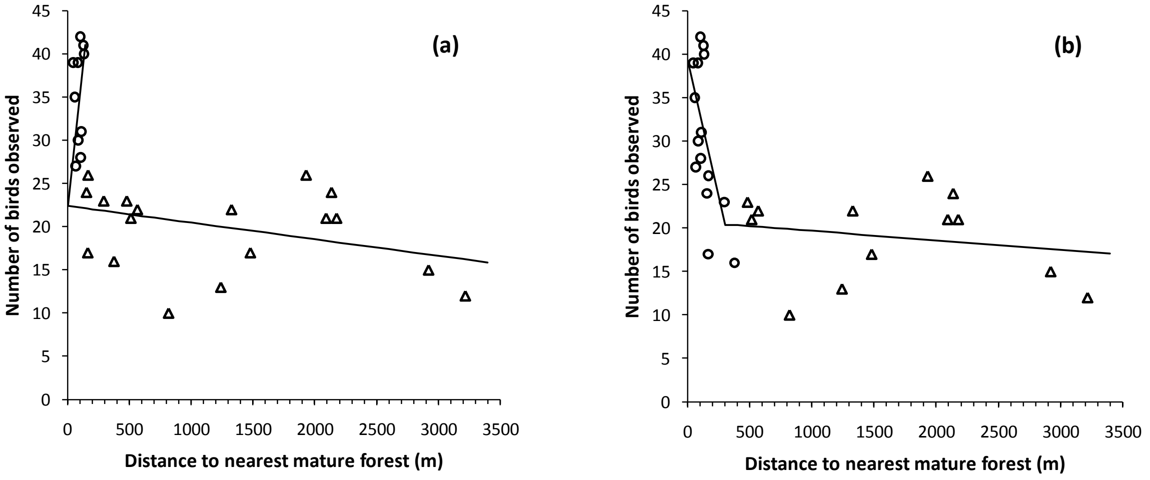


Figure 43. Broken-stick regressions of the abundance of dense forest birds with the distance to mature forest based on break-points of: (a) 150 m (minimise residual mean square); (b) 400 m (maximise significance of differences in slopes of the component sections of the regression).

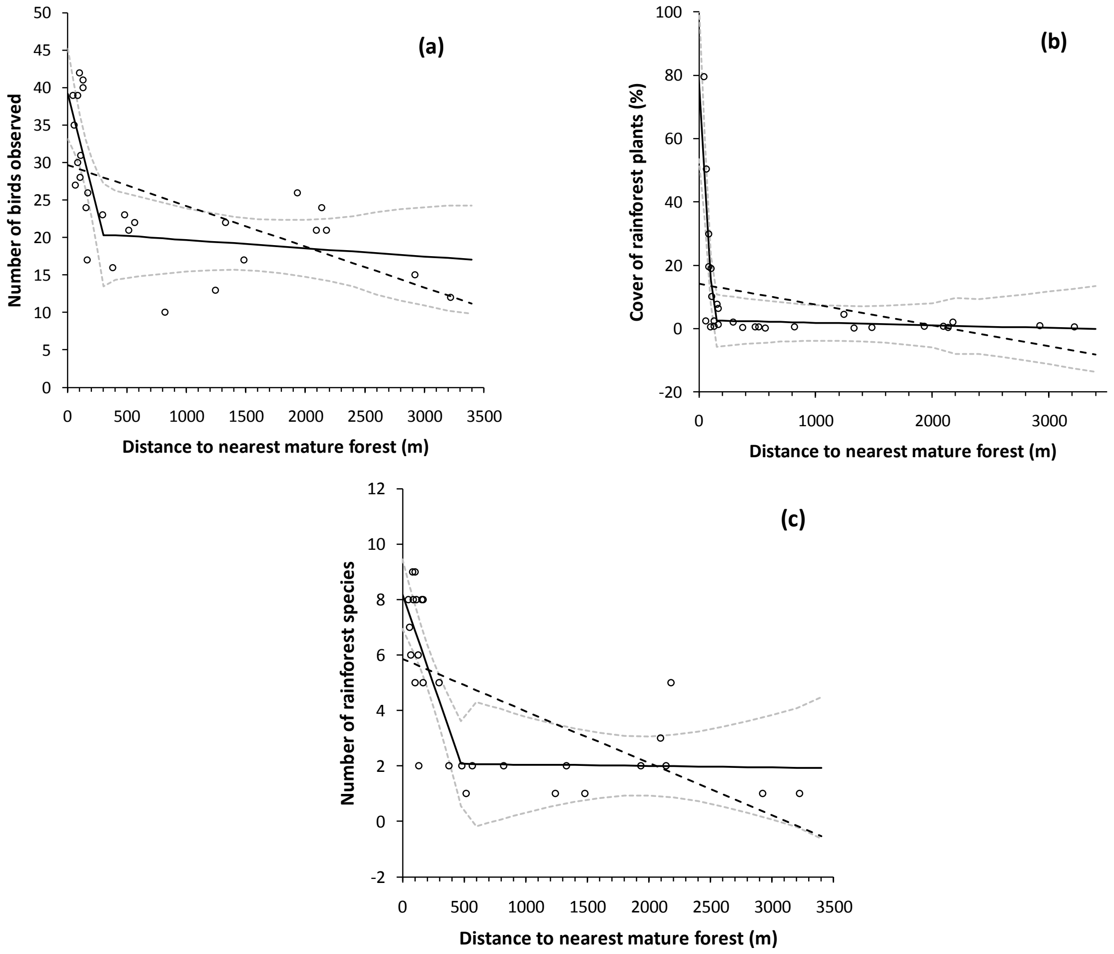


Figure 44. Broken-stick regressions of: (a) the abundance of dense-forest birds; (b) cover of rainforest plants; and (c) species-richness of rainforest plants in plots of older silvicultural regeneration with the distance to nearest patch of mature forest (eucalypt or rainforest). Broken-stick regressions (solid line with 95% confidence intervals shown in light dotted lines) are based on the break-point values indicated in Figure. The comparative linear regression model is shown by the black dashed lines.

The relationships between distance to mature forest and the amount of mature forest in the surrounding landscapes are a function of the configuration of the mature forest patches. The broken-stick models fitted to the data describing distance to mature versus proportion of mature eucalypt forest in the surrounding landscape data (Figure 41) were used to predict the amount of mature eucalypt forest in the surrounding landscape that corresponded to the break-points of the broken-stick regressions of the three dependent variables with distance to mature forest. The 150 m threshold of proximity to mature forest established as the break-point for the broken-stick model of cover of rainforest plants corresponded with the 1 - 4 km landscapes containing 28 - 31% mature eucalypt forest (Figure 45). The 400 m (mid-range) threshold of proximity to mature forest for the broken-stick model of the abundance of dense-forest birds corresponded with 1 - 4 km landscapes containing 11 - 16% mature eucalypt forest, respectively. The wider 600 m threshold from the broken-stick model of species-richness of rainforest plants predicted with the 1 - 4 km landscape would contain negligible mature forest.

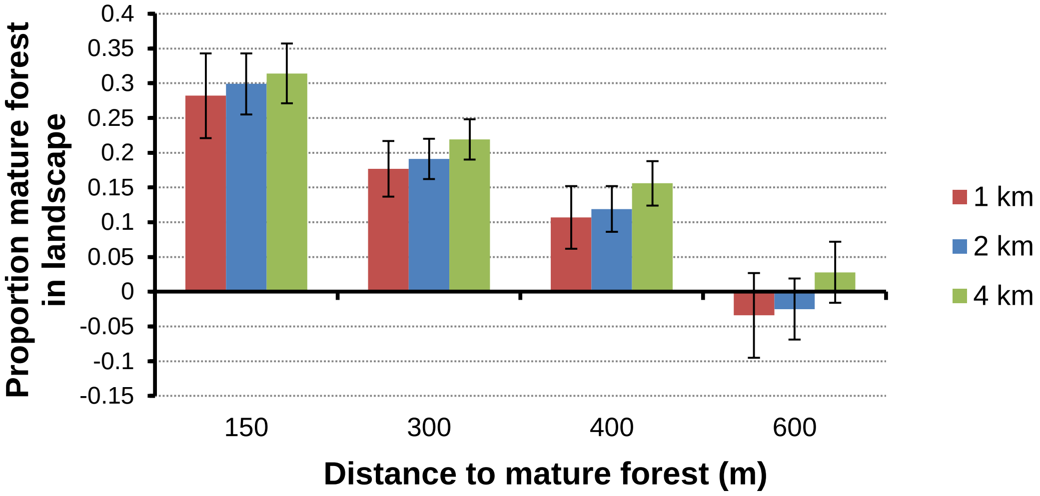


Figure 45. Predicted proportions of mature forest in the 1, 2 km and 4 km landscapes (and their 95% confidence intervals) corresponding to four distances to mature forest. The predictions were made using the broken-stick regressions of proportion of mature eucalypt forest in the landscape with distance to mature forest (shown in Figure 41).

Discussion

Did the SFEFL capture the intended gradient of disturbance intensity?

The disturbance gradient

The landscape disturbance metric – context-class – provided near-linear progression in the ratio of anthropogenic : natural vegetation-groups in the surrounding 500 m – 2 km radius landscapes. The ratios ranged from 80%:20% in the most intensively disturbed parts of the landscape (context-class 3) to 11%:89% in the least disturbed parts of the landscape (context-class 7). The gradient did not extend to cover landscapes with 0 and 100% in either anthropogenic or natural disturbance as Cushman and McGarigal (2003) did in their study for similar landscape scales (their 250-300 ha landscapes correspond with a 1 km radius landscape). This was because of the additional need to locate plots in both mature eucalypt forest and older silvicultural regeneration in this study. This requirement truncated sampling options at both ends of the anthropogenic : natural ratio range: it would have been impossible to locate any plots of older silvicultural regeneration in landscapes with 100% natural disturbance and vice versa. In fact, the SFEFL was unable to provide sufficient mature eucalypt forest to sample in the context-class corresponding to the maximum level of disturbance-intensity sampled (context-class 3), nor sufficient older silvicultural regeneration in the context-class corresponding to the lowest intensity of disturbance sampled (context-class 7).

The context-class score was a critical step involved in quantifying the disturbance gradient. The gradient reflected differing ratios of nine broad vegetation-groups within the surrounding landscape. The initial attempt used to establish a gradient involved using cluster analysis (k-means clustering) to assign each point in the landscape to a class based on the mix of the broad vegetation-groups in the surrounding landscape. While statistically sound, this method produced some clusters that were difficult to interpret with regard to their position along the disturbance gradient, since the clustering algorithm had no preconceived notion of the relative disturbance information signified by individual vegetation-groups. To overcome this problem a weighted approach was adopted, whereby the area of each vegetation-group in the landscape was weighted by a subjective score reflecting the position of the vegetation-group along a continuum of disturbance / ecological stability. While the position along that continuum was a subjective decision, it was informed by an understanding of the typical intervals between disturbance events that maintain that vegetation-group (e.g. Gilbert 1959). The approach is similar to the Landscape Development Intensity Index described by Brown and Vivas (2005), although the weighting they assigned to each particular land-use was quantitative based on the non-renewable energy inputs used to create that land-use. One risk of our approach is that an even mix of vegetation-groups at opposing ends of the continuum (e.g. rainforest and button-grass moorland) could produce mid-range context-scores rather than through the dominance of vegetation-groups in the mid-range of the disturbance continuum. However, our requirement to sample either older silvicultural regeneration or mature eucalypt forest in the landscapes helped to ensure that the landscapes with mid-range context-scores were not dominated by vegetation-groups at opposing ends of the disturbance continuum.

Other potentially confounding gradients

Our experimental aim was to test the effect of the disturbance-intensity gradient on the abundance, richness and assemblage composition of three focal groups. We therefore needed to ensure that the gradient of disturbance-intensity was not confounded with other gradients that would have prevented isolating the disturbance-intensity effect. While several other gradients were present within the SFEFL, they were generally not confounded with the context-class gradient to an extent that would mask the effects of any disturbance-intensity gradient on the three focal groups.

The disturbance-intensity gradient had a strong geographic component: the intensity of disturbance increased from west to east. This resulted in a significant climatic gradient (particularly reflected in rainfall, radiation and moisture) being superimposed on the disturbance-intensity gradient. However, only the open-forest and dense-forest bird habitat groups contained elements showing significant responses to the geographic and climatic gradients in parallel with their response to the gradient of disturbance-intensity. In these bird groups, significant responses in abundance and richness to the geographic / climatic and the disturbance gradients depended on the forest type of the plot: in MAT plots the abundance and richness varied significantly with the geographic / climatic gradient, but not the disturbance gradient; the converse occurred in SILV plots. Thus the geographic / climatic gradient did not impede the capacity to detect significant responses by the bird group to the disturbance gradient in SILV. In the other two focal groups there were significant responses in abundance, richness or assemblage composition to the geographic / climatic gradients. However, those responses never overlapped with significant responses to the gradient in disturbance-intensity.

The chemical properties of the topsoil in the plots varied significantly among context-classes along the disturbance-intensity gradient. This was due to two gradients: (i) positive correlations in the concentrations of calcium and magnesium, and soil pH that increased along soil principal components axis-1; (ii) the additive effect of soil aluminium and iron concentrations that decreased along soil principal components axis-2. Both gradients separated context-class 4 plots from plots in the other context-classes. While soil properties appeared in few Random Forests models describing the abundance of individual species, they nonetheless explained significant variation in assemblage composition of the beetle and plant communities. Soil PCA axis-1 score and context-class were confounded for beetle abundance at the overall context-class level. However, beetle response to the gradient of disturbance-intensity was determined to be relatively weak, given that no significant differences in either abundance or species richness were detected among context-classes within MAT or within

SILV (with or without soil PCA axis-1 as a covariate). The species-richness of rainforest plants in SILV plots also varied significantly with soil PCA axis-1; however, the significant responses to the disturbance gradient remained after controlling for the soil effect.

The assemblage composition of beetles varied significantly with the volume of CWD. Furthermore, there was a significant difference in CWD volumes among context-classes, with significantly lower volumes of CWD in the most disturbed parts of the landscape. Despite this, CWD volume only appeared as a significant covariate in the ANCOVA models testing for differences in the abundance and richness of the subset of disturbance-sensitive species. For this subset of beetles, CWD volume either alone, or with other covariates, confounded differences among context-classes.

There were two temporal gradients superimposed on the disturbance-intensity gradient: context-score based on mapped vegetation-groups from 1947 photography; and time since last fire. The gradient in 1947 context-score was never a significant covariate in ANCOVA models testing the effect of the disturbance gradient on the abundance / richness of any of the focal groups. Time since last fire was, however, a significant covariate in ANCOVA models testing the effect of disturbance-intensity on the cover of rainforest plants. However, controlling for time since last fire had little effect on the significance-level of differences due to disturbance-intensity.

Did mature forest continue to provide habitat for mature-forest species regardless of disturbance-intensity in the surrounding landscape?

Yes. We found very intact assemblages of plants and animals: all but two (both birds) of the 635 species recorded from MAT plots were native species; many were endemic to Tasmania. Mature eucalypt forests continue to provide viable habitat for birds and plants regardless of intensity of disturbance in the surrounding landscape. This included the most disturbance-sensitive elements – the dense-forest birds and rainforest plants. This interpretation is strengthened by the lack of significant differences extending down to the most disturbed landscapes sampled by MAT plots (context-class 4). MAT plots in context-class 4 have had a longer history of disturbance than MAT plots in context-classes 5-7: the context-scores of MAT plots in context-class 4 were already showing a significant reduction when they were calculated using forest type mapping from 1947 aerial photography (Figure17).

Species-richness in the subsets of rare (uncommon in SFEFL) species of birds and beetles in the MAT plots also showed no significant differences among context-classes. Furthermore, at the species-level, we could not detect any significant differences in abundance among context-classes in the great majority (97%) of the common species. The small number of species for which we did detect significant differences among context-classes of MAT plots could be explained by factors other than the intensity of management in the surrounding landscape.

While beetles as a group did not show a significant response to the landscape disturbance gradient, the subset of disturbance-sensitive species did: their abundance and richness in MAT plots were both lower in the most disturbed parts of the landscape. The lower abundance of disturbance-sensitive beetle species in MAT plots in the most disturbed parts of the landscape was explainable by the amount of CWD: MAT plots in the most-disturbed parts of the landscape had significantly lower amounts of CWD than MAT plots in less highly-disturbed parts of the landscape. The reason for the lower CWD volumes in context-class 4 MAT plots was not determined. However, it is most likely the legacy of long-term natural processes, because the mature eucalypt trees in the forests sampled in context-class 4 originated before the commencement of forestry in the SFEFL.

The lower species-richness of disturbance-sensitive beetles in MAT plots in the most disturbed parts of the landscape could be explained by the sum effects of low volumes of CWD, low amounts of mature eucalypt forest in the landscape and sensitivity to the density of roads in the landscape. Roading is unequivocally associated with production forestry. The restriction of sensitivity of disturbance-sensitive beetles to road density to context-class 4 suggests that sensitivity only emerges when the additional stress of low volume of CWD and mature eucalypts in the landscape are introduced. Lower volumes of CWD are likely the result of past disturbance events (wildfires) that predate forestry activities in the SFEFL. Spies *et al.* (1988) in one of the few studies documenting the long-term effects of fire history on CWD, found CWD volumes declined at mid-ages (80-120 years) since last fire and again in very old forests (>500 years). The long-term fire history of the SFEFL has not been documented. However, there is evidence that the more intensively-disturbed parts of the SFEFL may have a longer history of more regular fire disturbance. The data from the SILV plots suggest this: plots in context-classes 3-4, which had low volumes of CWD, were predominantly regrowth forests prior to the 1967 wildfire. While, Turner *et al.* (2009) could find no spatial pattering of stand replacing (typically in forests that are younger at the time of the fire) versus non-stand-replacing wildfires in southern Tasmania, a higher fire frequency in the eastern parts of the SFEFL would be consistent with local climatic gradients. The low amount of mature eucalypt forest in the more intensively-disturbed parts of the SFEFL thus may represent the combined effects of past forest harvesting as well as longer-term fire history. A study currently under way in the SFEFL (by co-authors CS and LF) is using molecular methods to determine population structures of several saproxylic beetle species, including *Prostomis atkinsoni* – a member of the disturbance-sensitive subset. This may provide evidence in support or otherwise of a long history of more regular disturbance in the eastern (lower context-classes) parts of the SFEFL.

The species-richness of rare/uncommon plant species differed significantly among context-classes: MAT plots in context-class 4 were richer in this subset of plant species than were MAT plots in the other context-classes. The suite of rare / uncommon plants in plots of context-class 4 was ecologically diverse and included rainforest species (*Prionotes cerinthoides, Trochocarpa gunnii*) through to moist/dry sclerophyll species (*Acacia verniciflua, Bedfordia salicina, Beyeria viscosa*). Mature-forest plots in context-class 4 spanned an east-west range that was 2.4 and 3.1 times wider than that of the range of MAT plots in context-classes 6 and 7, respectively. Thus the greater richness of rare /uncommon plants in plots in context-class 4 more likely reflects the wider geographic range spanned by plots in this context-class, rather than the higher intensity of management in the surrounding landscape.

There were some significant differences among MAT plots in different context-classes in the abundance of three bird species: one (Tasmanian scrubwren) was significantly less abundant in plots in context-class 4, while two (crescent honeyeater and yellow-throated honeyeater) showed the reverse trend. The abundances of the Tasmanian scrubwren and the yellow-throated honeyeater were each significantly correlated with plot easting – negatively and positively, respectively. This paralleled geographic differences among plots in different context-classes: plots in context-class 4 occupied significantly more easterly positions than plots in context-classes 6 and 7. The differences in abundances among plots in different context-classes for the Tasmanian scrubwren and yellow-throated honeyeater disappeared once the effect of plot easting was removed.

Several vascular plant species also showed significant, or nearly significant, differences in cover-abundance among MAT plots in different context-classes; however, those differences did not follow the gradient of management intensity represented by plot context-class. The differences were due to higher cover-abundance of some rainforest species, and lower abundance of some early successional species, in plots of context-class 5. Plots in context-class 5 occurred chiefly in parts of the SFEFL that escaped the 1934 wildfire, whereas a high proportion of plots in context-classes 6 and, particularly, 7 were in parts of the SFEFL affected by the 1934 wildfire. In much of the SFEFL the 1934 wildfire was not stand-replacing (Hickey *et al.* 1999, Turner *et al.* 2009). Although the 1934 wildfire was not stand-replacing where those MAT plots were sited, it nonetheless left an ecological signature. The cover-abundance of rainforest species was significantly positively correlated with time since last fire (as of 2010). The differences in cover-abundance among the context-classes disappeared after accounting for time since last fire.

Have mature-forest species successfully recolonised older silvicultural regeneration?

Not entirely yet. SILV and MAT did share many species (82%, 62% and 70% of birds, beetles and plants, respectively), which were overwhelmingly native to the local area, and often endemic to Tasmania: only two introduced species were detected (lyrebird and kookaburra). However, we detected significant differences in assemblage composition between MAT and SILV, and many more species were detected as significant indicators of MAT than of SILV.

Birds, particularly dense-forest birds, and rainforest plant species showed the strongest differences in both abundance and richness between the two forest types. However, those differences diminished as the intensity of disturbance in the landscape decreased to such an extent that in the least-disturbed landscapes differences between MAT and SILV were no longer significant. This was a surprising result. SILV, while old enough to have developed a closed canopy sufficient to exclude early seral species of birds and plants, was nonetheless still in the early phase of progression towards maturity. Previous studies in local tall eucalypt forests have found significant differences between mature and silvicultural regeneration in both birds (Hingston and Grove, 2011) and plants (Hickey 1994) at comparable regeneration ages. The key difference between this and previous studies comparing the biodiversity of mature and silviculturally regenerated forests is that this study controlled for plot context-class, that is, for the degree of landscape-level disturbance surrounding plots. We do not know the plot context-class in earlier studies, but, as this study has shown, plot context-class has a very strong influence on the degree to which silviculturally regenerated forest has progressed towards a mature-forest biodiversity by a given age.

For both birds (particularly dense-forest species) and rainforest plants, the declining contrast between MAT and SILV with increasing context-class (that is, decreasing landscape-level disturbance) could be explained by increases in the amount of mature eucalypt forest in the surrounding landscape. The decline in contrast between MAT and SILV with increasing context-class could also be explained by an increasing proximity of SILV to mature eucalypt forest and rainforest. We were unable to detect independent effects of proximity to mature forest and the amount of mature eucalypt forests in the surrounding landscapes, so for these particular taxa the two measures may reflect the same ecological process (the rate of successful recolonisation of regenerating forest from mature-forest refugia).

