Department of Environment and Conservation
Science Division

FORESTCHECK

REPORT OF PROGRESS 2011–12










Department of
Environment and Conservation

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Compiled by: Richard Robinson and Verna Tunsell
Science Division
Department of Environment and Conservation
Manjimup
Western Australia

This report highlights preliminary results for FORESTCHECK monitoring, determined by basic analysis and field observation, for the year 2011–12. This and previous FORESTCHECK Annual Reports should not be quoted or used as final results for the FORESTCHECK program. Publications based on detailed analyses using comprehensive statistical methods are published on a 5-year basis. All FORESTCHECK publications and reports are available on the DEC web site at www.dec.wa.gov.au .

Cover photos: The filmstrip represents biota monitored by FORESTCHECK: From left, reptiles, macrofungi, invertebrates, lichens, mammals, birds and vascular flora. Main photo: *Kingia australis*, the grass tree after which the vegetation complex 'Kingia' is named. Above right, the banjo frog, *Limnodynastes dorsalis*; centre right, the moaning frog, *Helioporus eyrei* and bottom right, the motorbike frog, *Litoria moorei*, were common frogs on the Blackwood Plateau FORESTCHECK grids in 2011–12 (photos: R. Robinson).

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The first round of monitoring all 48 FORESTCHECK grids was completed in 2006. The second round of monitoring commenced in spring 2007 and this report covers the second session of monitoring at the 11 Blackwood Plateau monitoring grids located in jarrah forest south and west of Nannup. These grids were initially established in 2005 and monitored in 2005–06. Monitoring of the Blackwood Plateau grids in 2011–12 and the publication of this report completes the second round of monitoring for FORESTCHECK grids subject to timber harvesting under Silvicultural Guideline 1/95.

All the monitoring grids at Blackwood Plateau are located in State forest, National park or conservation parks in Kingia vegetation complexes within the Jarrah Blackwood ecosystem. Harvested sites were matched to 1995-96, 1998 and 2002 harvest activities. The range of time since the last fire was 1 to 19 years. Since the initial monitoring sessions in 2005–06, the Layman external reference (FC40) and Butler selective cut (FC45) grids have been subject to prescribed fire; both were burnt in spring 2010. At all grids, forest attributes including forest structure, regeneration stocking and litter loads were measured and species richness and abundances of macrofungi, cryptogams (lichens and bryophytes), invertebrates, terrestrial vertebrates and vascular plants were recorded. In spring 2011 and 2012 leaf area index estimates were undertaken on all the FORESTCHECK monitoring grids, as well as retrospective measurements at intervals from 1998 to 2010.

FORESTCHECK monitoring is contributing to increased knowledge of jarrah forest biodiversity and ecology. The climate of southwest Western Australia has changed significantly in recent decades and data collected from FORESTCHECK grids are therefore an important source of objective information that could be used to inform discussion on matters such as the effects of a drying climate on tree health, regeneration and stand growth and how biodiversity may respond to any changes.

While the results presented here are from a preliminary analysis, highlights from the 2011–12 results and observations from comparisons with data from the same grids in 2005–06 include:

- Growth on external reference grids was small, as would be expected for mature stands dominated by large old trees, but silviculturally treated grids exhibited good growth with basal area increments ranging from 0.15-1.07 m^2 ha^{-1} yr^{-1} and recruitment of