The significant difference among plots in different context-classes in the assemblage composition of beetles in SILV was a subtle effect, contrasting context-classes 3 and 6. Neither the overall abundance nor species richness of beetles in older silvicultural regeneration differed significantly among plots in different context-classes. However, a small number of species did differ significantly in their abundance among plots in different context-classes or responded to specific measures of disturbance (road density, amounts of mature eucalypt forest / older silvicultural regeneration in the landscape) in Random Forests models.

The abundance of this subset of disturbance-sensitive species showed the same contrast between plots in context-classes 3/4 and 6 that was reflected in the results for assemblage composition. The same sub-set of beetles also showed a significant linear relationship in their richness with the amount of mature eucalypt forest in the surrounding landscape. This suggests that the subset might be dominated by species preferring mature forests. One species in the disturbance-sensitive subset, *Prostomis atkinsoni*, is known to prefer brown-rotted wood, which mainly develops in mature eucalypts and the large logs they generate (Yee *et al.* 2006, Wardlaw *et al.* 2009). However, too little is known about the ecology of Tasmanian forest-inhabiting beetles to know if the other species in the subset share similar preferences.

An unexpected finding was that beetle abundance, particularly of the disturbance-sensitive subset, was responding to different plot-level attributes in MAT versus SILV plots: the amount of CWD in MAT plots and soil chemistry (concentrations of calcium and magnesium, and pH) in SILV plots. This result is not readily explicable and is all the more curious given the lack of significant differences in the abundance or richness of beetles between plots in mature eucalypt forest and those in older silvicultural regeneration. One possible explanation is that elements of the beetle fauna might occupy a range of habitats including, but not restricted to, eucalypt CWD – for example fine woody debris or leaf-litter. A shift in the balance of these habitats between mature eucalypt forest and silvicultural regeneration could result in beetles responding more strongly to a particular habitat in mature forests (CWD) and a different habitat in silvicultural regeneration. However, no candidates for alternative habitats were identified: none of the site and landscape metrics screened to predict the abundance of beetle species using Random Forests showed marked contrast between mature eucalypt forests and older silvicultural regeneration.

Identifying biodiversity elements most sensitive to disturbance

A subset of species from each of the three focal groups showed a strong response to the disturbance-intensity gradient in the SILV plots. The subsets of the disturbance-sensitive birds and plants were each clearly separated from the other species within their respective focal group in NMS ordinations, suggesting ecological commonalities. By contrast, the subset of disturbance-sensitive beetles could not be differentiated from other beetle species in the NMS ordination. Results from previous studies in and around the Warra Supersite suggest the disturbance-sensitive beetles have a diverse range of ecological traits. Of the 38 disturbance-sensitive species, 16 have been documented from previous (mainly log-decay) studies. Four were identified as early colonisers of logs, while another two prefer large mature logs with brown rot (a mid- to late-decay-stage). Four species were sensitive to fuelwood harvesting but another three were insensitive to fuelwood harvesting. The remaining two species have broad habitat associations. Of these traits, only early log colonisation can be interpreted in the context of disturbance-sensitivity: SILV plots had significantly lower amounts of new CWD additions than did MAT plots (Appendix 2).

The disturbance-sensitive sub-set of birds – the dense-forest birds - was identified as a group, *a priori*, based on published descriptions (habitat description in Tasmanian Bird List: www.parks.tas.gov.au/index.aspx?base=20811) of the range of vegetation types they inhabit. Most in the group belong to the guild that feeds in the lower stratum of the forest (Lefort and Grove 2009), but not exclusively so: strong-billed honeyeater, a canopy species, was included in the dense-forest group based on its habitat being listed as “mature, wet forest, cool temperate rainforest, wet scrub and heath”. However, this species was an outlier of the dense-forest group in the species ordination. Neither were all of the species of the guild that feeds in the lower stratum classified as dense-forest species: four of the 10 lower-stratum guild in Lefort and Grove (2009) were categorised as generalists in the present study.

Table 28. Ecological traits of fifteen disturbance-sensitive beetles inferred from the results of published studies. [1.] Yee et al. (2005); [2.] Grove and Forster (2011b); [3.] Grove (2009); [4.] Lawrence (1994)

Log colonisation	Sensitivity to fuelwood harvesting	Diverse habitats
Early colonisers: • *Aleocharinae TFIC sp 066*[2] • *Macrohyliota bicolor*[2] • *Quedius sidneensis*[2] • *Hymaea succinifera*[2]	Sensitive: • *Nargomorphus consimilis*[3] • Ptiliidae TFIC sp 06[3] • *Sericoderus* TFIC sp 02[3] • *Sericoderus* TFIC sp 06[3]	• *Sirrhas variegatus*[4] • *Macroplectus CHANDLER Type 1*[2]
Brown-rot (late decay stage) preferred: • *Syndesus cornutus*[1] • *Prostomis atkinsoni*[1]	Insensitive: • *Litochrus alternans*[3] • *Nargomorphus globulus*[3] • Ptiliidae TFIC sp 08[3]	

Only 12 of the 22 bird species identified as indicators of mature forests in Lefort and Grove (2009) were identified as indicators of mature forests in this study. The differences between the two studies were even more marked for species identified as indicators of young regeneration: 10 species were indicators of young regeneration in Lefort and Grove (2009), while there were no indicators of silvicultural regeneration detected in this study. The stronger contrast in forest ages (mature versus 1-3 year-old regeneration) in Lefort and Grove's study is the likely reason for the differences, compared to the lesser contrast in forest age in this study. Despite the differences between the studies, the subset of dense-forest species showed full agreement with Lefort and Grove (2009): all except for two rarely encountered species were identified as indicators of mature forests in both studies.

The disturbance-sensitive plants were identified as a group, *a posteriori*, based on their significant negative response to disturbance. Disturbance-sensitive plants were subsequently recognised as an ecological group dominated by species inhabiting rainforest. The clustering of rainforest species in the ordination supported this. Many rainforest tree species only recolonise from seed liberated from surviving trees. Their dispersal propensities sharply attenuate with distance from these surviving trees (Tabor *et al.* 2007), and hence these species would have a low likelihood of dispersing into the centre of large clearfells. *Tmesipteris obliqua*, which was identified as disturbance-sensitive, is likely to be responding to a paucity of structural legacies to support its epiphytic growth habit. Hickey (1994) found that epiphytic ferns were the plant group most sensitive to clearfell harvesting.

An interesting result was the moderate to high correlations among the responses of the disturbance-sensitive subsets from the three focal groups. This is uncommon in multi-focal group studies (Lawton *et al.* 1998), and is a key factor discouraging the use of indicator species as surrogates for the response of a wider group of species. Indicator species that are easy to survey; are taxonomically tractable; and can predict the response of a wider group of species, would offer the prospect of relatively rapid assessments of the biodiversity status in other landscapes. While the narrow ecological focus on disturbance-sensitive species no doubt contributed to the high correlations among the three focal groups, it is this component of the biodiversity that is often of most use in evaluating the sustainability of production-forest landscapes. However, the results found in this study would need to be replicated elsewhere before firm conclusions could be made about the value of disturbance-sensitive species for rapid biodiversity status assessments for use more generally in tall, wet eucalypt forests.

Proximity to mature eucalypts or area of mature eucalypts in the landscape?

A key finding was that correlations in the responses of disturbance-sensitive species with the proportion of mature eucalypt forest in the surrounding, multi-scale, landscapes could be explained by their correlations with distance to closest patch of mature forest. This suggests strongly that a 'mature-forest influence' effect is a key driver affecting the colonisation of regenerating areas by disturbance-sensitive species in the SFEFL. The subset of disturbance-sensitive species from each of the three focal groups mostly showed a strong (reverse-J) decline in abundance with increasing distance from mature forest, suggesting maximum correlations would occur at small spatial scales (<500 m). However, each disturbance-sensitive subset maintained high correlations with the amount of mature eucalypt forest in the surrounding landscape at landscape scales far beyond that suggested by their response suggested by proximity. Four possible explanations for this are that:

(i) the correlations at larger spatial scales reflect undiscovered processes such as the scales at which disturbance events, which generate suitable habitat, operate;

(ii) the correlations at larger spatial scales reflect the coarse-scale choice by mobile species (birds and flighted beetles) of areas likely to contain suitable habitat;

(iii) the correlations at larger spatial scales reflect large territory sizes;

(iv) the correlations at larger spatial scales are simply an artefact of high correlations in the amount of mature eucalypt forest in the surrounding landscape between different spatial scales: correlation coefficients were consistently high (>0.8) for all paired combinations of the amount of mature forest in the landscape at the scales from 500 m to 8 km.

The scale of processes generating suitable habitat has been shown to be important for saproxylic beetles. Bergman *et al.* (2012) found that some saproxylic beetles dependent on mature oaks with hollows as habitat showed both small- and large-scale responses to the amount of oak forest in the surrounding landscape in southern Sweden. The small-scale response reflected patches with a high density of hollow-bearing mature oaks. The authors concluded that large-scale responses reflected longer-term forest dynamics: the amount of oak forest needed to provide an ongoing supply of small patches with a high density of hollow-bearing mature oaks over long time-spans. It is unlikely that such a mechanism is active in the tall, wet eucalypt forests. The major habitat is dead wood (CWD), particularly from mature trees. The least abundant fraction of the eucalypt dead wood was new additions of fresh CWD, a habitat that may be important for species that are early colonisers of CWD: four of the disturbance-sensitive species are considered early colonisers (Grove and Forster 2011b). While fresh CWD was rare in SILV plots, species identified as early colonisers were still present, albeit in reduced numbers compared with MAT plots. This suggests that these early colonisers have sufficient mobility to find fresh CWD where it occurs in the landscape.

In a North American study, Betts *et al.* (2006) found that the abundance of two songbirds, ovenbird (*Seiurus aurocapilla*) and Blackburnian warbler (*Dendroica fusca*), was affected by the amount of habitat in the landscape at scales much greater than their individual territories. In the case of ovenbird, a species occupying a similar habitat as the ground- and mid-layer-foraging dense-forest species in our study, it tended to avoid small patches, but only if those patches were isolated. The authors suggested that many forest birds rely on cues from conspecifics, and that small isolated patches would be less likely to contain a large number of individual to provide those cues. A similar mechanism cannot be discounted for the dense-forest species in the present study. The two most common dense-forest species, Tasmanian scrubwren and Tasmanian thornbill, both respond to observer calls (Sharland 1954), suggesting that they naturally respond to aural cues in the dense vegetation on the forest floor. However, without controlling for patch configuration as well as landscape disturbance-intensity it would be difficult to measure the effect of the size and isolation of mature eucalypt patches on conspecific cues at local and wider landscape scales.

Species with larger foraging or territorial ranges were recorded in the SFEFL – notably swift parrot, which has a foraging range estimated at up to 9 km (Brereton 1997 referenced in Webb 2008). However, this species was largely confined to the eastern sections of the SFEFL that are proximal to its preferred foraging habitat – open eucalypt woodlands with mature *E. globulus* and *E. ovata* (Brereton *et al.* 2004). Wedge-tailed eagle, which was also recorded in low numbers during surveys in the SFEFL, has territorial ranges of 20-30 km^2 (Bell and Mooney 1999). The conservation needs of both these species in production-forests are catered for separately under specific provisions of threatened-species legislation, which focus on their requirements at wider landscape scales. None of the dense-forest birds – the subset showing correlations in abundance at large landscape scales - are known to have large foraging ranges: most are surface fossickers (Thomas 1980).

Limitations in seed-dispersal for many of the disturbance-sensitive plants (Tabor *et al.* 2007) provide an ecological basis for the correlation between the richness of disturbance-sensitive plants and proximity to mature eucalypt forest or rainforest. The cover-abundance of all but three of the disturbance-sensitive plants (*Anodopetalum biglandulosum, Drymophila cyanocarpa* and *Pittosporum bicolor*) showed a characteristic "reverse-J" relationship with distance to the nearest patch of mature eucalypt forest or rainforest (results not shown). This is strong evidence that, for disturbance-sensitive plant species, limitation in seed-dispersal is a major driver of their patterns of recolonisation in older silvicultural regeneration. For the three exceptions, both *D.cyanocarpa* and *P. bicolor* produce fleshy fruit suggesting bird dispersal (French 1992) as the primary mechanism that these species use to recolonise areas after disturbance. *Anodopetalum biglandulosum* reproduces vegetatively in rainforest (Read and Hill 1988). It is not known if this species can regularly vegetatively recolonise areas after harvesting and regeneration burning, although vegetative coppicing has been recorded after intense wildfire (Hill and Read 1984).

While small-scale responses can explain the strong gradient in abundance and richness of rainforest plants, processes operating at wider spatial scales do affect vegetation. Past wildfires operate at wide landscape scales and affect the abundance of disturbance-sensitive species in those forests contained within the fire boundaries. This was demonstrated in MAT plots by the cover-abundance response of rainforest species to time since last fire. This may translate to fire-induced variation in the density of disturbance-sensitive species, available to provide seed to adjoining harvested areas. Tabor *et al.* (2007) showed that the density of *N. cunninghamii* and *A. moschatum* regenerating in harvest areas showed a positive response to the height and cover of the parent trees in the adjoining unharvested forest. Therefore we would expect that any reductions in the height and/or density of rainforest species in mature forest as a result of past fires would produce a lower density of rainforest seedlings at a given distance into the adjoining harvest areas than if the adjoining mature forest had suffered fire damage. However, we were unable to resolve such an effect because the structure and composition of the nearest mature forest to the SILV plots was not measured.

No ecological reasons were definitively identified to explain the abundance or richness of the disturbance-sensitive subsets of the three focal groups sustaining high correlations with the amount of mature forest into wider landscape scales. Furthermore, the consistent reverse-J response in abundance with distance from mature forest shown by most disturbance-sensitive species suggests that small-scale responses dominate. However, just applying a proximity criterion to guide retention of mature forest without consideration of the configuration of that mature forest could fail to deliver the desired outcomes for biodiversity conservation. At the most extreme, the objective of maximising the harvest area within a prescribed distance from retained mature forest can be achieved by retaining many small patches of mature forest. This outcome delivers the proximity targets for harvest areas while minimising the area retained. However, with this configuration the retained forest would have a high risk of being adversely affected by edge phenomena such as windthrow and damage from regeneration burns (Scott *et al.* 2012). A safer option than a proximity-only criterion to guide mature-forest retention would be to also set a target for the minimum area of mature forest to be retained in the landscape. As the configuration of mature-forest retention in the SFEFL is evidently maintaining disturbance-sensitive elements of the three focal groups examined, the relationship between proximity to retention and area of retention in this landscape can be used to develop retention criteria.

Were there threshold levels of disturbance-intensity?

Both dense-forest birds and rainforest plants showed clear 'inverse-threshold' responses with distance to mature forest. The richness of disturbance-sensitive beetle species also showed a non-linear decline in species-richness with increasing distance to mature forest, but a threshold model did not provide a significantly better fit than a linear model. The break-points of the threshold models varied from a low of 150 m for the cover of rainforest plants to a high of 600 m for the species-richness of rainforest plants: the abundance of dense-forest birds was mid-way along the range with a value of 400 m. While the species-richness of disturbance-sensitive beetles did not show a significant threshold response the threshold model providing the best fit had a break-point of 150 m.

The break-point for the broken-stick model for cover of rainforest plants with distance to mature forest is close to the inflexion point of the empirical relationship found by Tabor *et al.* (2007) (Figure 46). They reported a sharp decline in the density of rainforest seedlings over the first 50 m into harvest areas from the edges of intact forests. This has led to the conventional wisdom of the one-tree-height measure for 'forest influence' adopted by variable retention silviculture in Tasmania (Baker and Read 2011). However, the data of Tabor el al. (2007) do show a long tail in the decline of seedling density extending out to the maximum distance from edge that they sampled (200 m): seedling density at 200 m was still 75% of the density measured at 100 m. Hence, it seems likely that rainforest seedlings are capable of establishing in low numbers at distances beyond 200 m from the edge, although this has not been shown empirically. Species-richness, as a presence-absence measure, reflects this long tail of rainforest species being present albeit at low cover.

The threshold response shown in the abundance of dense-forest birds may be the result of two quite different mechanisms. Abundance of dense-forest birds may simply be responding to the greater cover of rainforest plant species in silvicultural regeneration proximal to mature forest. Alternatively, it may be a direct response to the closer proximity of mature forests, particularly if mature forest provides a coarse-scale cue that the birds use to select high quality habitat. This has been shown for ovenbird (Betts *et al.* 2006), a North American species with comparable foraging and nesting niches to the dense-forest birds in the present study. What we know of the feeding ecology and habitat preference of the most populous of the dense forest species – scrubtit, Tasmanian thornbill, Tasmanian scrubwren and pink robin – does not indicate a specific requirement for rainforest species or for mature-forest structures (Thomas 1974, 1980; Ratkowsi and Ratkowski 1977). Two of these species – scrubtit and pink robin – appear to have very narrow habitat preferences, being largely confined to wet gullies (Ratkowski and Ratkowski 1977). Additionally, all dense-forest species still occupied SILV located at distances from mature forest considerably beyond the 150-metre threshold for rainforest cover; it is just that they did so at lower abundance. This was reflected in the abundance of dense-forest birds being much more strongly correlated with the richness of rainforest plant species than with the cover of rainforest plant species. Thus it seems more likely that dense-forest birds are responding to the amount of mature forest in an area as a primary attractor.

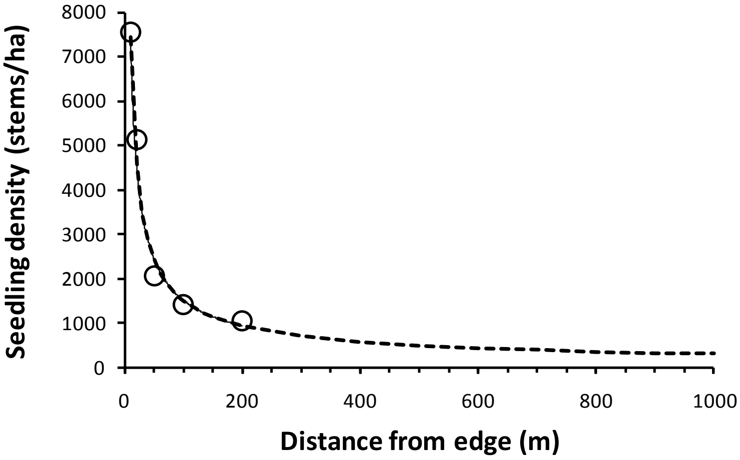


Figure 46. Scatterplot of the density of rainforest seedlings (in regenerating harvest areas) at varying distances (10 - 200 m) from unharvested edges. The fitted model: $y = 36672x^{-0.693}$ (R2 = 0.979) is shown with predictions extrapolated to 1 km. Based on data from Tabor *et al.* (2007).

The responses of the disturbance sensitive species in SILV plots to the gradient of disturbance-intensity separated context-classes 3-4 from 5-6. The significant declines in abundance of disturbance-sensitive birds and plants in SILV plots in context-class 4 compared with context-class 5 reflect a sharp change in distance to mature forest: in context-class 5 and 6 all plots were within 400 m of mature forest (many within 150 m), but in context-class 3 and 4 most plots were further than 600 m from mature forest (Figure 47). Thus the levels of mature eucalypt forest currently in context-class 5 were sufficient to ensure silvicultural regeneration was within the 400 m necessary to start getting the positive response shown by dense-forest birds to proximity with mature forest. This was achieved with an average of 21% mature eucalypt forest in the surrounding 1 km landscape (Figure 48). Significantly, at this level of mature forest retention a large proportion of silvicultural regeneration was also within the 150 m necessary to begin getting the positive response shown by the cover of rainforest plants to proximity with mature forest.

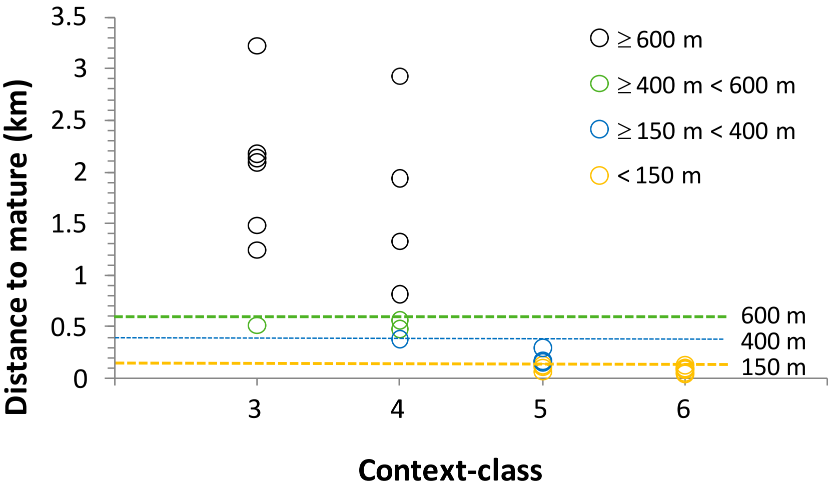


Figure 47. Scatterplot of distance to nearest mature forest for each of the seven SILV plots in each of the four context-classes. Points have been colour-coded according to position of the plot relative to the three threshold distances: 150 m, 400 m and 600 m.

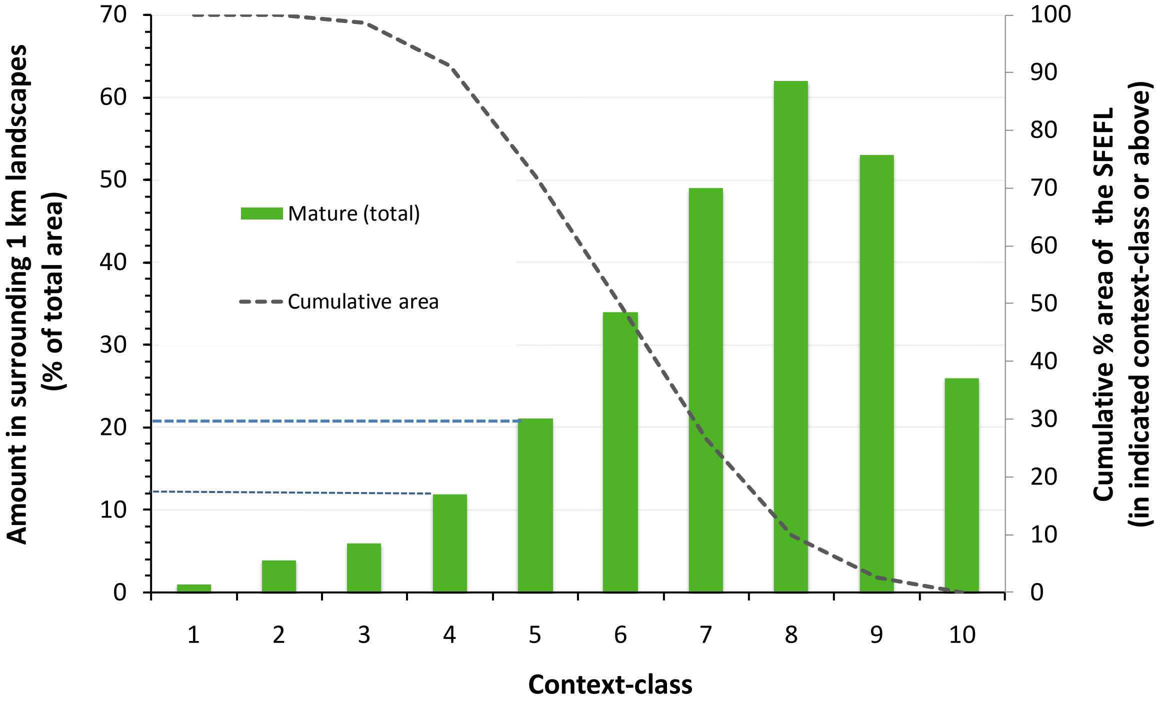


Figure 48. Average percentage area in 1 km landscapes surrounding 50 x 50 pixels (aggregated by context-class) containing mature eucalypt forests; mature forest protected from harvesting; and, mature + wildfire regrowth forests protected from harvesting. Values of the proportion of landscape containing mature forest corresponding to context-classes 4 and 5 are shown by the blue dashed lines.

While, on average, 22% of the 1 km landscapes in context-class 5 are mature eucalypt forest, only 13% of that is protected in reserves or excluded from harvesting. The broken-stick model of proximity to mature forest with the amount of mature eucalypt forest in the landscape predicts 11% retention in the 1 km landscape at proximity of 400 m to mature forest (Figure 45). This equates to the break-point at which the abundance of dense-forest birds rapidly increases with proximity to mature forest. Thus current levels of protection of mature eucalypt forest in context-class 5 are close to the minimum required for dense-forest birds to begin to get the benefits of proximity to mature forest. However, this level of protected mature forest is below that needed to meet the 150 m proximity threshold required for cover of rainforest plants to begin responding. Nonetheless, a large proportion of harvest areas would be within 150 m of unharvested edges (which may or may not be protected mature forest): more than 60% of a circular 50 ha harvest area (400 m radius) would be within 150 m of an unharvested edge.

Has the RFA approach for biodiversity conservation worked?

Post-European land-use has occurred in the SFEFL since the early 1900s; the RFA and the Forest Practices Code (FPC) were introduced over last two - three decades of this period. Despite their recent introduction, these two instruments have, nonetheless, been applied throughout the SFEFL. However, the landscape was not a blank slate; sections of the SFEFL, primarily represented by context-class 4 and below, had undergone substantial modification from European land-use prior to their introduction (Figure 49). It is with this in mind that the effectiveness of the RFA and FPC for biodiversity conservation in the SFEFL is evaluated.

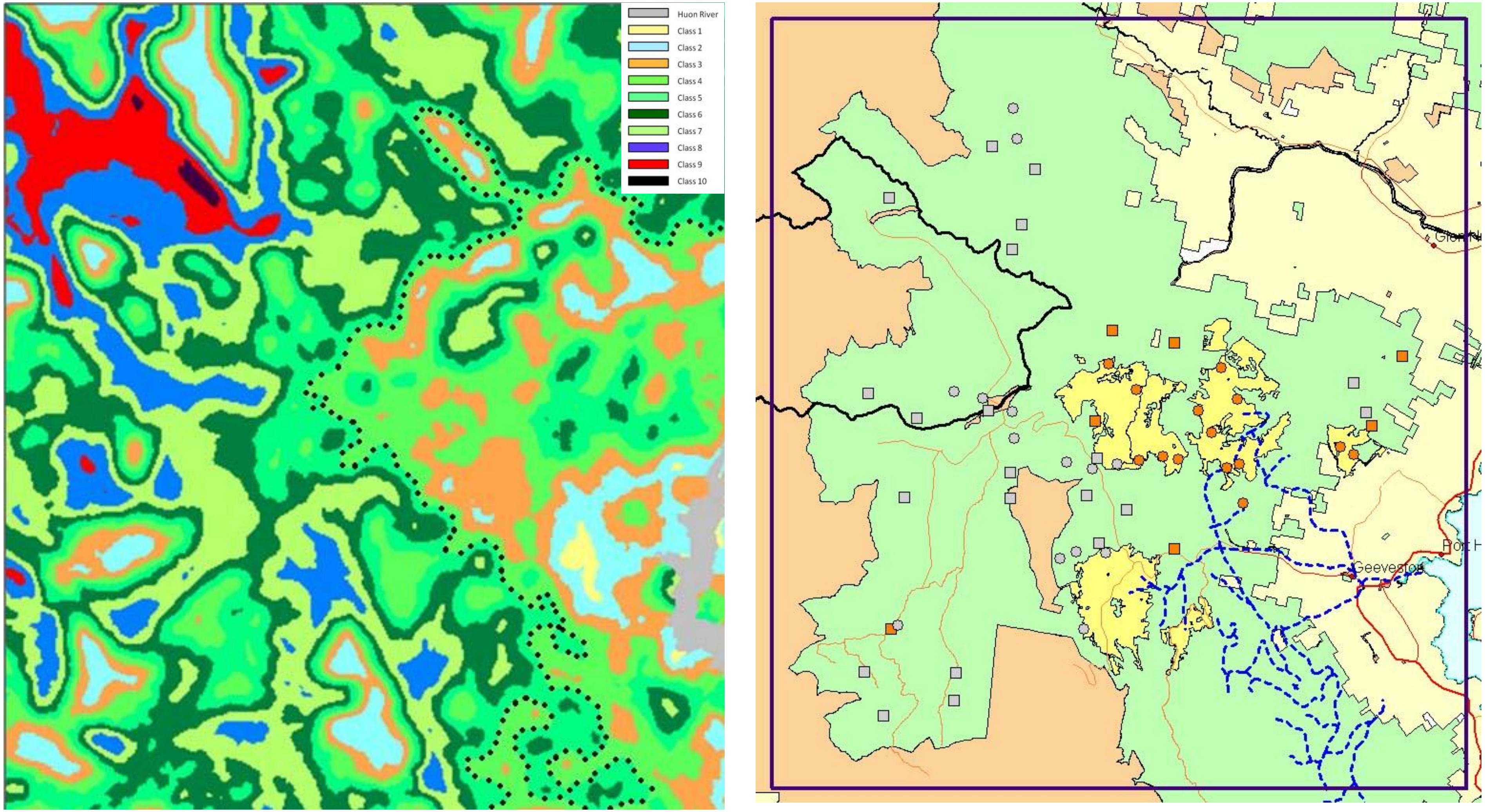


Figure 49. *Left*: SFEFL showing the mapped distribution of context-classes at the 1 km radius scale, with the dotted line delineating the boundary of context class 4 and below (to the east) and context-class 5 and above (to the west). Right: SFEFL showing land tenure (orange – formal reserves; green – State forest; cream – freehold) superimposed with routes of 1900-60 logging tramways (blue dashed line), plots (context-class 4 and below in orange; context-class 5 and above – grey) and areas burnt in 1966 and 1967 wildfires and subsequently logged (yellow).

Mature eucalypt forest in the 91% of the SFEFL that is context-class 4 or higher (Figure 50) is continuing to maintain populations of the most disturbance-sensitive bird and plant species. While the species-richness of disturbance-sensitive beetles declined in context-class 4 this decline was associated with forestry superimposed on a naturally more disturbed landscape. The component effect of forestry and natural disturbance processes in context-class 4 could not be disentangled. Thus in parts of the SFEFL where most forestry activities occurred after the introduction of the FPC and RFA (context-class 5 and above) mature eucalypt forests continue to sustain mature-forest affiliated species.

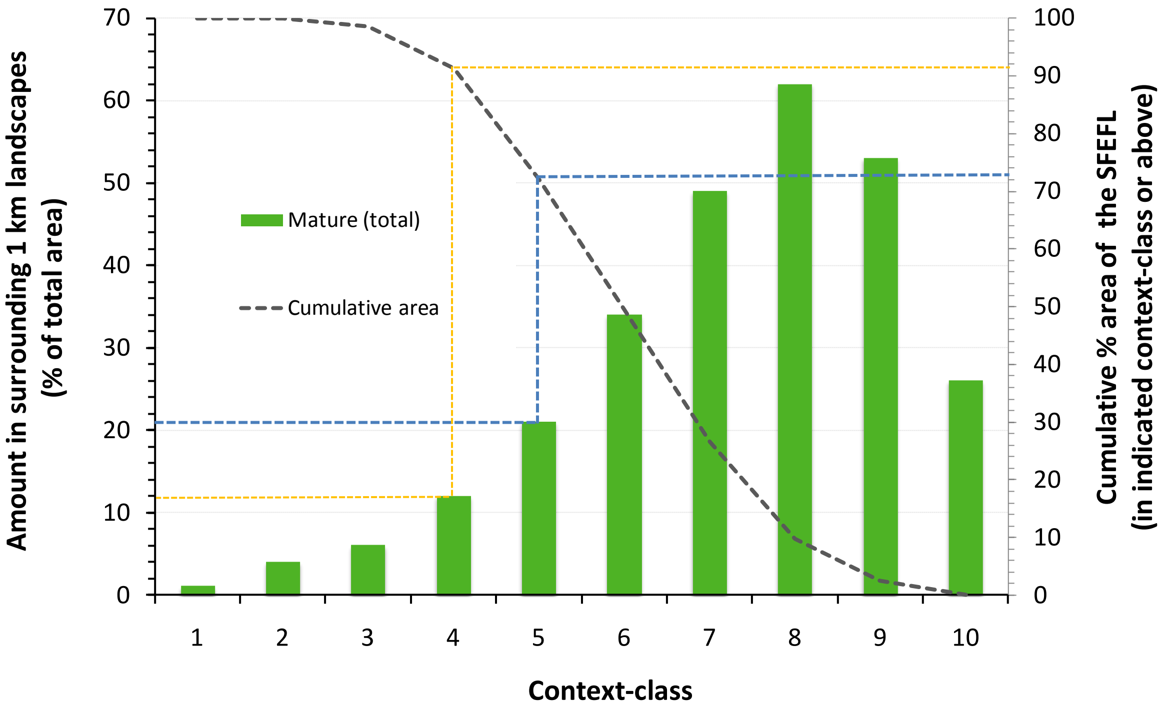


Figure 50. Amount (as a percentage of total area) of mature eucalypt forest in the 1 km landscape, by context-class; and the cumulative percentage of the total area of the SFEFL in the indicated context-class or higher. Orange dashed line represents the level of retention sufficient for the disturbance-sensitive species of the three focal groups to persist in mature eucalypt forest at population levels comparable with levels in least-disturbed landscapes. Blue dashed line represents the level of retention sufficient for the disturbance-sensitive bird and plant species to persist in mature eucalypt forest at population levels comparable with levels in least-disturbed landscapes.

Retention of sufficient mature forest to provide “influence-through-proximity” assisted the recolonisation of harvest areas by those elements of the bird, plant and beetle biodiversity most-sensitive to disturbance. The levels of mature eucalypt forest retention in context-classes 5 and 6 (and presumably higher) were sufficient for disturbance-sensitive elements of the three focal groups recolonising SILV plots to show positive responses to proximity with mature forest. Thus 73% of the SFEFL, represented by context-class 5 and higher (Figure 50), has sufficient mature eucalypt forest retained to allow disturbance-sensitive species recolonising harvested areas to get the benefits of mature forest influence. These context-classes reflect forestry activities that occurred largely after the introduction of the FPC and RFA, suggesting that post- RFA forestry has so far retained sufficient mature forest to allow for the recolonisation of harvested areas by mature-forest affiliated species.

The level of mature eucalypt retention corresponding to SILV plots being with 400 m of mature forest was predicted to be 11-16% (for 1 – 4 km landscape scales). This represents the modelled minimum necessary for the disturbance-sensitive birds recolonising SILV to begin showing positive responses to proximity with mature forest. Given 12% is the current average level of mature eucalypt forest in the 1 km landscape that has been shown to sustain disturbance-sensitive birds and plants in those mature forests, this should be the minimum level of mature eucalypt forest retention. The current levels of mature forest retention in context-class 4 provide this, overall, but not evenly as the SILV plots in context-class 4 only had, on average, 2.5% mature eucalypt forest in the 1 km landscape. Thus the 19% of the area of the SFEL in context-class 4 has sufficient retained mature eucalypt forest but it is not distributed sufficiently evenly to meet the 400 m proximity target in at least some of the areas where SILV is concentrated. The concentration of the SILV plots in areas affected by the 1967 wildfire (with subsequent harvest of burnt areas) undoubtedly contributed to this uneven distribution of retained mature forest in context-class 4.

Not all mature eucalypt forest in the SFEFL is retained in CAR reserves or excluded from harvesting under FPC or other provisions. Therefore the measured biodiversity responses may change if mature forest is harvested, reducing the amount retained to below the threshold-levels discovered in this study. If all mature eucalypt forest not currently reserved or excluded from harvesting were to be harvested then only 72% of the SFEFL (context-class 5 and above) would have sufficient mature forest to meet the 400 m proximity criterion (Figure 51). Further, only 50% of the SFEFL (context-class 6 and above) would have sufficient mature eucalypt forest to meet the proximity target that allows disturbance-sensitive species of all three focal groups that are recolonising harvested areas to begin getting the benefit of mature forest influence. About 3,200 ha of mature eucalypt forest in context-classes 4 and 5 is unprotected and could provide significant biodiversity benefit if protected. In contrast, the current levels of mature eucalypt forests that is protected in context-classes 6, and higher, is 160% of that needed to meet minimum levels needed to sustain populations of disturbance-sensitive species of the three focal groups.

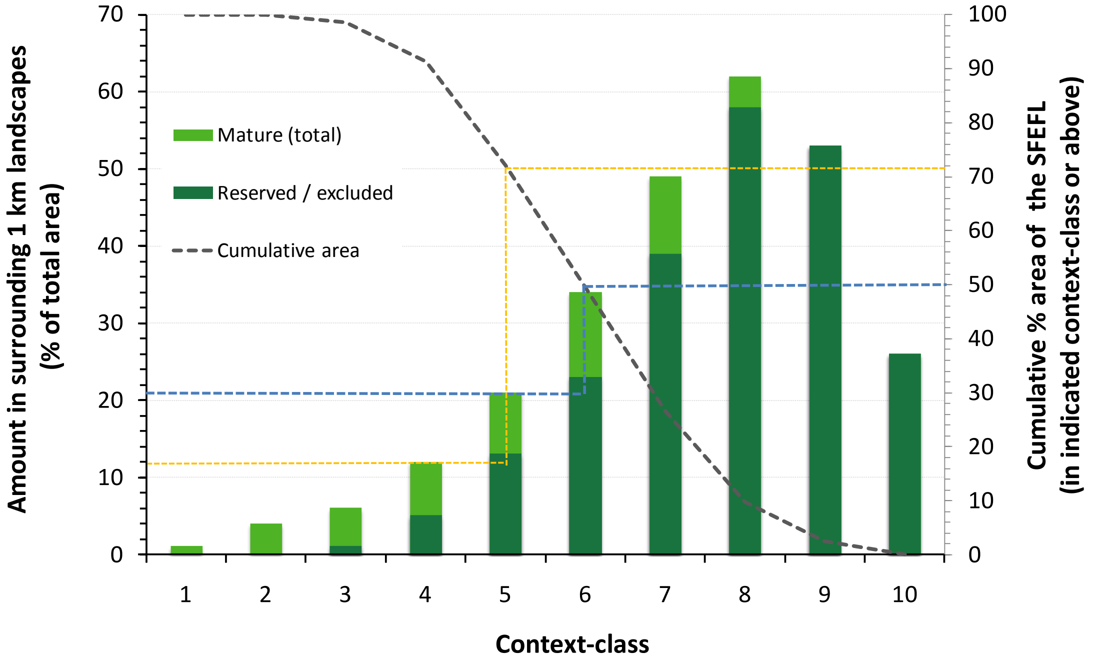


Figure 51. Total amount (as a percentage of total landscape area) and the amount reserved / excluded from harvesting of mature eucalypt forest in the 1 km landscape, by context-class; and the cumulative percentage of the total area of the SFEFL in the indicated context-class or higher. Blue dashed line represents the level of retention sufficient for the disturbance-sensitive species of the three focal groups recolonising harvested areas to be close enough to mature forest to begin showing positive response to mature forest influence. Orange dashed line represents the level of retention corresponding to 400 m proximity – the distance below which dense-forest birds respond positively to proximity to mature forest.

As discussed in the previous section, the current levels of mature forest retention in context-class 4 are well below the minimum levels required for many of the areas regenerating after harvested to get the benefit of proximity to mature forest. The paucity of mature eucalypt forest in the landscapes around SILV plots in context-classes 3 and 4 can be attributed to harvesting operations in areas affected by the 1967 wildfire: more than three-quarters of the SILV plots in those two context-classes originated from harvesting operations in burnt forests. The deficiency of mature forest in the landscapes around SILV plots in context-classes 3 and 4 is offset to some extent by the RFA and FPC through the reservation / exclusion from harvesting of wildfire regrowth forests (Figure 52). This is particularly the case in context-class 4 where the protected regrowth forest when added to mature eucalypt forest that is protected reaches levels currently provided by mature eucalypt forest currently in context-class 5. Importantly six of the seven SILV plots in context-class 4 were within 300 m of wildfire regrowth forests. In the absence of wildfires this regrowth forest could become mature eucalypt forest in the future. However, forest-typing based on the 1947 aerial photography indicated that a high proportion of the SILV plots in context-classes 3 and 4 were regrowth forest prior to the 1967 wildfire and subsequent harvesting (Table A2.8). Thus those parts of the landscape that are currently context-classes 3 and 4 may have been deficient in mature eucalypt forest for a long time, possibly as the result of naturally-higher fire frequencies. Climate in these parts of the SFEFL may support more regular fires as context-class 3 and 4 had significantly lower rainfall and moisture and significantly higher radiation than higher context-classes.

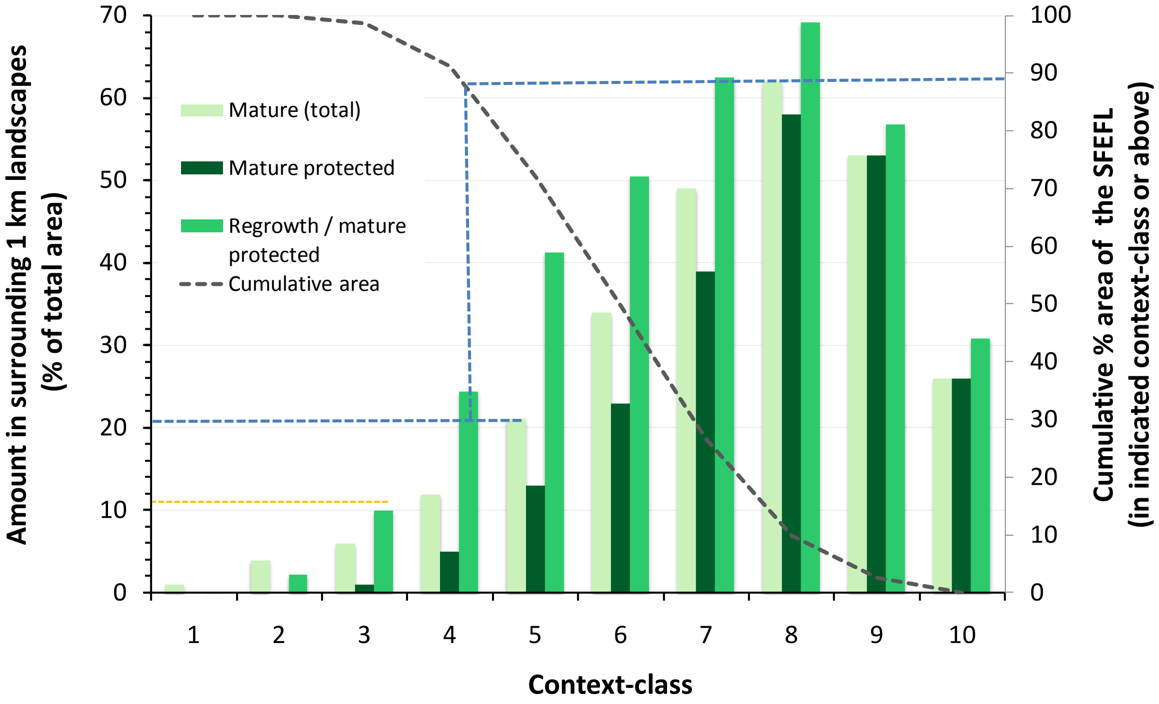


Figure 52. Total amount of mature eucalypt forest (as a percentage of total landscape area) reserved / excluded mature forest and reserved / excluded mature and regrowth eucalypt forest in the 1 km landscape, by context-class; and the cumulative percentage of the total area of the SFEFL in the indicated context-class or higher. Blue dashed line represents the level of retention sufficient for the disturbance-sensitive species of the three focal groups recolonising harvested areas to be close enough to mature forest to begin showing positive response to mature forest influence. Orange dashed line represents the level of retention corresponding to 400 m proximity – the distance below which dense-forest birds respond positively to proximity to mature forest.

What are the implications of this study for forest management?

The study has provided important new understanding on how three key groups representing mature-forest biodiversity persist in tall, wet eucalypt forest landscapes. This understanding can provide an ecological basis for demonstrating or verifying claims of sustainable forest management with respect to mature-forest biodiversity in tall, wet eucalypt production-forest landscapes. Furthermore, three key findings of the study can inform conservation planning and management to help land-managers achieve predictable outcomes with respect to sustaining mature-forest biodiversity (at least for the three groups tested) in tall, wet eucalypt production-forest landscapes:

i. There is a subset of the biodiversity in tall, wet eucalypt forests that is sensitive to the intensity of disturbance in the surrounding landscape. Our understanding of the ecology of those disturbance-sensitive subsets, particularly the birds and vascular plants, is consistent with their demonstrated sensitivity to the intensity of disturbance in the surrounding landscape.

ii. The abundance and richness of the most disturbance-sensitive elements of the bird and plant biodiversity in retained mature eucalypt forest shows little response to variation in the intensity of disturbance in the surrounding landscape. We can, therefore, be confident that so long as at least 12% of mature eucalypt forest is retained (1 km radius landscapes) those retained mature forests will sustain populations of birds and plants. The richness of disturbance-sensitive beetles was not sustained in MAT plots in the most disturbed parts of the landscape. This was due to the combined effects of forestry-related disturbance (roading and harvesting of mature forest) and natural processes (reductions in CWD volumes suggestive of a history of regular wildfires with a coincident reduction in the amounts of mature forest).

iii. The recolonisation of harvested areas by the most disturbance-sensitive elements of the biodiversity benefits from having retained mature forest nearby. The disturbance-sensitive subset of the biodiversity showed clear inverse-threshold responses to the proximity of harvest areas to retained mature forest. This allows a minimum level of retention to be defined that ensures mature forest can be sufficiently close to provide a proximity benefit for disturbance-sensitive elements of the biodiversity to recolonise the forest after harvesting.

An additional outcome has been the development of the context-score and associated context-class as a way of measuring the intensity of disturbance in the surrounding landscapes. While similar in concept to other landscape tools that have been developed to measure the intensity of land-use / land modification (Brown and Vivas 2005, Mutendeudzi and Thackway 2010), context-score /context-class provides greater resolution in measuring gradients of disturbance in largely forested landscapes. It may be possible to reinterpret existing data from biodiversity surveys conducted in other forested landscapes, particularly tall, wet eucalypt forests, by controlling for the intensity of disturbance in the surrounding landscape using context-score / context-class.

The subset of disturbance-sensitive species, particularly the birds and plants, may be useful to use for more rapidly assessing the biodiversity status of other tall, wet eucalypt forest landscapes where those species occur. This is important, because to generalise the findings from the SFEFL it needs to be demonstrated that other tall, wet eucalypt forest landscapes respond in a comparable way. In tall, wet eucalypt forests that have a different suite of species, it may be possible to identify a comparable subset of disturbance-sensitive species by identifying those that have similar habitat specialisation (for birds - primarily ground and mid-level foragers in dense forest) or ecological traits (for plants – shade-tolerant, slow-growing, fire-sensitive species reliant on natural seedfall from nearby trees for regeneration). The responses to landscape disturbance-intensity of the disturbance-sensitive species in retained mature eucalypt forest and in older silvicultural regeneration can translate to practical, quantitative criteria to apply in conservation planning and management. For example:

i. Retain at least 12% of mature eucalypt forest in the 1 km landscape to ensure that the retained mature forest continues to sustain populations of disturbance-sensitive birds and plants;
ii. Retaining 12-22% mature eucalypt forests in the 1 km radius landscapes, configured to maximise the area of production forest that is within 150-400 m of that retention. This will ensure that high proportion of the harvest area is sufficiently close to the retained mature forest for disturbance-sensitive species to show a positive proximity-to-mature response;

Using the first criterion we can evaluate whether mature tall, wet eucalypt forests in other landscapes will provide suitable habitat for forest-dependent species using the, now calibrated, context-class metric. Thus, we can be confident that mature forest embedded in a landscape of at least context-class 4 at the 500 m - 2000 km scale will continue to provide suitable habitat for birds, beetles and plants.

The second criterion provides a scientifically defensible value of proximity to mature forests and landscape-level retention to guide the management of production-forest landscapes. Because the proximity metric captures responses shown by disturbance-sensitive species across multiple spatial scales, it represents a simple tool for evaluating management from the coupe-scale to the scale of entire landscapes. A similar tool ("Forest Influence Calculator") has already been developed by Forestry Tasmania for planning and evaluating variable retention operations at the coupe scale (Scott *et al.* 2011). A simple recalibration of the Forest Influence Calculator would allow the immediate implementation of other proximity thresholds in landscapes containing tall eucalypt forests.

Taken together, the context-class criterion and the mature-forest proximity criterion provide the tools that enable the biodiversity function of tall, wet eucalypt production-forest landscapes to be predicted. This can be done at all levels from the coupe- and coupe-context level through to entire estates. At the coupe-level we can use the proximity criterion to report on the proportion of harvested area that is within, for example, the 400-metre threshold level necessary for dense-forest birds to start responding to proximity with mature forest, i.e. as a quality standards tool to report on the outcomes of the harvesting operation. As with all quality standards measures, we can set a target for the percentage of harvest area within 400 metres (or 150 m for rainforest plants) of mature forest and report on the extent to which that target has been met. Monitored over time this becomes a way of evaluating continuous improvement.

At the coupe-context level we can evaluate the function of the retained mature forest, particularly that within the CAR reserves; the level of reservation or long-term retention of mature forest (or future mature forest) against the 12-22% target; and the extent to which the planned harvest areas will meet the 400 m (or lower) proximity threshold (Figure 53). Thus all patches of mature forest within CAR reserves or long-term exclusion can be tested to ensure 12% retention is maintained under a range of possible future harvest scenarios in the surrounding production-forests. Combining this with an evaluation of the surrounding production-forest against the proximity metric allows refinement of the boundaries of informal CAR reserves and areas outside reserves set aside for long-term retention. This could be effected as a simple optimisation to find the configuration of the CAR reserves / long-term retention that maximises the influence provided to the surrounding production-forest areas while still meeting the 12-22% reservation / retention target.

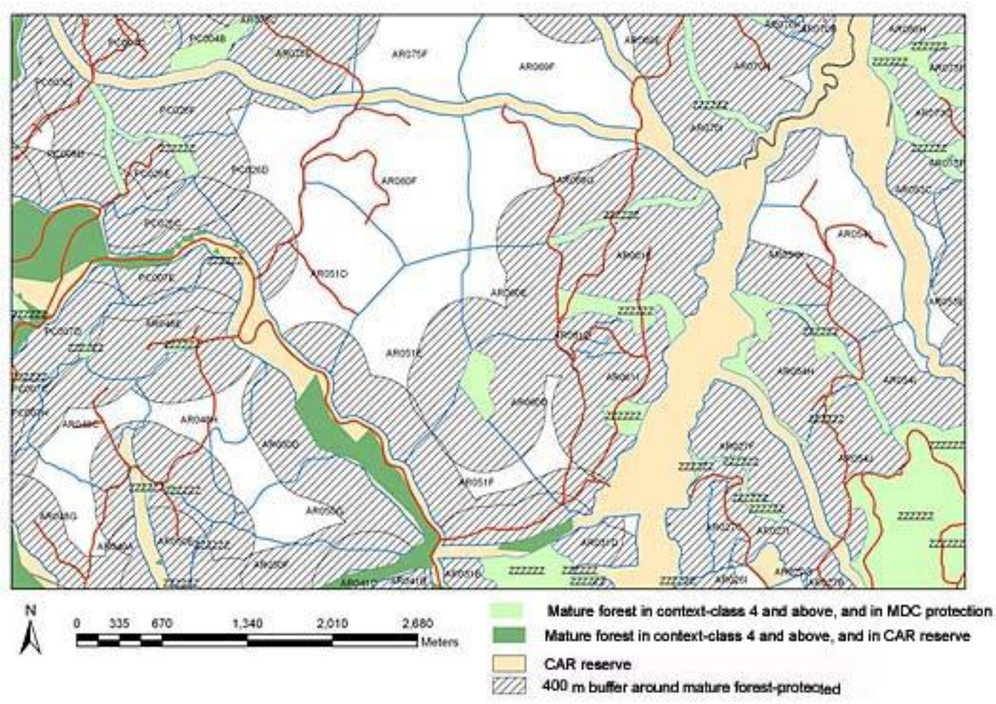


Figure 53. An example of applying mature-forest status and proximity rules in production forest landscape. CAR reserves and other set-asides containing mature forest meeting the context-class ≥4 criterion are shown in shades of green. Production-forests that are within 400 m of context-class≥4 mature forest are shown by cross-hatching. Production-forest areas not within 400 m of mature forest comprise the white areas. The CAR reserves shown in light brown contain wildfire regrowth, which may provide future influence to many of the (white) production-forest areas not currently within 400 m of mature forest.

The same approach has been extended to evaluate proximity to CAR reserves and to mature forests across the entire State forest estate in Tasmania (Figure 54). This allows the results of management to be monitored over times. It also provides an objective way of identifying areas of State forests that have low levels of influence (from mature forests or CAR reserves) and may derive greatest benefit for additional protection / retention (Figure 55).

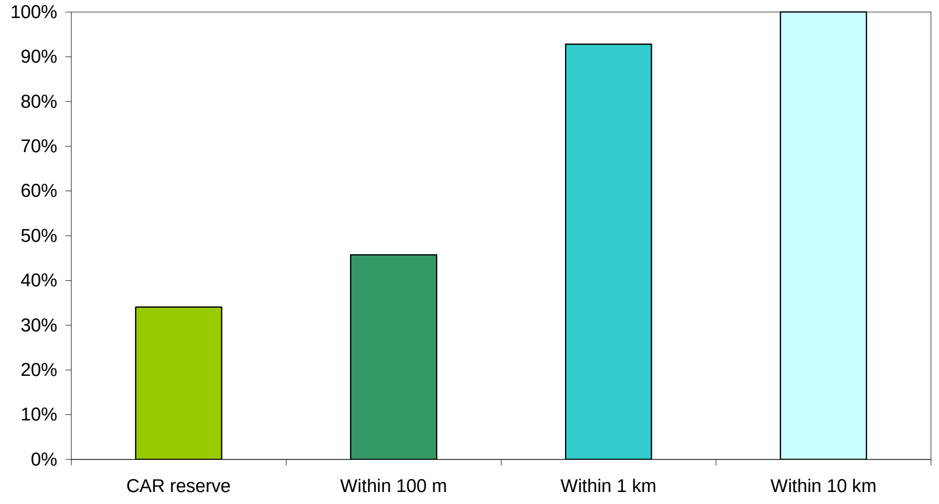


Figure 54. Proportion of the area of State forest in Tasmania that is in CAR reserves or within the indicated distances of CAR reserves.

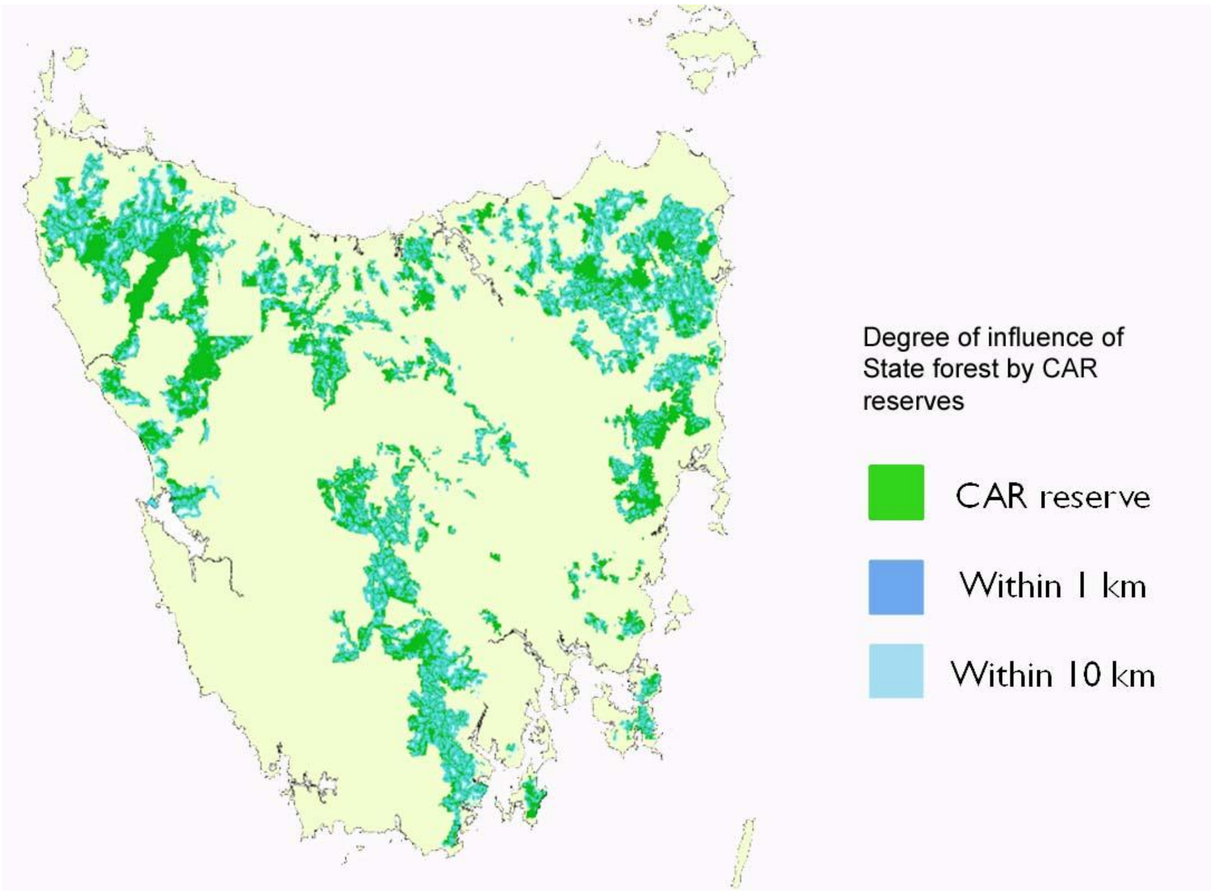


Figure 55. State forest in Tasmania that is within CAR reserves, within 1 km of CAR reserves, or within 10 km of CAR reserves. Red circles show areas of State forest with low levels of influence by CAR reserves (areas of concern).

Conclusions

The SFEFL proved to be a useful landscape to study the effects of disturbance-intensity on the biodiversity of mature forests and older silvicultural regeneration. Disturbance-intensity was the dominant gradient associated with measured biodiversity responses and, where there were other gradients superimposed on the disturbance gradient, their effects could be separated.

Two hypotheses were tested using birds, beetles and vascular plants as surrogates for forest biodiversity in tall, wet eucalypt forests:

1. *That mature forest maintains similar populations of dependent species regardless of the intensity of disturbance in the surrounding landscape*;
2. *That the recolonisation of silvicultural regeneration by mature-forest species is independent of the intensity of disturbance in the surrounding landscape.;*

Hypothesis 1 was proven for all but the small subset of disturbance-sensitive beetles, which showed a decline in species-richness in the most disturbed parts of the landscape attributed to the effects of anthropogenic disturbance superimposed on a naturally more disturbed landscape. Hypothesis 2 was rejected: the level of recolonisation by mature-forest species 30-50 years after harvesting declined with increasing intensity of landscape disturbance. This decline was correlated with the amount of mature eucalypt forest in the surrounding landscape across multiple spatial scales; those multi-scale correlations could be captured by a simple metric “proximity-to-mature-forest”. The disturbance-sensitive subset of each of the three focal groups showed inverse threshold responses with “proximity-to-mature-forest”: abundance or richness rapidly increased with decreasing distance to mature forest below the threshold distance but was low and non-changing beyond that threshold distance. These results inform guidelines for mature-forest retention in tall, wet eucalypt production forests to sustain biodiversity. For example:

1. *Mature forests in CAR reserves, and set-asides outside reserves, will provide functional habitat for most mature-forest biodiversity so long as the landscape-disturbance context-class of the landscape in which they are embedded is 4 or higher (corresponding with a retention of at least 12% mature eucalypt forest in the surrounding 1 km radius landscape).*
2. *Silvicultural regeneration can recover to eventually have a similar biodiversity to mature forest if mature forest is within 400 m (or 150 m where a high cover of rainforest plants is important) provided through the reservation / retention of at 12 - 22% mature eucalypt forest in the surrounding 1 km landscape.*

With the current levels of mature forest, 75% of the SFEFL (primarily the post-RFA forestry sections of the landscape) meet these two retention criteria. The network of CAR reserves, and complementary management (long-term retention) in production areas outside reserves, has delivered at least this level of reservation / long-term retention of mature eucalypt forest in two-thirds of this. In the other third there is sufficient mature eucalypt forest to meet the retention criteria but only 62% of that mature eucalypt forest is currently in CAR reserves or long-term retention. The deficiency of mature forest in the remaining 25% of the SFEFL could be attributed to the combination of early (pre-1960s) forestry and evidence of more regular natural disturbance. In 20 of that 25% currently deficient in mature eucalypt forests there is sufficient wildfire regrowth forest in CAR reserves or in long-term retention to meet the retention criteria for mature forest in the future. That requires those areas of regrowth remain protected from wildfire or other disturbance until they reach maturity.

Recommendations

1. Intensity of disturbance in the landscape is a major influencing effect on biodiversity response in tall, wet eucalypt forests and should be controlled to properly interpret the results of studies measuring biodiversity responses to disturbance treatments, both anthropogenic or natural

2. Landscape-disturbance context-class (for mature forest in reserves or long-term retention) and mature forest retention / proximity criteria be adopted to evaluate the biodiversity function of other tall eucalypt production forest landscapes. The threshold values of ≥4 for context-class; 12-22% for mature eucalypt forest in long-term retention; and, thresholds of <150 m (rainforest plants) - 400 m (for dense-forest birds) for proximity to mature forests be used in adopting these metrics

3. Evaluate and report on the extent to which tall eucalypt forest on Tasmania’s State forest meets the criteria for landscape-disturbance context-class (protected forests) and mature forest proximity (forests available for wood production)

4. The findings of this study be used to inform Forest Practice Code provisions for biodiversity conservation

5. Incorporate an evaluation of these metrics into three-year wood production plans

6. Incorporate mature forest proximity in Quality Standards, including targets for harvest area meeting the criterion

7. The key findings of the study and the outcomes for management be synthesised in an easily digested format and made available to the wider community. Use this to raise awareness and promote more informed discussions on striking a balance between wood production and conservation

References

Alcorn PJ, Dingle JK, Hickey JE. 2001. Age and stand structure in a multi-aged wet eucalypt forest at the Warra silvicultural systems trial. *Tasforests* 13(2): 245–259.

Anderson MJ. 2001. A new method for non-parametric multivariate analysis of variance. *Austral Ecology*, 26:32–46.

Ashton DH. 1981. The ecology of the boundary between *Eucalyptus regnans* F.Muell. and *E. obliqua* L'Herit. In Victoria. *Proceedings of the Ecological Society of Australia*, 11: 75-94.

Baker SC. 2006. A comparison of litter beetle assemblages (Coleoptera) in mature and recently clearfelled *Eucalyptus obliqua* forest. *Australian Journal of Entomology* 45: 130–136.

Baker SC, Richardson AMM, Seeman OD, Barmuta LA. 2004. Does clearfell, burn and sow silviculture mimic the effect of wildfire? A field study and review using litter beetles. *Forest Ecology and Management*, 199: 433–448.

Baker SC, Grove SJ, Forster L, Bonham KJ, Bashford R. 2009. Short-term responses of ground-active beetles to alternative silvicultural systems in the Warra Silvicultural Systems Trial, Tasmania, Australia. *Forest Ecology and Management* 258: 444–459.

Baker SC, Read SM. 2011. Variable retention silviculture in Tasmania's wet forests: ecological rationale, adaptive management and synthesis of biodiversity benefits. *Australian Forestry*, 74(3): 218–232.

Bashford R, Taylor R, Driessen M, Doran N, Richardson A. 2001. Research on invertebrate assemblages at the Warra LTER site. *Tasforests*, 13(1): 109-128.

Bell P, Mooney NJ. 1992. Wedge tail eagle recovery plan 1998-2003. Department of Primary Industries and Water, Hobart, Tasmania.

Bergman K, Jansson N, Claesson K, Palmer MW, Milberg P. 2012. How much and at what scale? Multiscale analyses as decision support for conservation of saproxylic oak beetles. *Forest Ecology and Management* 265: 133–141.

Betts MG, Forbes GJ, Diamond AW, Taylor PD. 2006. Independent effects of fragmentation in forest songbirds: An organism-based approach. *Ecological Applications*, 16(3): 1076-1089.

Brereton R, Mallick SA, Kennedy SJ. 2004. Foraging preferences of swift parrots on Tasmanian blue gum: tree size, flowing frequency and flowering intensity. *Emu*, 104: 377-383.

Brown MT, Vivas MB. 2005. Landscape development intensity index. *Environmental Monitoring and Assessment*, 101: 289-309.

Browning BJ, Jordan GJ, Dalton PJ, Grove SJ, Wardlaw TJ, Turner PAM. 2010. Succession of mosses, liverworts and ferns on coarse woody debris, in relation to forest age and log decay in Tasmanian wet eucalypt forest. *Forest Ecology and Management* 260: 1896–1905.

Buchanan AM. 2009. A census of the vascular plants of Tasmania. Tasmanian Museum and Art Gallery.

Commonwealth of Australia. 1995. National Forest Policy Statement: A new focus for Australia's forests. 2nd Edition. Commonwealth of Australia, Canberra. 36 pp +appendices.

Commonwealth of Australia. 2008. *Climate of Australia*. Australian Bureau of Meteorology. 213 pp.

Commonwealth of Australia and the State of Tasmania. 2005. A Way Forward for Tasmania's Forests: The Tasmanian Community Forests Agreement. www.daff.gov.au/__data/assets/pdf_file/0007/49237/A_way_forward_for_tasmanias_forests.pdf accessed 13th June 2012.

Commonwealth of Australia and the State of Tasmania. 2011. Tasmanian Forests Intergovernmental Agreement between the Commonwealth of Australia and the State of Tasmania. www.environment.gov.au/land/forests/pubs/tasmanian-forests-intergovernmental-agreement.pdf accessed 13th June 2012.

Corbett S, Balmer J. 2001. Map and description of the Warra vegetation. *Tasforests*, 13(1): 45-76.

Christidis L, Boles WE. 2008. *Systematics and Taxonomy of Australian Birds*. CSIRO Publishing, Melbourne.

Cushman SA, McGarigal K. 2003. Landscape-level patterns of avian diversity in the Oregon Coast range. *Ecological Monographs*, 73(2): 259-281.

Dufrệne M, Legendre P. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological Monographs*, 67:345–366.

Forest Practices Authority. 2000. Forest Practices Code. Forest Practices Authority, Hobart. 120 pp.

Forestry Tasmania. 2010. Special Timbers Strategy. Forestry Tasmania, Hobart. 42 pp.

Franklin JF. 1990. Biological legacies: A critical management concept from Mount St. Helens. Pp 216-219 in McCabe, R.E. (Ed) Transactions of the 55th North American Wildlife and Natural Resources Conference. March 16-21, 1990. Denver, Colorado.

Franklin JF, Mitchell RJ, Palik BJ. 2007. Natural disturbance and stand development principles for ecological forestry. USDA Forest Service Northern Research Station, General Technical Report NRS-19. USDA Forest Service, Newtown Square, PA.

Gilbert JM. 1959. Forest succession in the Florentine Valley, Tasmania. *Papers and Proceedings of the Royal Society of Tasmania*, 93: 129-151.

Grant JC, Laffan MD, Hill RB, Nielsen WA. 1995. *Forest Soils of Tasmania: A Handbook for Identification and Management.* Forestry Tasmania, National Landcare Program and the Forest and Forest Industries Council. 189 pp.

Green G, Grey A, McQuillan P. 2004. Biodiversity impacts and sustainability implications of clearfell logging in the Weld Valley, Tasmania. Timber Workers for Forests, Kingston, Tasmania. 19 pp.

Grove S. 2001. Litter invertebrate assemblages in wildlife habitat strips in plantation forests in northeast Tasmania. Unpublished report, Forestry Tasmania, Hobart. 20 pp.

Grove S. 2009. Beetles and fuelwood harvesting: a retrospective study from Tasmania's southern forests. *Tasforests*, 18: 77-99.

Grove S. 2004 The effectiveness of wildlife habitat strips in maintaining mature forest carabid beetle assemblages at Tarraleah in Tasmania's central highlands. Technical Report 24/2004. Division of Forest Research and Development, Forestry Tasmania, Hobart. 26 pp.

Grove SJ, Bashford R. 2003. Beetle assemblages from the Warra log-decay project: insights from the first year of sampling. *Tasforests*, 14: 117-130.

Grove S, Yaxley B. 2004 Wildlife habitat strips and native beetles in plantation nodes in damp sclerophyll forest, north-eastern Tasmania. Technical Report 1/2004. Division of Forest Research and Development, Forestry Tasmania, Hobart. 30 pp.

Grove S, Taylor R, Bonham K, Mesibov R. 2004. Long-term responses of mollusc assemblages to experimental logging and to wildfire in dry sclerophyll forest at Old Chum Dam, northeast Tasmania. Technical Report 2/2004. Division of Forest Research and Development, Forestry Tasmania, Hobart. 23 pp.

Grove SJ, Forster L. 2011a. A decade of change in the saproxylic beetle fauna of eucalypt logs in the Warra long-term log-decay experiment, Tasmania. 1. Description of the fauna and seasonality patterns. *Biodiversity and Conservation***,** 20(10): 2149-2165.

Grove SJ, Forster L. 2011b. A decade of change in the saproxylic beetle fauna of eucalypt logs in the Warra long-term log-decay experiment, Tasmania. 2. Log-size effects, succession, and the functional significance of rare species. *Biodiversity and Conservation*, 20(10): 2167-2188.

Grove SJ, Stamm L, Wardlaw TJ. 2011. How well does a log decay-class system capture the ecology of decomposition? – A case-study from Tasmanian *Eucalyptus obliqua* forest. *Forest Ecology and Management* 262: 692–700.

Hickey JE, Su W, Rowe P, Brown MJ, Edwards L. 1999. Fire history of the tall wet eucalypt forests of the Warra ecological research site, Tasmania. *Australian Forestry* 62, 66–71.

Hingston AB, Grove S. 2010. From clearfell coupe to old-growth forest: Succession of bird assemblages in Tasmanian lowland wet eucalypt forests. *Forest Ecology and Management*, 259: 459-468.

Holland JD, Bert GD, Fahrig L. 2004. Determining the spatial scale of species' response to habitat. *Bioscience*, 54(3): 227-233.

Houlder D, Hutchinson M, Nix H, McMahon J. 2000. ANUCLIM Version 5.2. Centre for Resource and Environmental Studies, Australian National University, Canberra.

JANIS. 1997. Nationally Agreed Criteria for the Establishment of a Comprehensive, Adequate and Representative Reserve System for Forests in Australia. Joint ANZECC / MCFFA National Forest Policy Statement Implementation Sub-committee. Canberra.

Jarman SJ, Brown MJ. Kantvilas G. 1984. *Rainforest in Tasmania*. Tasmanian National Parks and Wildlife Service, Hobart.

Jarman SJ, Brown MJ. Kantvilas G. 1999. Floristic composition of cool temperate rainforest. Pp 145-159. In Reid JB, Hill RS, Brown MJ, Hovenden MJ. Editors. *Vegetation of Tasmania*. Flora of Australia Supplementary Series No. 8. Australian Biological Resources Survey, Environment Australia, Canberra.

Kavanagh RP, Bamkin KL. 1995. Distribution of nocturnal forest birds and mammals in relation to the logging mosaic in south-eastern New South Wales, Australia. *Biological Conservation*, 71: 41-53.

Kirkpatrick JB. 1998. Nature conservation and the Regional Forest Agreement process. *Australian Journal of Environmental Management*, 5: 31-37.

Kostoglou P. 1995. Historic timber getting between Glendevie and Franklin – Block 3. Archaeology of the Tasmanian Timber Industry. Forestry Tasmania and the Tasmanian Forest Research Council. 175 pp.

Laffan MD. 2001. Geology and soils of the Warra LTER site. *Tasforests*, 13(1): 23-30.

Law BS, Law PR. 2011. Early responses of bats to alternative silvicultural treatments in wet eucalypt forests of Tasmania. *Pacific Conservation Biology*, 17: 36–47.

Lawrence JF. 1994. The larvae of *Sirrhas variegatus* sp. nov., with notes on the Perimylopidae , Ulodidae (stat. nov.), Zopheridae and Chalcodrydae (Coleoptera: Tenebrionoidae). *Invertebrate Taxonomy*, 8: 329-349.

Lawton JH, Bignell DE, Bolton B, Bloemers GF, Eggleton P, Hommond PM, Hodda M, Holts RD, Larsen TB, Mawdsley NA, Stork NE, Srivastava DS, Watt AD. 1997. Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forest. *Nature*, 391: 72-76.

Lefort P, Grove SJ. 2009. Early responses of birds to clearfelling and its alternatives in lowland wet eucalypt forest in Tasmania, Australia. *Forest Ecology and Management*, 258: 460–471.

Lindenmayer DB, Cunningham RB, Donnelly CF. 1993. The conservation of arboreal mammals in the montane ash forests of the Central Highlands of Victoria, southeastern Australia. IV The presence and abundance of arboreal mammals in retained linear habitats (wildlife corridors) within logged forests. *Biological Conservation,* 66: 207-221.

Lindenmayer DB, Cunningham RB, McCarthy MA. 1999. The conservation of arboreal mammals in the montane ash forests of the Central Highlands of Victoria, southeastern Australia. VIII. Landscape analysis of the occurrence of arboreal marsupials. *Biological Conservation*, 89: 83-92.

Lindenmayer DB, Knight E, McBurney L, Michael A, Banks SC. 2010. Small mammals and retention islands: An experimental study of animal response to alternative logging practices. *Forest Ecology and Management*, 260: 2070–2078.

MacDonald MA, Apiolaza LA, Grove SG. 2005. The birds of retained vegetation corridors: A pre- and post-logging comparison in dry sclerophyll forest in Tasmania. *Forest Ecology and Management,* 218: 277-290.

Marsden-Smedley JB. 1998. Changes in the south-west Tasmanian fire regimes since the early 1800s. *Papers and Proceedings of the Royal Society of Tasmania*, 132, 15-29.

McCune B, Mefford MJ. 2006. *PC-ORD. Multivariate analysis of ecological data, version 5.31*. MjM Software Design, Gleneden Beach.

McGarigal K, Cushman S. 2002. Comparative evaluation of experimental approaches to the study of habitat fragmentation effects. *Ecological Applications,* 12(2): 335-345.

Mendel LC, Kirkpatrick JB. 2002. Historical progress of biodiversity conservation in the protected-area system of Tasmania, Australia. *Conservation Biology*, 16(6): 1520-1529.

Mutendeudzi M, Thackway R. 2010. A method for deriving maps of landscape alteration levels from vegetation condition datasets. Bureau of Rural Sciences, Canberra.

Mineral Resources Tasmania. 2008. Geology of southeast Tasmania. 1:250,000. Edition 2008.1.

Muller-Dombois D, Ellenberg H. 1974. *Aims and Methods of Vegetation Ecology*. Reprinted by The Blackburn Press. Cardwell, NJ, USA. 547 pp.

Parkes R, Halsey LG, Woakes AJ, Holder RL, Butler PJ. 2002. Oxygen uptake during post dive recovery in a diving bird *Arthya fuligula*: implications for optimal foraging models. *Journal of Experimental Biology*, 205: 3495-3954.

Pressey RL, Whish GL, Barrett TW, Watts ME. 2002. Effectiveness of protected areas in north-eastern New South Wales: recent trends in six measures. *Biological Conservation*, 106: 57–69

Scott R, Neyland M, Baker S. 2011. Variable Retention Manual. DFRD Technical Report 5/2011. Forestry Tasmania, Hobart. 30 pp.

Scott RE, Neyland MG, McElwee DJ, Baker SC. 2012. Burning outcomes following aggregated retention harvesting in old-growth wet eucalypt forests. *Forest Ecology and Management*, 276: 165–173.

Sharland M. 1954. The Tasmanian scrubtit. *Emu*, 54(2): 80-88.

Spies TA, Franklin JF, Thomas TB. 1988. Coarse woody debris in douglas fir forests of western Oregon and Washington. *Ecology*, 69(6): 1689-1702.

Statistical Graphics Corporation. 1996. *Statgraphics Plus for Windows Version 2.1*. Statistical Graphics Corporation, Warrenton, VA, USA.

Tabor J, McElhinny C, Hickey J, Wood J. 2007. Colonisation of clearfelled coupe edges by rainforest tree species from mature mixed forest edges, Tasmania, Australia. *Forest Ecology and Management*, 240: 13–23.

Thomas DG. 1974 The scrub-tit *Acanthornis magnus* – status and ecology. *Tasmanian Naturalist*, 38: 1-8.

Thomas DG. 1980. The bird community of Tasmanian temperate rainforest. *Ibis*, 122: 298-306.

Turner PAM, Balmer J, Kirkpatrick JB. 2009. Stand replacing wildfires? The incidence of multi-aged and even-aged *Eucalyptus regnans* and *E. obliqua* forests in southern Tasmania. *Forest Ecology and Management* 258, 366–375.

Turner PAM, Kirkpatrick JB. 2009. Do logging, followed by burning, and wildfire differ in their decadal scale effects on tall open-forest bryophytes and vascular plants? *Forest Ecology and Management*, 258: 679–686

van Wagner CE. 1968. The line-intersect method in forest fuel sampling. *Forest Science*, 14: 20-26.

Wardlaw T, Grove S, Hopkins A, Yee M, Harrison K, Mohammed C. 2009. The uniqueness of habitats in old eucalypts: contrasting fungi and saproxylic beetles of young and old eucalypts. *Tasforests*, **18**: 17-32.

Webb M. 2009. Swift Parrot Breeding Season Survey Report – 2007/08. Department of Primary Industries and Water, Hobart, Tasmania. 20 pp.

Westphalen G. 2003. The ecology of edges in Tasmanian wet forests managed for wood production. PhD thesis, University of Tasmania. 249 pp.

Williams K, Duncan F, Taylor R. 1990. Biological conservation in Tasmania’s production forests. *Tasforests*, 2(1): 73-78.

Yee M, Grove SJ, Richardson AMM, Mohammed CL. 2006. Brown rot in inner heartwood: Why large logs support characteristic saproxylic beetle assemblages of conservation concern. pp 42-56. In Grove SJ, Hanula JL. Editors. *Insect Biodiversity and Dead Wood*: Proceeding of a Symposium for the 22nd International Congress of Entomology. 15-21 August 2004, Brisbane, Australia. General Technical Report SRS-93. Southern Research Station, United States Department of Agriculture Forest Service,

Zimmerman GM, Goetz H, Mielke PW. 1985. Use of an improved statistical method for group comparisons to study effects of prairie fire. *Ecology*, 66:606–611.

Acknowledgements

This study was a voyage of discovery for us. Landscape ecology is complex but provides a way of better understanding how the forest inhabitants perceive the landscape our management is providing. We benefited from the insights of our steering committee - John Hickey, Fred Duncan, Richard Loyn, Kim Whitford and Rod Kavanagh - in advising us during the initial study design and as the study progressed.

Forest landscapes are complex and we are indebted to Rob Musk in helping us design ways of measuring that complexity and analysing the data to reveal the patterns and relationships reported here. We benefited enormously from the deep understanding of Ruiping Goa and Marie Yee of Forestry Tasmania’s GIS and conservation planning system that enabled us to map our landscape and the derived measures that describe it.

Our study was only possible because of a dedicated team who helped us to find and establish the field sites and then assess the birds, beetles and plants within. Leigh Edwards and Dave McElwee provided the cool heads during the frantic search for sites and the establishment of the plots. Liam Hindrum gave us the benefit of his botanical skills during the floristic surveys. Gregoire Thauvin and Elsa Libis assessed the coarse woody debris, compiled the resulting datasets and did the initial analyses of that data. Chloe Hill and Yijin Ong completed the second season of beetle surveys and together with Nita Ramsden and Kevin Bonham spent countless hours sorting, identifying and databasing the 90,000 beetle specimens collected in this study.

Finally, we thank Amy Koch, Sarah Munks, members of the steering committee and two anonymous referees who provided valuable feedback to us on an earlier version of this report.

Appendix 1: Glossary

Context-class	A decile class of all context-scores.
Context-scores	A value calculated for a point in the landscape based on the sum of the proportional areas of each disturbance-weighted vegetation group within a specified area (as a radial distance) around that point.
Coupe-context	The landscape context of a forest coupe based on the composition of the surrounding landscape. The size of the surrounding landscape may be jurisdiction-specific: Forestry Tasmania uses a 400 ha surrounding landscape (approx 1 km radius circle) to describe coupe-context.
Disturbance-weighting	A subjective, but ecologically informed, value assigned to a vegetation group based on the typical return intervals of disturbance events that allow that vegetation group to persist. Values range from 1 (most regularly disturbed) to 10 (rarely disturbed).
Focal group	A discrete taxonomic rank that is used as a target group for a biodiversity survey. In the context of this study the focal groups were birds (Order: Aves), beetles (Class: Coleoptera), vascular plants (Sub-division: Euphyllophytina)
Habitat group	A subset of a focal group that share a similar habitat or ecological trait.
Landscape-scale	The specified size of a surrounding landscape described as the radius of the circle at the central point of that landscape.
Landscape-context	An attribute given to a point in the landscape based on the make-up of the landscape in which that point is embedded.
Older silvicultural regeneration	Previously harvested forest areas that have been regenerated and have progressed to a closed canopy state sufficient to eliminate early seral species.
Scale-consistent	Points in the landscape at which the surrounding 500 m, 1 km and 2 km radius landscapes all have the same context-class.
Vegetation groups:	A grouping of different photo-interpreted forest types into broad categories of vegetation, e.g. rainforest, agricultural land, mature eucalypt forest.

Appendix 2: Variation in independent variables between plot types and among landscape context-classes

Geographic and topographic variables

Among the ten geographic variables, only one – plot easting - showed strongly significant differences ($P<0.001$) among landscape context-classes: context-classes 3 and 4 were significantly further to the east than context-classes 5, 6 and 7 (Table A2.1). Slope also differed significantly ($P<0.05$) among context-classes reflecting a trend for slope to increase with increasing context-class. Differences in northing among context-classes approached statistical significance and reflected the more northerly location of plots in context-class 7 compared with the other context-classes. The only geographic variable that differed between plot types was "degrees from north": MAT plots occupied a significantly more southerly aspect than SILV plots.

Geographic variable	MAT vs SILV	Context-class
1) Location: (Geocentric Datum of Australia 1994)		
a) Easting	P = 0.081; S>M	P<0.001; 3, 4>5, 6, 7
b) Northing	n.s.	P=0.056; 7>3-6
2. Altitude: in metres	n.s.	n.s.
3. Aspect: in degrees from true north	n.s.	n.s.
4. Degrees from north (0 - 180°)	P = 0.031; M>S	n.s.
5. Westerly aspect (1,0)	n.s. (χ^2)	n.s. (χ^2)
6. Slope: in degrees	n.s.	P = 0.048; +ve
7. Plan curvature	n.s.	n.s.
8. Profile curvature	n.s.	n.s.
9. Feature	P=0.07 (χ^2); M planar vs S ridge	n.s. (χ^2)

Table A2.1. Significance of differences between plot types and among context-classes for ten geographical variables.

Climatic variables

The variables within each of the four main climate parameters – temperature, rainfall, radiation and moisture – were, with few exceptions, highly correlated with one and other. Principal components analysis of the full suite of climate variables (excepting three moisture variables – moisture of moistest month, moisture of the moistest quarter and moisture of the coldest quarter - for which all sites had the maximum value) found that three component axes captured 95.6% of the total variation (Table A2.2).

Axis 1, which explained 69% of the variation, described variation in moisture regime. Low values on axis 1 described plots that had high radiation and low moisture during the warmer periods resulting in overall high moisture seasonality (Table A2.2). This axis was strongly negatively correlated with altitude and position in the SFEFL (easting and northing): plots with low axis 1 values were located at lower altitudes in the northern and eastern parts of the SFEFL (Table A2.3). Principal component axis 1 values differed significantly ($F_{2,39}=3.82$; $P=0.031$; $MSE=22.3$) among context-classes: plots in context-class 4 had significantly lower axis 1 values than context-classes 5 and 6 (TableA.1.2). The significant differences in axis 1 values among context-classes remained after accounting for the significant covariance between axis 1 values and the three geographic variables.

	Axis 1	Axis 2	Axis 3
Cumulative percentage of variation explained	69	91	95.6
Annual mean temperature	-0.135	0.288	0.054
Mean temperature of the warmest quarter	-0.148	0.269	-0.022
Mean temperature of the driest quarter	-0.149	0.267	-0.013
Minimum temperature of the coldest month	-0.156	0.246	-0.136
Maximum temperature of the warmest month	-0.062	0.323	0.332
Mean temperature of the coolest quarter	-0.119	0.304	0.136
Mean temperature of the wettest quarter	-0.143	0.261	0.172
Mean diurnal range	-0.168	0.187	-0.288
Temperature isothermality	-0.122	0.265	0.149
Temperature range	-0.172	0.142	-0.364
Temperature seasonality	-0.144	-0.054	-0.574
Annual rainfall	0.202	0.117	-0.003
Rainfall in wettest month	0.200	0.118	-0.033
Rainfall in driest month	0.204	0.133	-0.040
Rainfall of the wettest quarter	0.198	0.059	0.067
Rainfall in driest quarter	0.205	0.079	0.049
Rainfall of the coolest quarter	0.200	0.123	-0.008
Rainfall of the warmest quarter	0.206	0.077	0.054
Rainfall seasonality	0.128	0.231	-0.288
Mean annual radiation	-0.204	-0.102	-0.021
Radiation in the highest month	-0.203	-0.100	-0.021
Radiation in the lowest month	-0.186	-0.165	-0.057
Radiation of the wettest quarter	-0.167	-0.114	0.222
Radiation of the driest quarter	-0.205	-0.085	-0.070
Radiation of the warmest quarter	-0.205	-0.086	-0.055
Radiation of the coolest quarter	-0.102	-0.282	0.231
Radiation seasonality	0.164	0.178	-0.064
Mean annual moisture	0.205	-0.023	-0.096
Moisture of the driest month	0.210	-0.022	-0.065
Moisture of the driest quarter	0.208	-0.026	-0.082
Moisture of the warmest quarter	0.205	-0.032	-0.105
Moisture seasonality	-0.208	0.027	0.085
MAT vs SILV	n.s.	n.s.	**P=0.013** S < M
Context-class	**P=0.031** 4<5, 6	n.s.	P=0.055; 6<4

Table A2.2. Component weights of climate variables for the first three principal component axes; and the significance of differences of those three principal component axes between MAT and SILV plots, and among landscape context-classes. Component weights contributing most strongly to axis response are shaded.

Principal components axis 2, which explained 22% of the variation among the climate variables, described a general variation in temperature. Low values on axis two described plots that had cooler temperatures during all times of the year (Table A2.2). This axis was strongly negatively correlated with altitude and east-west position in the landscape: plots with low values of axis 2 were at higher altitudes and more westerly (inland) positions (Table A2.3).

Principal components axis 3, which explained 4.6% of the total variation, described variation in temperature seasonality and diurnal range. Low values of axis 2 described plots with cooler winter temperatures and higher temperature seasonality and diurnal range (Table A2.2). Axis 3 was strongly negatively correlated with north-south position: plots with low values of axis 2 were in more northerly positions in the SFEFL (Table A2.3). Differences among context-classes in axis 3 values approach statistical significance (Kruskal-Wallis statistic = 5.77; P=0.056) with context-class 4 having significantly higher axis3 values than context-class 6 (Table A.1.2). PCA axis 3 also differed significantly ($F_{1,40}$=6.81; P=0.013; MSE=1.20) between plot types: plots in MAT had significantly higher axis 3 values than plots in SILV (Table A.1.2).

Correlations with:	Axis 1	Axis 2	Axis 3
Position east	-0.486 (P=0.0001)	-0.604 (P<0.0001)	0.376 (P<0.0043)
Position north	-0.563 (P<0.0001)	-0.369 (P=0.005)	-0.656 (P<0.0001)
Altitude	-0.595 (P<0.0001)	-0.797 (P<0.0001)	-0.064 (P=0.6)

Table A2.3. Pearson correlation coefficients for the least square linear regressions of each of the three principal component axes with three plot-level geographic variables. Probability values for the regressions are shown in parentheses.

Principal components analysis of each the four groups of climatic parameters yielded one-axis solutions that each captured more than 80% of the total variance within each group (Table A2.4). The one-axis solution for each of the four climate parameters positively weighted each of the variables (except seasonality) within their respective groups equally. Thus each PCA axis-one simply describes the range from low to high values of each of the four climatic parameters. None of the four PCA axis-one variables differed significantly between MAT and SILV plots. However, all except for temperature PCA differed significantly between context-classes. Each of those significant (Table A2.4) differences was due to plots in context-class 4 being significantly different from plots in context-classes 5 and 6.

	Temperature	Rainfall	Radiation	Moisture
Axis 1: % variance explained	82.1	93.0	87.0	99.4
Mean annual	0.347	0.366	40.1	44.6
Lowest month	0.291	0.353	39.4	44.7
Highest month	0.34	0.366	40.1	-
Wettest quarter	0.338	0.361	35.2	-
Driest quarter	0.348	0.366	39.6	44.8
Coldest quarter	0.341	0.362	29.0	-
Warmest quarter	0.348	0.362	39.7	44.7
Seasonality	0.121	0.279	-	-44.8
Diurnal range	0.312	-	-	-
Isothermality	0.307	-	-	-
Plot type	n.s.	n.s.	n.s.	n.s.
Context-class	n.s.	$F_{2,39}$=5.65, P=0.007 4 < 5,6	$F_{2,39}$=6.18, P=0.005 4 > 5,6	$F_{2,39}$=4.12, P=0.024 4 < 5,6

Table A2.4. Summary of the first principal component axis for each of the four climate variable groups showing percentage of variance explained, component weights and tests of the significance of their values between plot type and among context-classes.

Geology and soils variables

Calcium and magnesium were significantly positively correlated (r = 0.59; P<0.001) with each other; positively correlated with pH (r = 0.7 and 0.55 respectively, P<0.001) and copper (r = 0.38 [P<0.05] and 0.46 [P<0.001], respectively), and negatively correlated with aluminium concentrations (r = -0.49 and -0.43 respectively, P<0.001).

Principal components analysis of the nine soil chemical variables found the first three axes captured 62% of the variation. Axis 1 was strongly and positively weighted by calcium and magnesium concentrations and by pH. Axis 2 was strongly negatively weighted by concentrations of iron and aluminium. There were significant (P=0.049) differences among context-classes in PCA axis -1: context-class 4 had significantly higher PCA-1 values than context-classes 5 and 6. Axis-2 also differed significantly ($F_{2,\,39}$=4.44, P=0.018) among context-classes: plots in context-class 4 had significantly higher values of PCA-2 than plots in context-class 5. This effect was even stronger ($F_{2,39}$=7.98, P=0.0012) if the sum of the concentrations of aluminium and iron was used instead of PCA-2.

There was a highly significant (χ^2_6 = 18.9, P<0.01) association between soil classification and landscape context-class in SILV plots. Chromosols were the dominant soil class in the lower context-classes (3 and 4) while ferrosols were the dominant soil class in the higher context-classes. The association between geology (based on the detailed code) and context-class was statistically significant in SILV plots (χ^2_{21}P= 0.02). This was reflected in Triassic sandstone being concentrated in the lower context-classes, while Permian sedimentary rocks and

Quaternary talus were concentrated in the higher context-classes. Geological period was unrelated to context-class despite the significant association between geology and context-class.

None of the geological or soil properties differed significantly between MAT and SILV plots.

Streams and roads

There were eight instances where differences among context-classes in the density of streams at any of the spatial scales reached statistical significance (Table A2.5). In all cases the differences were due to a higher density of streams in context-classes 3 and 4 than in context-classes 5 and 6 (and 7 for all stream classes at the 4 and 8 km scales). The significance of the differences were magnified when context-classes were amalgamated into two groups: 3-4 and 5-7. Context-classes 3-4 had between 16.1 - 25.4% higher density of class 1-4 streams and of all stream classes at the 2 – 8 km scales than context-classes 5-7.

Analysis of variance detected six instances where the density of streams in surrounding landscapes differed significantly ($P<0.05$) between SILV and MAT plots (Table A2.5). However four of these were at small scales (62.5 and 125 m) where zero values predominated. The other two instances were at the 8 km scale. The density of streams of all classes at the 8 km scale was 8% higher in SILV (22.72±1.01 m/ha) than MAT (21.04±1.14 m/ha). The difference was almost identical for class 1-4 streams at the 8 km scale.

There were no significant differences among context-classes in distance from plots to the nearest stream, regardless of stream class. Distance to the nearest class 1 stream approached statistical significance ($P=0.051$). Plots in context-classes 4 and 5 were significantly closer to class 1 streams than in context-classes 7; plots in context-class 5 were also significantly closer to class 1 streams than in context-class 7.

There were no significant differences between MAT and SILV plots in their distance to the nearest stream regardless of stream class.

Differences in the density of roads among context-classes reached statistical significance at scales of 1 km and beyond. Each of these statistically significant differences reflected a linear decrease in the density of roads with increasing context-class. Least squares linear regressions of the relationships between road density and context-class for those combinations of road class and landscape scale that differed significantly among context-classes are shown in Figure A2.1.

Differences in the density of roads between MAT and SILV plots reached statistical significance at scales of 2 km or greater (Table A2.6). In all cases those differences were due to a higher road density in the landscapes surrounding SILV plots compared with MAT plots.

Distance from plots to the nearest road did not differ significantly among landscape context-classes although the distance to the nearest class 1 road almost reached statistical significance ($P=0.072$): distance to class 1 roads was greater in context-class 7 than context-class 3. The general lack of significant differences in distance to nearest road among context-classes is an unsurprising result given the practical decision to select plots close to road access. Mirroring the result for comparison among context-classes, the distance to the nearest road did not differ significantly between MAT and SILV plots except for class 1 roads, which were significantly ($P=0.011$) closer to SILV plots than MAT plots.

Stream class[1]	Radius (metres) of landscapes surrounding plots																	
	31.25		62.5		125		250		500		1000		2000		4000		8000	
Class 1 stream	-	-	ns		ns		ns	(*) “~”	ns	(*) “~”	ns	ns	ns	* -ve	(*) S>M	* -ve	** S>M	(*) -ve
Class 1 & 2 streams	ns	ns	ns	ns	ns	(*) “~”	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	(*) S>M	ns
Class 1, 2 and 3 streams	ns	ns	* M>S	ns	* M>S	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Class 1, 2, 3 and 4 streams	(*) M>S	ns	* M>S	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	* -ve	ns	*** -ve	* S>M	*** -ve
All stream classes	(*) M>S	ns	* M>S	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	* “∪”	ns	*** -ve	* S>M	*** -ve

Table A2.5. Full list of metrics measuring the density of streams within 31.25 m – 8 km radii landscapes surrounding sample plots. Significance of differences (tested using analysis of variance) in the metrics between MAT and SILV plots (shaded columns) and among landscape context-classes are shown by asterisks that indicate level of significance (***P<0.001; **P<0.01; *P<0.05; (*)P<0.1; “-“ all zero values) and by the direction of those differences.

[1] Stream classes as defined in the Forest Practices Code (Forest Practices Authority 2003)

Road class[1]	Radius (metres) of landscapes surrounding plots																	
	31.25		62.5		125		250		500		1000		2000		4000		8000	
Class 1 road	-	-	-	-	ns	ns	ns	ns	ns	ns	ns	ns	* S>M	* -0.36	** S>M	** -0.46	** S>M	*** -0.65
Class 1 & 2 roads	-	-	-	-	ns	ns	ns	ns	ns	ns	ns	ns	* S>M	* -0.36	** S>M	** -0.46	** S>M	*** -0.65
Class 1, 2 and 3 roads	-	-	ns	ns	ns	ns	ns	ns	ns	ns	ns	* -0.34	* S>M	*** -0.56	** S>M	*** -0.68	* S>M	*** -0.63
All road classes	-	-	ns	ns	ns	ns	ns	ns	ns	ns	ns	** -0.49	** S>M	*** -0.72	* S>M	*** -0.72	* S>M	*** -0.62

Table A2.6. Full list of metrics measuring the density of roads within 31.25 – 8 km radii landscapes surrounding sample plots. Significance of differences (tested using analysis of variance) in the metrics between MAT and SILV plots (shaded columns) and among landscape context-classes are shown by asterisks that indicate level of significance (***P<0.001; **P<0.01; *P<0.05; (*)P<0.1; “-“ all zero values) and by the direction of those differences (Pearson correlation coefficients for context-classes).

[1] Road classes as defined in the Forest Practices Code (Forest Practices Authority 2003)

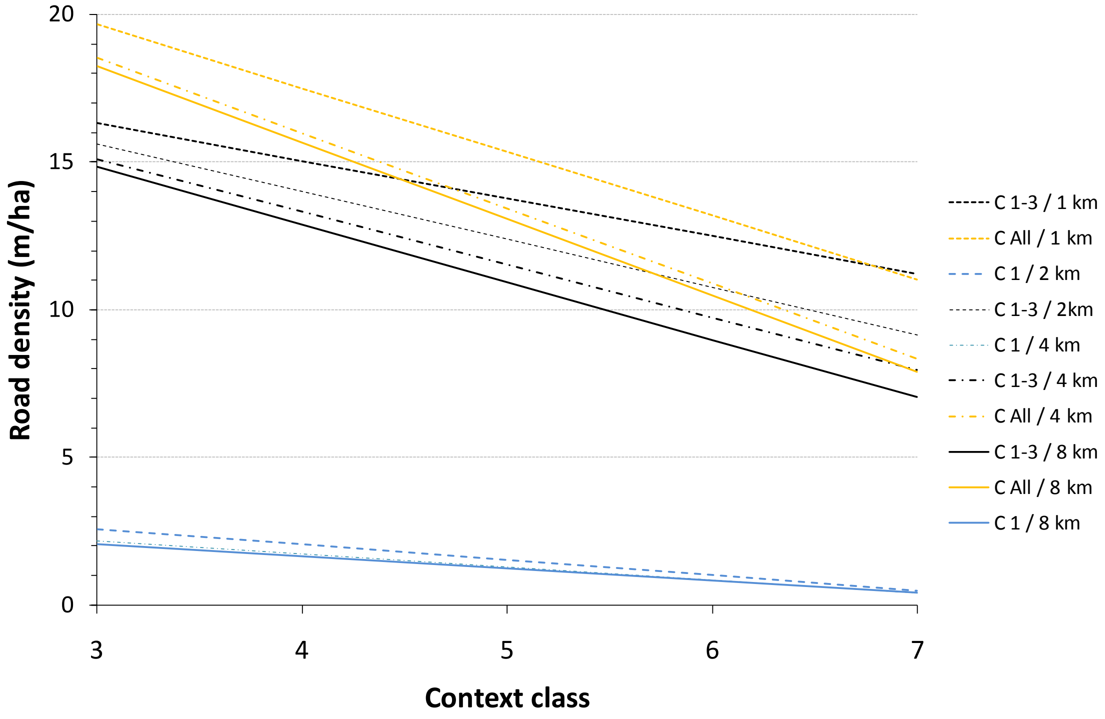


Figure A2.1. Linear least squares regressions of road density versus landscape context-class for combinations of road class and landscape scale with significant differences in road density among landscape context-classes.

Coarse woody debris

Volumes of CWD within the 56 plots ranged between 7-1,296 m^3/ha, with 80% of the plots having volumes of between 201-913 m^3/ha. MAT and SILV plots did not differ significantly in their CWD volumes or in the number of pieces of CWD, either in total or by diameter class (Figure A2.2 and Table A2.7).

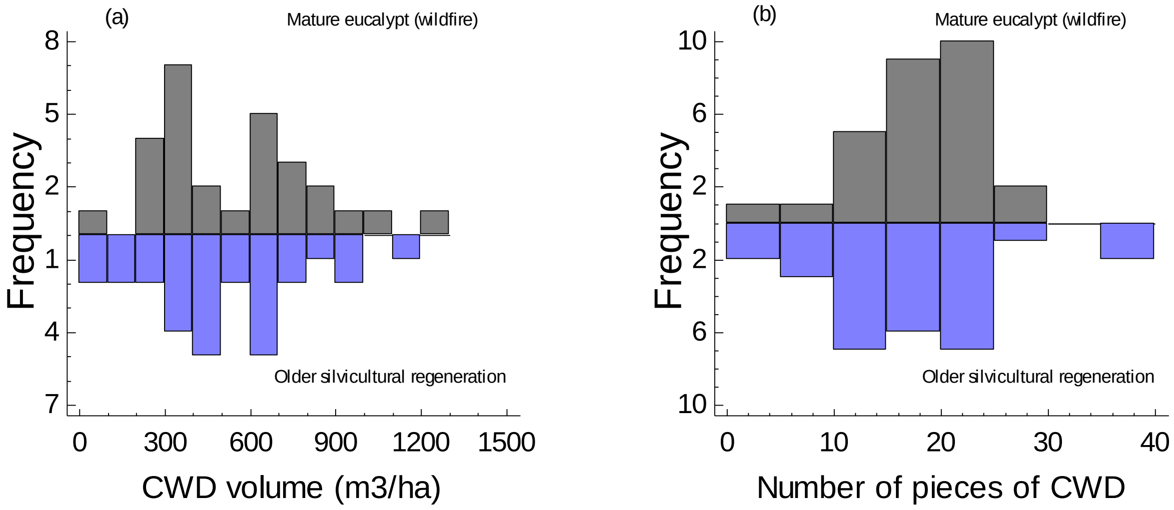


Figure A2.2. Frequency distribution of (a) CWD volume and (b) number of pieces of CWD in mature and older silvicultural regeneration plots.

The total volume and number of pieces of CWD both differed significantly ($P<0.001$) among context-classes (Table A2.9): context-classes 3 and 4 had 39% fewer pieces of CWD than context-classes 5-6 (12.8 compared with 20.9 pieces) and 52.6% lower CWD volume than context-classes 5-7 (315.9 compared with 662.2 m^3/ha). The differences in CWD volume among context-classes can be attributed smaller volumes and fewer numbers of small diameter (30-60 cm) CWD and of mid-diameter (91-120 cm) CWD in context-classes 3 and 4 compared with the other context-classes, particularly context-class 5. Unsurprisingly, the mean diameter of CWD also differed significantly ($P<0.01$) among context-classes: the diameter of CWD in context-classes 3 and 4 was significantly less than context-class 7. CWD in context-class 4 was also significantly smaller in diameter than in context-classes 5 and 6.

The significant differences in CWD volume among context-classes occurred in both the SILV and MAT plots. For SILV plots, those in context-classes 3 and 4 had 52% lower volumes of CWD than those in context-classes 5 and 6 (331.6 versus 688.5 m^3/ha). The lower CWD volumes of SILV plots in context-classes 3 and 4 paralleled a significant (χ^2_3 =15.7; $P<0.01$) association between context-class and the estimated number of fires since 1850: context-class 3 and 4 had a disproportionately high number of plots that had experienced two fires, while context-classes 5 and 6 had a disproportionately high number of plots that had only experienced one fire since 1850 (Table A2.8). In MAT, plots in context-class 4 had significantly ($P<0.001$) lower volumes of CWD than the other context-class. Although the estimated number of fires was also significantly (χ^2_6 =19.5; $P<0.01$) associated with context-class in MAT plots, that association was ambiguous with regards differences in CWD among context-classes.

Diameter class (cm)	MAT vs SILV		Context	
	Volume	Number of pieces	Volume	Number of pieces
30-60	n.s.	n.s.	<0.05; 3,4<5 | 3<6-7	<0.05; 3,4,7<5 | 3<6
61-90	n.s.	n.s.	n.s.	n.s.
91-120	n.s.	n.s.	<0.01; 3,4<5	<0.01; 3,4<5
121-150	n.s.	n.s.	n.s.	n.s.
>150	n.s.	n.s.	n.s.	n.s.
Total	n.s.	n.s.	<0.001; 3,4<5-7	<0.001; 3-4<5-6 | 7<5

Table A2.7. Results from analysis of variance tests of the significance of differences in CWD volume, partitioned by diameter class, between MAT and SILV and among landscape context-classes.

Context-class	1 fire	2 fires
3 and 4	1	13
5 and 6	11	3

Table A2.8. Cross-tabulation of the number of fires since 1850 and context-class of SILV plots.

There were significant differences between MAT and SILV in the volume of CWD in decay classes 1 and 2 (Table A2.9), which together approximately represent CWD that has been added since the time of harvest of the SILV plots (new additions). MAT had four times the volume of "new additions" CWD that SILV although, in absolute terms, the volumes were relatively small (21.7 and 86.7 m^3/ha). SILV also had nearly 50% lower volume of decay class 5 CWD than MAT, a difference that approached statistical significance.

There were significant differences among context-classes in the volume of decay class 3 CWD and the volume of new additions CWD (Table A2.9). Context-classes 3 and 4 had nearly 50% less decay class 3 CWD than the other context-classes. The significantly lower volume of "new additions" CWD accords with the significantly lower "new additions" CWD in SILV compared with MAT; context-class 3 only had SILV plots.

Decay class	MAT vs SILV	Context
1	<0.01; M>S	0.05<P<0.1; 5, 7↑
2	<0.01; M>S	n.s.
New additions	<0.001; M>S	<0.05; 3<6, 7
3	n.s.	<0.01; 3,4 < 5-7
4	n.s.	n.s.
5	0.05<P<0.1; M↑	n.s.
Legacy	n.s.	n.s.

Table A2.9. Results from analysis of variance tests of the significance of differences in CWD volume, partitioned by decay class, between MAT and SILV and among landscape context-classes.

Floristics and fire history

Differences in mean species richness per plot approached statistical significance (P=0.096): plots in context-class 3 had 26% lower species richness than the other context-classes (10.02±1.78 versus 13.5±0.91). This result mirrored a significant difference (P<0.01) in species richness between MAT and SILV plots, with SILV plots having 17% lower species richness than MAT plots (11.83±1.08 versus 14.27±1.26). There were no significant differences in mean species richness among context-classes when the analysis was restricted to the three context-classes that had both MAT and SILV plots (4-6).

Time since last fire was weakly, but significantly, correlated (r=0.36; P<0.01) with mean species richness: species richness increased in proportion to the logarithm of time since last fire (Richness = 4.51 + 2.08[Log TSLF]). There was a significant (P=0.034) interaction in time since last fire between MAT and SILV among context-classes 3-6 (Figure A2.3). In SILV, time since last fire decreased with increasing context-class reflecting the westward progression, over time, of contemporary forest harvesting. In contrast, time since last fire in MAT declined in context-class 6, which was universally affected by the 1934 wildfire. The lack significant differences in species richness among context-classes 4-6 are consistent with the time since last fire interaction between plot type and context-class.

Community composition (derived from cluster analysis) was not significantly associated with landscape context-class. There was, however, a significant association between community composition and plot type: MAT had a disproportionately high number of callidendrous and thamnic plots, while SILV had a disproportionately high number of *Pomaderris* and *Monotoca* plots. Time since last fire differed significantly ($P<0.001$) among the four community types: the time since last fire was significantly less for the *Pomaderris* and *Monotoca* communities than the callidendrous community, which was in turn significantly less than the thamnic community. Community composition was strongly influenced by soil chemical properties. There were highly significant differences ($P<0.001$) among community types in the concentrations of aluminium, calcium and magnesium and in the pH of the surface soils (Table A2.10). These differences separated the *Pomaderris* community from the other three communities: the *Pomaderris* community occurred on plots characterised as having surface soils with higher calcium and magnesium concentrations resulting in a higher pH and lower aluminium concentration.

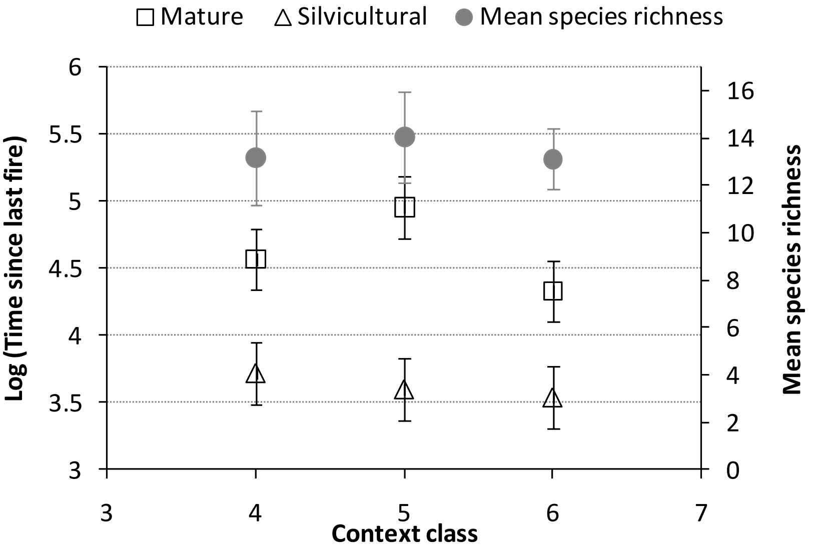


Figure A2.3. Least square means (and 95% confidence intervals) of time since last fire (logarithm) versus context-class for plots in mature forest and older silvicultural regeneration.

Soil property	Analysis result	Range tests
Aluminium	$F_{3,52} = 6.52$; $P<0.001$	*Pomaderris* < all other communities
Ammonium	n.s.	
Calcium	K-W = 31.31; $P<0.001$	*Pomaderris* > all other communities
Conductivity	$F_{3,52} = 2.72$; $P = 0.054$	*Pomaderris* > *Monotoca*
Copper	$F_{3,52} = 2.38$; $P = 0.081$	*Pomaderris* > *Monotoca* and Thamnic
Iron	n.s.	
Magnesium	K-W = 13.11; $P<0.001$	*Pomaderris* > all other communities
pH	$F_{3,52} = 11.82$; $P<0.001$	*Pomaderris* > all other communities
Potassium	n.s.	

Table A2.10. Summary of analysis of variance testing the significance of differences in soil chemical properties among the four vegetation communities.

None of the three axes extracted from the non-metric scaling (NMS) ordination of the plant assemblage composition differed significantly among landscape context-class, although axis-3 approached statistical significance ($P=0.052$). This was reflected in axis-3 scores being significantly lower in context-classes 3 and 4 compared with 5 and 7. Axis-3 scores were significantly correlated (r = -0.396; P<0.01) with time since last fire. Residuals from the regression of axis-3 and time since last fire did not differ significantly among context-classes suggesting the differences in axis-3 scores among context-classes was due to time since last fire.

NMS axes 1 and 3, but not axis 2 differed significantly (both P<0.01) between MAT and SILV plots. Scores in both axis 1 and axis 3 were significantly lower in SILV plots than MAT plots. However, these significant differences between MAT and SILV disappeared once the relationship with time since last fire was removed from the axis 1 and axis 3 scores.

The evenness in the abundance of species as measured by the Shannon diversity index (or its exponent) did not differ significantly among landscape context-classes, or between MAT and SILV plots. Between plot heterogeneity, as measured by Sorenson’s distance measure, differed significantly (P=0.01) among landscape context-classes. Plots in context-classes 3 and 4 were significantly less heterogeneous than plots in context-classes 6 and 7. Sorenson’s distance was moderately well strongly correlated with time since last fire (r = -0.42; P=0.0014) and four soil chemical properties: aluminium (r = 0.37; P<0.01), calcium (r = -0.44; P<0.001), magnesium (r = -0.40; P<0.01) and pH (r = -0.33; P<0.05). The significant difference in Sorenson’s distance among context-classes disappeared after accounting for its correlation with soil concentrations of any one of aluminium, calcium or magnesium.

Sorenson’s distance also differed significantly (P<0.001) between MAT and SILV plots, reflected in MAT plots being significantly more heterogeneous than SILV plots. However, this difference disappeared after accounting for the significant correlation between Soreson’s distance and time since last fire.

There were no significant differences among context-classes in either litter cover or the log cover. Litter cover did, however, differ significantly (P<0.05) between MAT and SILV plots with the latter having significantly higher litter cover.

There was a significant (χ^2_{16} = 224; P<0.001) association between the number of fires since 1850 and context-class. Context-class 3 had a disproportionately high number of plots that have experienced two fires since 1850, while context-class 7 had a disproportionately high number of plots that have experienced no fires since 1850. Unsurprisingly, there was also a significant association between the number of fires since 1850 and plot type: there was a disproportionately high number of MAT that have experienced no fires since 1850 and a disproportionately high number of SILV plots that have experienced two fires since 1850.

Vegetation groups

The proportional abundance measured in 107 of the 180 combinations of vegetation group and landscape scale differed significantly among landscape context-classes (Table A2.11); in a further 5 combinations, the differences approached statistical significance (0.05<P<0.1). The majority (93) of those significant differences occurred at landscape scales of 250 metres or above. Differences due to the proportional abundance increasing with increasing context-class (positive relationship) occurred in 73 of the 107 combinations. All but two of these 73 cases occurred in vegetation groups that contained rainforest, mature eucalypts or wildfire eucalypt regrowth. Differences due to the proportional abundance decreasing with increasing context-class (negative relationship) occurred in 28 of the 107 combinations. All but three of those 28 cases occurred in vegetation groups resulting from either forestry or agricultural activities.

Thus positive relationships were in vegetation groups that originated from a history infrequent natural disturbance and negative relationship in vegetation groups that originated from human-induced disturbance.

The proportional abundance measured in 92 of the 180 combinations of vegetation group and landscape scale differed significantly between MAT and SILV plots (Table A2.11); in a further 13 combinations, the differences were nearly statistically significant ($0.05<P<0.1$). Significant differences between MAT and SILV in proportional abundance of the different vegetation groups occurred uniformly across landscape scales (<250 m: 29; 250 m – 1 km: 28; >1 km: 35). Only 15 of the 92 significant differences reflected proportional abundances in SILV being greater than in MAT. These 15 cases were confined to vegetation groups that included plantations or older silvicultural regeneration (including thinned regeneration).

Distance from plots to the nearest patch of a given vegetation group showed highly significant ($P<0.001$) relationships with context-class for all but three of the 20 combinations of vegetation group - young silvicultural regeneration, wildfire regrowth and other native forest (Figure A2.4). The vegetation groups that included combinations of agricultural land, plantations or older silvicultural regeneration showed positive correlations between distance to nearest patch and context-class. Vegetation groups that included combinations of rainforest and mature eucalypt forest showed negative correlations between distance to the nearest patch and context-class.

Distance to nearest patch of a vegetation group differed significantly between MAT and SILV for 14 of the 20 vegetation group combinations (Table A2.12). All but two (young and old silvicultural regeneration) of the 14 showing significant differences were for vegetation groups that included mature eucalypt forests. SILV plots were significantly closer to patches of young and old silvicultural regeneration than MAT plots. Conversely, MAT plots were significantly closer than SILV plots to vegetation groups that included mature eucalypt forests in their combination.

Three of the four measures of vegetation group heterogeneity (richness, Shannon’s index and Simpson’s index) were strongly correlated with each other. Each of the three was significantly different among context-classes at scales of 2 km or larger (Table A2.13). At these scales differences among context-classes in the evenness metric approached or just met statistical significance. In all cases context-class 7 tended to have fewer vegetation groups giving a less heterogeneous landscape than the other context-classes.

There were also significant differences between MAT and SILV in the heterogeneity of vegetation groups in the surrounding landscapes at spatial scales of 1 km or less (Table A2.14). Landscapes surrounding MAT plots had significantly more heterogeneity in vegetation groups than SILV plots.

Vegetation group	Radius (metres) of landscapes surrounding plots																	
	31.25		62.5		125		250		500		1000		2000		4000		8000	
1) Native non-forest						(*) -ve		* -ve		** -ve		* -ve		(*) -ve		(*) “∪”		** +ve
2) Agricultural land + native non-forest								* -ve		* -ve		** -ve		* -ve		* “∪”		** +ve
3) Plantation	-	-	-	-				** -ve		*** -ve		*** -ve	* S>M	*** -ve	(*) S>M	*** -ve	* S>M	*** -ve
4) Agricultural land + plantation	-	-	-	-				** -ve		*** -ve		*** -ve	* S>M	*** -ve	* S>M	*** -ve	(*) S>M	*** -ve
5) Young silvicultural regeneration	-	-	-	-	* M>S	* “~”	** M>S	* “∩”	** M>S		*** M>S		** M>S		* M>S		n.s.	** -ve
6) Older silvicultural regeneration	*** S>M		*** S>M	* -ve	*** S>M	** -ve	*** S>M	*** -ve	*** S>M	*** -ve	*** S>M	*** -ve	*** S>M	*** -ve	*** S>M	*** -ve	** S>M	** -ve
7) Thinned silvicultural regeneration	-	-	-	-									** S>M		** S>M	(*) “∩”	** S>M	
8) Other native forest																* “∩”		* “∩”
9) Wildfire eucalypt regrowth			(*) M>S		** M>S		* M>S	* +ve	(*) M>S	* +ve	* M>S	* +ve	** M>S	* +ve	(*) M>S			* “~”
10) Mature eucalypt (total)	*** M>S	* +ve	*** M>S	** +ve	*** M>S	*** +ve	*** M>S	*** +ve	*** M>S	*** +ve	*** M>S	*** +ve	** M>S	*** +ve	** M>S	*** +ve	* M>S	*** +ve
11) Mature eucalypt (in CAR reserves)	*** M>S	(*) “~”	*** M>S	(*) “~”	** M>S		*** M>S		* M>S	* +ve	*** M<S	*** +ve	** M>S	*** +ve	* M>S	*** +ve	(*) M>S	*** +ve
12) Rainforest (total)	-	-	-	-				* +ve		* +ve		** +ve		*** +ve	(*) M>S	*** +ve	(*) M>S	*** +ve
13) Rainforest (in CAR reserves)	-	-	-	-	-	-	(*) S>M					** +ve		** +ve	* M>S	*** +ve	(*) M>S	*** +ve
14) Mature eucalypt + rainforest (total)	*** M>S		*** M>S		** M>S		* M>S	** +ve		*** +ve	* M>S	*** +ve	* M>S	*** +ve	* M>S	*** +ve	* M>S	*** +ve
15) Mature eucalypt + rainforest (in CAR reserves)	* M>S		* M>S		(*) M>S					* +ve	* M>S	*** +ve	* M>S	*** +ve	* M>S	*** +ve	(*) M>S	*** +ve
16) Mature eucalypt + rainforest + wildfire eucalypt regrowth (total)	*** M>S	** +ve	*** M>S	** +ve	*** M>S	*** +ve	*** M>S	*** +ve	*** M>S	*** +ve	*** M>S	*** +ve	*** M>S	*** +ve	* M>S	*** +ve	(*) M>S	*** +ve
17) Mature eucalypt + rainforest + wildfire eucalypt regrowth (in CAR reserves)	** M>S		** M>S		** M>S		* M>S	(*) +ve	(*) M>S	** +ve	** M>S	*** +ve	* M>S	*** +ve	* M>S	*** +ve	(*) M>S	*** +ve
18) “Core” mature eucalypt[1]	*** M>S	* +ve	*** M>S	** +ve	*** M>S	** +ve	*** M>S	*** +ve	*** M>S	*** +ve	** M>S	*** +ve	** M>S	*** +ve	* M>S	*** +ve	* M>S	*** +ve
19) Mature eucalypt forest not dissected by hard edges[2]	*** M>S	* +ve	*** M>S	** +ve	*** M>S	*** +ve	*** M>S	*** +ve	*** M>S	*** +ve	*** M>S	*** +ve	** M>S	*** +ve	** M>S	*** +ve	* M>S	*** +ve

Table A2.11. Full list of metrics measuring the proportional contribution of vegetation groups to the area of 31.25 m – 8 km radii landscapes. Significance of differences (tested using analysis of variance) in the metrics between MAT and SILV plots (shaded columns) and among landscape context-classes are shown by asterisks that indicate level of significance (***P<0.001; **P<0.01; *P<0.05; (*)P<0.1; blank-no significant difference; “-“ all zero values) and by the direction of those differences.

[1] Residual area of after excluding a 50 m internal buffer around the perimeter of each patch

[2] Residual area of mature eucalypt forest after excluding 50 m internal buffer at boundaries with roads, rivers, non-forest, plantation or young silvicultural regeneration.

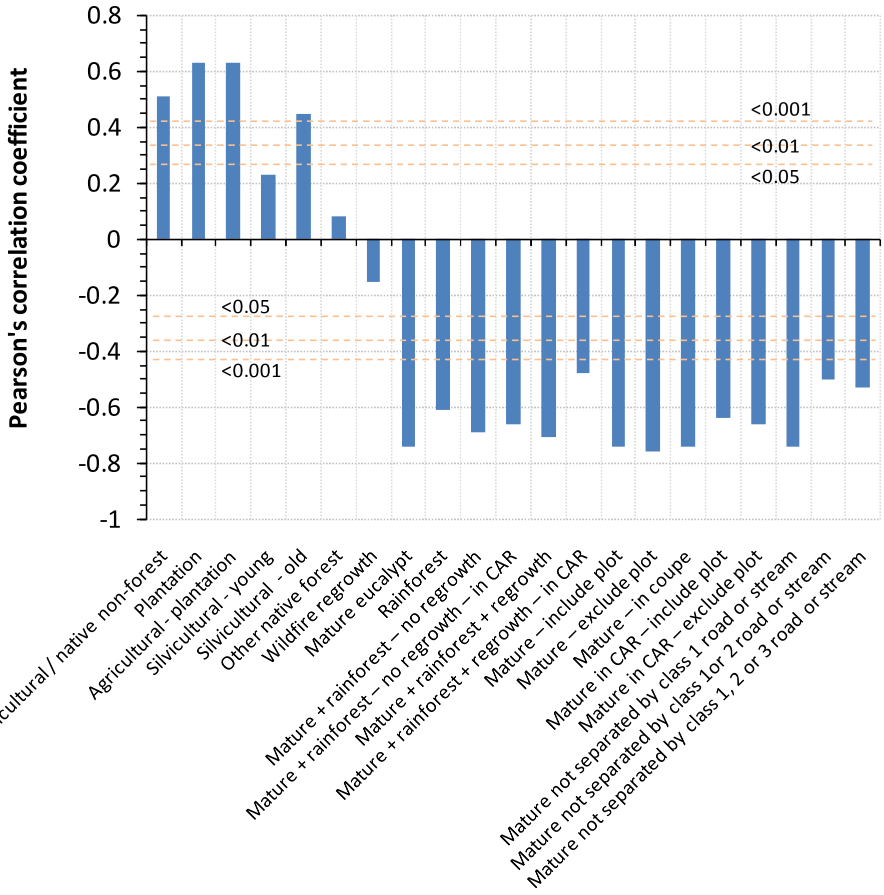


Figure A2.4. Pearson's correlation coefficient for the regression of distance to the nearest patch of the indicated vegetation groups with landscape context-class.

1. Agricultural and native non-forest n.s.	2. Agricultural and plantation n.s.	3. Plantation n.s.
4. Silvicultural - young P=0.002; SILV < MAT	5. Silvicultural -old P<0.001; SILV < MAT	6. Other native forest n.s.
7. Wildfire regrowth eucalypt n.s.	8. Mature eucalypt P<0.001; MAT < SILV	9. Rainforest n.s.
10. Mature (excluding plot) P<0.001; MAT < SILV	11. Mature (including plot) P < 0.001; MAT < SILV	12. Couped-up mature P < 0.001; Mat < SILV
13. Mature in CAR Reserve (excluding plot) P < 0.001; MAT < SILV	14. Mature in CAR Reserve (including plot) P < 0.001; MAT < SILV	15. Mature + rainforest P=0.006; MAT < SILV
16. Mature + rainforest in CAR Reserve P=0.066	17. Mature + rainforest + wildfire regrowth P < 0.001; MAT < SILV	18. Mature + rainforest + wildfire regrowth in CAR Reserve P=0.02; MAT < SILV
19. Mature not separated by a class 1 stream or road P < 0.001; MAT < SILV	20. Mature not separated by a class 1-2 stream or road P < 0.001; MAT < SILV	21. Mature not separated by a class 1-3 stream or road P<0.001; MAT < SILV

Table A2.12. Results of analysis of variance testing the significance of differences in distance to the nearest patch of the indicated vegetation group between MAT and SILV.

	125 m	250 m	500 m	1 km	2 km	4 km	8 km
Evenness	n.s.	n.s.	0.05<P<0.1 4 > 3, 5, 7	n.s.	P<0.05 7<4, 5 | 3<5	0.05<P<0.1 7 < 3	0.05<P<0.1 7 < 3
Richness	n.s.	n.s.	0.05<P<0.1 3 < 5, 6	n.s.	n.s.	P<0.01 7 < 4-6	P<0.01 7 < 4-6
Shannon	n.s.	n.s.	n.s.	n.s.	P<0.05 7 < 4, 5, 6	P<0.001 7 < 3-6	P<0.001 7 < 3-6
Simpson	n.s.	0.05<P<0.1 3, 7 < 6	0.05<P<0.1 3 < 5, 6	n.s.	P<0.05 7 < 5, 6	P<0.001 7 < 3-6	P<0.001 7 < 3-6

Table A2.13. Results of analysis of variance testing the significance of differences among landscape context-classes in four measures of vegetation group heterogeneity in 125 m – 8 km landscapes surrounding plots.

	125 m	250 m	500 m	1 km	2 km	4 km	8 km
Evenness	P<0.05 MAT>SILV	0.05<P<0.1 MAT↑	n.s.	n.s.	0.05<P<0.1 SILV↑	P<0.01 SILV>MAT	P<0.01 SILV>MAT
Richness	P<0.001 MAT>SILV	P<0.01 MAT<SILV	P<0.01 MAT<SILV	P<0.01 MAT<SILV	n.s.	n.s.	n.s.
Shannon	P<0.01 MAT>SILV	P<0.01 MAT>SILV	P<0.05 MAT>SILV	n.s.	n.s.	n.s.	n.s.
Simpson	P<0.01 MAT>SILV	P<0.01 MAT>SILV	P<0.01 MAT>SILV	P<0.05 MAT>SILV	n.s.	n.s.	n.s.

Table A2.14. Results of analysis of variance testing the significance of differences between MAT and SILV in four measures of vegetation group heterogeneity in 125 m – 8 km landscapes surrounding plots.

Appendix 3. Birds recorded the SFEFL and the results of statistical tests of their abundance among context-classes and forest types.

Explanations:

- $^{1.}$ Species labelled with “^{c}” (common) occurred in 7 or more plots and with “^{r}” (rare) in fewer than 7 plots.
- $^{2.}$ Habitat: d – dense forest; o – sclerophyll forest and woodland, w – widespread
- $^{3.}$ Indicator species labelled M or S for species that were significantly associated with MAT or SILV respectively in Indicator Species Analysis.
- $^{4.}$ Species labelled M or S in Random Forest indicated species yielding Random Forest models with pseudo-R^2 values ≥ 40% for MAT or SILV plots respectively.
- Significance of differences (tested by analysis of variance) in species abundance between MAT and SILV, and among context-classes are as follows: (*) – 0.05<P<0.1; * - P<0.05; ** - P<0.01; *** - P<0.001
- Trend of species abundances among levels of context-class are as follows: -ve – negative; R-J – reverse “J” shape; +ve – positive; J – “J” shaped; H – “∩” shaped; U – “∪” shaped; ~ - irregular shaped.

Common name$^{1, 2}$ (taxon)	Numbers in MAT	SILV	Indicator species^{3}	Random Forest^{4}	MAT vs SILV	Context	Context within MAT	SILV
Bassian thrush$^{c, d}$ (*Zoothera lunulata*)	27	8	M		M>S*			
Beautiful firetail$^{r, w}$ (*Stagonopleura bella*)	3							
Black currawong$^{c, o}$ (*Strepera fuliginosa*)	35	16	M					
Black-faced cuckoo-shrike$^{c, o}$ (*Coracina novaehollandiae*)	13	2			M>S*			
Black-headed honeyeater$^{c, w}$ (*Melithreptus affinus*)	108	41	M		M>S*			+ve$^{(*)}$
Brown falcon$^{r, w}$ (*Falco berigora*)	2							
Brown goshawk$^{r, o}$ (*Accipiter fasciatus*)	2	1						
Brown thornbill$^{c, o}$ (*Acanthiza pusilla*)	17	23						
Common bronzewing$^{r, w}$ (*Phaps chalcoptera*)		1						
Crescent honeyeater$^{c, w}$ (*Phylidonyris pyrrhoptera*)	153	92			M>S*		-ve*	∪*
Dusky robin$^{r, o}$ (*Melanodryas vittata*)	5	3						
Dusky woodswallow$^{r, o}$ (*Artamus cyanopterus*)	1							
Eastern spinebill$^{c, w}$ (*Acanthorhynchus tenuirostris*)	61	9	M		M>S$^{(*)}$			
Fan-tailed cuckoo$^{r, o}$ (*Cacomantis flabelliformis*)	4	1						
Flame robin$^{c, w}$ (*Petroica phoenicea*)	10	3						
Forest raven$^{c, w}$ (*Corvus tasmanicus*)	4	5					-ve$^{(*)}$	
Golden whistler$^{c, w}$ (*Pachycephala pectoralis*)	47	32						
Green rosella$^{c, w}$ (*Platycercus caledonicus*)	197	82	M		M>S**			
Grey currawong$^{r, o}$ (*Strepera versicolour*)	1	1						
Grey fantail$^{c, w}$ (*Rhipidura fuliginosa*)	205	120	M	M	M>S*			
Grey shrike-thrush$^{c, w}$ (*Colluricincla harmonica*)	59	52				+ve*		+ve$^{(*)}$

Common name	Numbers in		Indicator species	Random Forest	MAT vs SILV	Context	Context within	
	MAT	SILV					MAT	SILV
Laughing kookaburra$^{r, w}$ (*Dacelo novaeguineae*)	2	1						
Olive whistler$^{c, w}$ (*Pachycephala olivacea*)	13	15						+ve$^{(*)}$
Pink robin^{c} (*Petroica rodinogaster*)	150	63	M		M>S*			
Satin flycatcher$^{r, d}$ (*Myiagra cyanoleuca*)	14							
Scarlet robin$^{r, o}$ (*Petroica multicolor*)	3	3						
Scrubtit$^{c, d}$ (*Acanthornis magnus*)	84	32	M		M>S$^{(*)}$			+ve*
Sulphur-crested cockatoo$^{r, w}$ (*Cacatua galerita*)	1							
Superb lyrebird$^{c, d}$ (*Menura novaehollandiae*)	40	25						
Strong-billed honeyeater^{c,d} (*Melithreptus validirostris*)	51	36	M					
Superb fairywren$^{c, w}$ (*Malurus cyaneus*)	12	11						
Swift parrot$^{c, o}$ *Lathamus discolour*)	18	1			M>S$^{(*)}$			
Tasmanian scrubwren$^{c, d}$ (*Sericornis humilis*)	312	203	M				+ve*	
Tasmanian thornbill$^{c, d}$ (*Acanthiza ewingii*)	450	338	M	M, S	M>S**	+ve***	+ve$^{(*)}$	+ve***
Wedge-tailed eagle$^{r, w}$ (*Aquila audax*)	1	1						
Welcome swallow$^{r, w}$ (*Hirundo neoxena*)		1						
Yellow-tailed black cockatoo$^{c, w}$ (*Calyptorhynchus funereus*)	10	6						
Yellow throated honeyeater$^{c, w}$ (*Lichenostomus flavicollis*)	37	7	M		M>S**	-ve(*)	-ve*	
Yellow wattlebird$^{r, o}$ (*Anthochaera paradoxa*)	6	2						

Appendix 4. List of the 255 common beetles sampled from the SFEFL and the results of statistical tests of their abundance among context-classes and forest types.

Explanations:

- Indicator species labelled M or S for species that were significantly associated with MAT or SILV respectively in Indicator Species Analysis.
- Species labelled M or S in Random Forest indicated species yielding Random Forest models with pseudo-R^2 values ≥ 40% for MAT or SILV plots respectively.
- Significance of differences (tested by analysis of variance) in species abundance between MAT and SILV, and among context-classes are as follows: (*) – 0.05<P<0.1; * - P<0.05; ** - P<0.01; *** - P<0.001
- Trend of species abundances among levels of context-class are as follows: -ve – negative; R-J – reverse “J” shape; +ve – positive; J – “J” shaped; H – “∩” shaped; U – “∪” shaped; ~ - irregular shaped.

	Numbers in				MAT		Context in:	
Family: subfamily: Species	MAT	SILV	Indicator species	Random Forest	vs SILV	Context	MAT	SILV
ADERIDAE:								
Aderidae TFIC sp 06	13	4						H**
Aderidae TFIC sp 11	3	5			M>S$^{(*)}$			R-J*
ANOBIIDAE: ANOBIINAE								
Hadrobregmus areolicolle	27	39						
ANOBIIDAE: XYLETININAE								
Lasioderma serricorne	4	5						
ANTHRIBIDAE:								
Erichsonocis ECZ sp 08	10	3						
ARCHEOCRYPTICIDAE:								
Enneboeus ovalis	19	17		M				
ATTELABIDAE: RHYNCHITINAE								
Auletobius TFIC sp 08	28	8						
BIPHYLLIDAE:								
Diplocoelus angustulus	429	324						
CARABIDAE: HARPALINAE								
Lecanomerus TFIC sp 02	151	50		M, S				
CARABIDAE: PENTAGONICINAE								
Pentagonica vittipennis	13	26		M				
CARABIDAE: PSYDRINAE								
Amblytelus (?) *longipennis*	6	9					-ve$^{(*)}$	-ve*
CARABIDAE: TRECHINAE								
Trechimorphus diemenensis	363	232				+ve$^{(*)}$		
CERAMBYCIDAE: CERAMBYCINAE								
Mecynopus cothurnatus	22	42		M, S				
CERYLONIDAE:								
Cerylonidae TFIC sp 04	8	13						
CHRYSOMELIDAE: CHRYSOMELINAE								
Paropsisterna bimaculata	5	4						
CIIDAE: CIINAE								
Cis cervus	24	19		S				

Family: subfamily: Species	Numbers in MAT	SILV	Indicator species	Random Forest	MAT vs SILV	Context	Context in: MAT	SILV
Cis TFIC sp 04	30	30						
Cis TFIC sp 14	7	2						
Xylographus LAWRENCE sp 697	19	14		M				
CLAMBIDAE: CLAMBINAE								
Clambus bornemisszai	1689	388		M				
Clambus simsoni	424	781						
Sphaerothorax pubiventris	23	10						
Sphaerothorax tasmani	1480	1005	M	M				
COCCINELLIDAE: COCCIDULINAE								
Rhyzobius TFIC sp 05	1	27			S>M*			
CORYLOPHIDAE: CORYLOPHINAE								
Sericoderus TFIC sp 02	605	599		M		+ve*		~$^{(*)}$
Sericoderus TFIC sp 03	6	11	S			U$^{(*)}$		
Sericoderus TFIC sp 05	1	27		M				
Sericoderus TFIC sp 06	61	40	M	M			+ve$^{(*)}$	
Sericoderus TFIC sp 10	7	2			M>S*			
CRYPTOPHAGIDAE:								
Cryptophagidae TFIC sp 01	40	33						
Cryptophagidae TFIC sp 02	41	39	M			U$^{(*)}$	+ve$^{(*)}$	
Cryptophagidae TFIC sp 05	21	40	M					
Cryptophagidae TFIC sp 06				S		+ve*		
Cryptophagidae TFIC sp 09	174	118		S		+ve$^{(*)}$		+ve$^{(*)}$
Cryptophagidae TFIC sp 13	18	7						
Cryptophagidae TFIC sp 14	12	10						
Cryptophagidae TFIC sp 15	156	198	S			H$^{(*)}$		
CRYPTOPHAGIDAE: CRYPTOPHAGINAE								
Cryptophagus gibbipennis	3295	2680						
Cryptophagus tasmanicus	359	294		S		+ve$^{(*)}$	+ve$^{(*)}$	
CUCUJIDAE:								
Cucujidae TFIC sp 02	5	31						
CURCULIONIDAE: CRYPTORHYNCHINAE								
Cryptorhynchinae TFIC sp 21	2	11						
Cryptorhynchinae TFIC sp 62	11	5						
Exithius capucinus	5	5					~$^{(*)}$	
Pseudometyrus ANIC sp 01	14	21		M				
CURCULIONIDAE: DRYOPHTHORINAE								
Dryophthorus ECZ sp 01	2	24			S>M*			
CURCULIONIDAE: PLATYPODINAE								
Platypus subgranosus	573	319	M	M				H*
CURCULIONIDAE: SCOLYTINAE								
Acacicis abundans	639	1643		M				
Xylechinus acaciae	12	240						

Family: subfamily: Species	Numbers in		Indicator species	Random Forest	MAT vs SILV	Context	Context in:	
	MAT	SILV					MAT	SILV
DERODONTIDAE: LARICOBINAE								
Nothoderodontus darlingtoni	41	24		M	M>S$^{(*)}$	H*		
ENDOMYCHIDAE:								
Endomychidae TFIC sp 02	8	1			M>S**			
EROTYLIDAE: DACNINAE								
Thallis vinula	41	60	M	M		U$^{(*)}$		
EUCINETIDAE:								
Eucinetus TFIC sp 04	9	15		M				
EUCNEMIDAE: DIRRHAGINAE								
Dirrhaginae MUONA sp 02	13	4			M>S$^{(*)}$			
EUCNEMIDAE: MACRAULACINAE								
Euryptychus concolor	5	20			S>M*	R-J**	J$^{(*)}$	
EUCNEMIDAE: MELASINAE								
Agalba MUONA sp 01	9	38						
Agalba rufipennis	10	9						
HISTERIDAE: ABRAEINAE								
Teretriosoma sorellense	14	19						
HOBARTIIDAE:								
Hobartius eucalypti	2207	2462		M, S				
HYDROPHILIDAE: SPHAERIDIINAE								
Notocercyon ANIC Hansen 01	12	4						
LAEMOPHLOEIDAE:								
Laemophloeidae TFIC sp 01	17	18				+ve*		
Laemophloeus ramsayi	357	164		M, S				H*
Microbrontes blackburni	5	6						
Placonotus australasiae	35	26	M	M				
LAMINGTONIIDAE: LAMINGTONIINAE								
Lamingtonium loebli	48	44	M	M, S				~*
LATRIDIIDAE: CORTICARIINAE								
Bicava verrucifera	116	148	M			-ve*		H*
Corticaria ferruginea	7	7						
Cortinicara REIKE sp nov 1	76	87						
LATRIDIIDAE: LATRIDIINAE								
Aridius minor	76	85						
Aridius nodifer	1708	2865						
Aridius TFIC sp 03	31	14						
Enicmus priopterus	4415	6919		M, S		+ve*		
Enicmus REIKE sp nov 1	56	51						
Enicmus REIKE sp nov 2	108	42						
Enicmus REIKE sp nov 3	51	28		M				
Latridius TFIC sp 01	30	11			M>S$^{(*)}$	H*		H$^{(*)}$
LEIODIDAE:								
Sogdini SEAGO gen nov A TFIC sp 01	13	20						J(*)

	Numbers in						Context in:	
Family: subfamily: Species	MAT	SILV	Indicator species	Random Forest	MAT vs SILV	Context	MAT	SILV
LEIODIDAE: CAMIARINAE								
Agyrtodes atropos	562	534				H$^{(*)}$		
Myrmicholeva acutifrons	256	306		M, S				-ve$^{(*)}$
Neopelatops TFIC sp 01	182	108		S	M>S$^{(*)}$	H*		R-J**
LEIODIDAE: CHOLEVINAE								
Catoposchema tasmaniae	138	156		M				
Choleva TFIC sp 01	21	17						
Nargiotes gordoni	919	720				+ve$^{(*)}$		
Nargomorphus apicalis	101	27		M			+ve$^{(*)}$	
Nargomorphus confertus	344	308	M	S		+ve**		+ve$^{(*)}$
Nargomorphus consimilis	588	123				H***	J*	~$^{(*)}$
Nargomorphus globulus	160	183		M, S			-ve*	
Nargomorphus leanus	37	46						
Nargomorphus victoriensis	490	335				+ve$^{(*)}$		~$^{(*)}$
Paragyrtodes percalceatus	141	104						
LEIODIDAE: LEIODINAE								
Colenisia TFIC sp 01	10	6				U$^{(*)}$		
Sogdini TFIC sp 01	10	37		M		H*	~*	
Zeadolopus TFIC sp 01	233	242		M				
LUCANIDAE: SYNDESINAE								
Syndesus cornutus	126	181		M, S		+ve*		U$^{(*)}$
LYCIDAE: METRIORRHYNCHINAE								
Porrostoma simsoni	11	7						
MELANDRYIDAE: MELANDRYINAE								
Callidircaea venusta	16	15						
Orchesia minuta	6	5				H*		
Orchesia TFIC sp 11	12	16		M, S				
MORDELLIDAE: MORDELLINAE								
Mordella promiscua	37	20	M	M		+ve$^{(*)}$		
Mordella TFIC sp 02	3	8					~$^{(*)}$	
Mordella TFIC sp 04	6	2						
Mordella TFIC sp 05	32	72						
MYCETOPHAGIDAE: MYCETOPHAGINAE								
Litargus intricatus	5	4						
NITIDULIDAE: CILLAEINAE								
Brachypeplus planus	29	29	M	M				
NITIDULIDAE: NITIDULINAE								
Epuraea victoriensis	15	8	M					
Thalycrodes cylindricum	2	12			S>M*			
Thalycrodes pulchrum	44	75						
PERIMYLOPIDAE:								
Sirrhas limbatus	4	5						
Sirrhas variegatus	18	13					~*	J**

Family: subfamily: Species	Numbers in MAT	SILV	Indicator species	Random Forest	MAT vs SILV	Context	Context in: MAT	Context in: SILV
PHALACRIDAE:								
Phalacridae TFIC sp 05	24	15						
PHALACRIDAE: PHALACRINAE								
Litochrus alternans	70	44		M			+ve$^{(*)}$	
Litochrus TFIC sp 02	6	4				J*		
PHLOEOSTICHIDAE: HYMAEINAE								
Hymaea succinifera	58	76						R-J**
PROSTOMIDAE:								
Dryocora cephalotes	28	193	M			+ve$^{(*)}$		
Prostomis atkinsoni	22	37		M, S				
PTILIIDAE:								
Ptiliidae TFIC sp 04	18	49	M		M>S$^{(*)}$			
Ptiliidae TFIC sp 06	74	16	M				+ve*	
Ptiliidae TFIC sp 07	41	55				H$^{(*)}$		H$^{(*)}$
Ptiliidae TFIC sp 08	62	47				+ve*	+ve*	~*
Ptiliidae TFIC sp 10	58	35						
Ptiliidae TFIC sp 13	44	11				H$^{(*)}$		
Ptiliidae TFIC sp 16	22	24						
Ptiliidae TFIC sp 18	85	2			M>S*			
SALPINGIDAE: SALPINGINAE								
Neosalpingus hybridus	6001	4866	M		M>S*			
Orphanotrophium frigidum	4	28	M					
SCARABAEIDAE: APHODIINAE								
Saprosites mendax	24	18				-ve$^{(*)}$		
Saprus griffithi	19	9						
SCARABAEIDAE: MELOLONTHINAE								
Phyllochlaenia TFIC sp 01	8	25						
Telura vitticollis	4	8						
SCARABAEIDAE: SCARABAEINAE								
Onthophagus mutatus	15	17						
SCIRTIDAE:								
Cyphon TFIC sp 05	11	1			M>S$^{(*)}$			
Prionocyphon latusmandibularis	23	21						
Prionocyphon warra	31	28		S		H$^{(*)}$		+ve*
Pseudomicrocara spilotus	9	22		M				
SILVANIDAE:								
Silvanidae TFIC sp 04	69	62		S				
SILVANIDAE: BRONTINAE								
Macrohyliota bicolor	15	7		M			H$^{(*)}$	
SPHINDIDAE: SPHINDINAE								
Aspidiphorus humeralis	1500	1430		M		H$^{(*)}$		
Notosphindus slateri	73	54						

Family: subfamily: Species	Numbers in MAT | SILV		Indicator species	Random Forest	MAT vs SILV	Context	Context in:	
							MAT	SILV
STAPHYLINIDAE: ALEOCHARINAE								
Aleochara TFIC sp 01	13	9					H$^{(*)}$	H$^{(*)}$
Aleochara TFIC sp 02	6	9				+ve$^{(*)}$		
Aleocharinae TFIC sp 015	22	26		M				
Aleocharinae TFIC sp 021	43	148						
Aleocharinae TFIC sp 027	65	29			M>S*			
Aleocharinae TFIC sp 032	24	19		S				+ve$^{(*)}$
Aleocharinae TFIC sp 033	37	34		S			H$^{(*)}$	
Aleocharinae TFIC sp 037	50	20		M, S				U$^{(*)}$
Aleocharinae TFIC sp 038	61	64		M		H*	~$^{(*)}$	
Aleocharinae TFIC sp 066	506	164		M	M>S**	+ve$^{(*)}$		H*
Aleocharinae TFIC sp 068	62	64		M				
Aleocharinae TFIC sp 080	20	29						H$^{(*)}$
Aleocharinae TFIC sp 100	30	90					J*	
Aleocharinae TFIC sp 103	21	6					~$^{(*)}$	
Aleocharinae TFIC sp 115	79	206				H$^{(*)}$		~*
Aleocharinae TFIC sp 116	13	15						
Aleocharinae TFIC sp 118	7	29					+ve$^{(*)}$	
Aleocharinae TFIC sp 127	60	132		M		+ve$^{(*)}$		U$^{(*)}$
Aleocharinae TFIC sp 130	65	11			M>S$^{(*)}$		U$^{(*)}$	
Aleocharinae TFIC sp 131	9	12						
Aleocharinae TFIC sp 133	12	7						
Aleocharinae TFIC sp 135	3	7						
Aleocharinae TFIC sp 139	121	133		M				
Aleocharinae TFIC sp 140	31	79						R-J$^{(*)}$
Aleocharinae TFIC sp 143	259	446						
Aleocharinae TFIC sp 144	42	19				+ve*	+ve*	
Aleocharinae TFIC sp 145	29	63						
Aleocharinae TFIC sp 147	11	10						
Aleocharinae TFIC sp 151	7	20				H$^{(*)}$		
Aleocharinae TFIC sp 153	4	6						
Aleocharinae TFIC sp 155	68	36						
Aleocharinae TFIC sp 159	13	12				U$^{(*)}$		
Aleocharinae TFIC sp 162	7	6						
Aleocharinae TFIC sp 165	5	5						
Atheta TFIC sp 02	14	10						
Falagria TFIC sp 01	106	37						
Falagria TFIC sp 05	93	72						
Oxypodini TFIC sp 03	9	22						J*
Spanioda carissima	266	266		M, S		H**		~**
Tetrabothrus claviger	12	4	M					
STAPHYLINIDAE: MICROSILPHINAE								
Microsilpha ANIC Thayer sp 15	88	76			M>S*			

	Numbers in		Indicator species	Random Forest	MAT vs SILV	Context	Context in:	
Family: subfamily: Species	MAT |	SILV					MAT	SILV
STAPHYLINIDAE: OMALIINAE								
Hapalarea sp	20	9		M	M>S*			
Ischnoderus parallelus	169	81		M				
Ischnoderus TFIC sp 01	5	9						
Metacorneolabium? darlingtoni	5	3						
Phloeonomus tasmanicus	22	3				U**		
STAPHYLINIDAE: OXYTELINAE								
Anotylus TFIC sp 04	250	534		M, S		H$^{(*)}$		
Anotylus TFIC sp 07	31	241						
STAPHYLINIDAE: PROTEININAE								
Alloproteinus ANIC Thayer sp nov	55	56		M		+ve$^{(*)}$		
Austrorhysus TFIC sp 01	56	28			M>S*			
Austrorhysus TFIC sp 04	56	19			M>S*	+ve$^{(*)}$		H$^{(*)}$
STAPHYLINIDAE: PSELAPHINAE								
Anabaxis CHANDLER Type 1	8	8	S				~*	
Aulaxus CHANDLER Tas 1	27	28		M, S		+ve*	+ve***	
Aulaxus TFIC sp 01	45	28		M				
Chichester CHANDLER Tas 1	106	66						
Eupinella tarsalis	5	6						
Eupines CHANDLER Tas 1	4	4						
Euplectitae nr Gordon TFIC sp 01	20	11						R-J*
Euplectops CHANDLER Tas 1	120	105						
Euplectops TFIC sp 01	27	5			M>S*			
Logasa TFIC sp 01	11	3						
Macroplectus CHANDLER Type 1	164	201		M				+ve**
Macroplectus quadratipennis	14	8				+ve*		
Macroplectus tasmanicus	28	16			M>S*			
Macroplectus TFIC sp 01	26	24	M	M				
Plectusodes CHANDLER Tas 1	24	27						
Protoplectus CHANDLER Tas 1	29	20		S		H$^{(*)}$		H*
Rybaxis parvidens	70	86		M				
Sagola CHANDLER Tas 1	12	2			M>S*			
Sagola CHANDLER Tas 2	2	9						
Sagola rugicornis	95	195		M, S				
Startes CHANDLER Tas 1	7	19						-ve$^{(*)}$
Tasmanityrus newtoni	8	6						
STAPHYLINIDAE: SCAPHIDIINAE								
Baeocera TFIC sp 02	15	15						
Baeocera TFIC sp 03	8	31				-ve*		
Scaphidium alpicolum						R-J$^{(*)}$		
Scaphisoma indutum	20	19		M				
Scaphisoma TFIC sp 01	6	7						
STAPHYLINIDAE: SCYDMAENINAE								
Euconnus TFIC sp 02	8	20						

Family: subfamily: Species	Numbers in MAT	SILV	Indicator species	Random Forest	MAT vs SILV	Context	Context in: MAT	SILV
Euconnus TFIC sp 04	24	29	M					
Euconnus TFIC sp 06	23	28						
Euconnus TFIC sp 07	65	79		M		U*		~$^{(*)}$
Euconnus TFIC sp 08	13	18		S				J$^{(*)}$
Euconnus TFIC sp 12	19	32		M				H$^{(*)}$
Euconnus TFIC sp 15	19	13	M					
Euconnus TFIC sp 16	18	11						
Heterothops pictus	15	21						
Heterothops TFIC sp 03	7	2						
Heterothops TFIC sp 04	8	6		M				
Horaeomorphus TFIC sp 02	14	11						
Horaeomorphus TFIC sp 10	43	85		S		+ve*		+ve*
Horaeomorphus TFIC sp 16	36	19	M					
Horaeomorphus TFIC sp 17	13	12	M	M		U*	~$^{(*)}$	~**
Horaeomorphus TFIC sp 18	12	51						
Scydmaeninae nr *Scydmoraphes*	22	9				+ve*		
Philonthus TFIC sp 04	54	78						
Philonthus TFIC sp 06	6	3						
Quediomimus hybridus	31	21						
Quediomimus TFIC sp 01	4	5						
Quedius baldiensis	170	152		M				
Quedius inaequalipennis	125	111		M	M>S*			
Quedius sidneensis	2614	2116		M, S		+ve*	+ve*	H*
Quedius stenocephalus	49	386		M				
Quedius tepperi	11	11						
Quedius TFIC sp 07	302	140		S		+ve$^{(*)}$	R-J$^{(*)}$	+ve$^{(*)}$
STAPHYLINIDAE: TACHYPORINAE								
Coproporus TFIC sp 02	9	4						
Sepedophilus TFIC sp 08	9	5						
TENEBRIONIDAE: ALLECULINAE								
Nypsius aeneopiceus	31	39	M	M, S		+ve$^{(*)}$		R-J*
Nypsius TFIC sp 02	1	8			S>M*			~$^{(*)}$
THROSCIDAE: THROSCINAE								
Aulonothroscus elongatus	20	19						
ULODIDAE:								
Ganyme sapphira	2	14						
ZOPHERIDAE: COLYDIINAE								
Ablabus bicolor	22	14		M, S		U*		-ve$^{(*)}$
ZOPHERIDAE: ZOPHERINAE								
Latometus differens	52	41						
Pycnomerus fuliginosus	11	13						
Pycnomerus TFIC sp 02	12	5						

Appendix 5. Common vascular plants recorded the SFEFL and the results of statistical tests of their abundance among context-classes and forest types.

Explanations:

- Indicator species labelled M or S for species that were significantly associated with MAT or SILV respectively in Indicator Species Analysis.
- Species labelled M or S in Random Forest indicated species yielding Random Forest models with pseudo-R^2 values ≥ 40% for MAT or SILV plots respectively.
- Significance of differences (tested by analysis of variance) in species abundance between MAT and SILV, and among context-classes are as follows: (*) – 0.05<P<0.1; * - P<0.05; ** - P<0.01; *** - P<0.001
- Trend of species abundances among levels of context-class are as follows: -ve – negative; R-J – reverse “J” shape; +ve – positive; J – “J” shaped; H – “∩” shaped; U – “∪” shaped; ~ - irregular shaped.

	Indicator species	Random Forest	MAT vs SILV	Context	Context within	
Family: species					MAT	SILV
APIACEAE						
Hydrocotyle hiratam				U*		
ASTERACEAE						
Olearia argophylla	M					
CUNONIACEAE						
Anodopetalum biglandulosum	M	M, S	M>S*	H$^{(*)}$		
Bauera rubioides						
ELAEOCARPACEAE						
Aristotelia pedunculata	M		M>S**			
EPACRIDACEAE						
Cyathodes glauca						
Leptecophylla juniperinum		S				+ve*
Monotoca glauca		M, S				
Trochocarpa cunninghamii						
ESCALLONIACEAE						
Anopterus glandulosa		M				+ve*
EUCRYPHIACEAE						
Eucryphia lucida	M	M		H*		H*
FAGACEAE						
Nothofagus cunninghamii	M	M, S		H*		+ve**
MIMOSACEAE						
Acacia dealbata	S		S>M**			
Acacia melanoxylon						
Acacia verticellata						
MONIMIACEAE						
Atherospermum moschatum	M		M>S**	H*		+ve*
MYRTACEAE						
Eucalyptus obliqua		M, S		U$^{(*)}$	~$^{(*)}$	
Eucalyptus regnans						
Leptospermum scoparium						
Melaleuca squamea		S				
PITTOSPORACEAE						
Pittosporum bicolor		M				
PROTEACEAE						
Cennarrhenes nitida	M	S	M>S$^{(*)}$			+ve$^{(*)}$

Family: species	Indicator species	Random Forest	MAT vs SILV	Context	Context within	
					MAT	SILV
RANUNCULACEAE						
Clematis aristata		S				
RHAMNACEAE						
Pomaderris apetala	S	M, S	S>M*			
RUBIACEAE						
Coprosma nitida					~$^{(*)}$	
Coprosma quadrifida			M>S*		~$^{(*)}$	
RUTACEAE						
Nematolepis squamea		S				
Zieria arborescens		S		U$^{(*)}$		-ve$^{(*)}$
THYMELAEACEAE						
Pimelea cinerea						
Pimelea drupaceae	S	S	S>M$^{(*)}$			
WINTERACEAE						
Tasmannia lanceolata						+ve**
CYPERACEAE						
Gahnia grandis		M, S				
LILIACEAE						
Dianella tasmanica		S				
Drymophyla cyanocarpa		M				
PODOCARPACEAE						
Phyllocladus aspleniifolius		M		H**		+ve***
BLECHNACEAE						
Blechnum nudum					~$^{(*)}$	
Blechnum wattsii	M		M>S***			
DENNSTAEDTIACEAE						
Histiopteris incisa		M				
Hypolepis rugosa						
Pteridium esculentum				U$^{(*)}$		
DICKSONIACEAE						
Dicksonia antarctica						
DRYOPTERIDACEAE						
Polystichum proliferum						
Rumohra adiantiformis		M, S		H*		
HYMENOPHYLLACEAE						
Hymenophyllum australe				H$^{(*)}$		
Hymenophyllum cupressiforme		S		H$^{(*)}$		
Hymenophyllum flabellatum	M	S				
Hymenophyllum peltatum						
Hymenophyllum rarum	M	S	M>S*	H*		
POLYPODIACEAE						
Ctenopteris heterophylla	M	S	M>S*			
Grammitis billarideri	M	S	M>S$^{(*)}$			
Microsorum pustulatum		M				
PSILOTACEAE						
Tmesipterus obliqua	M	M	M>S*	H*		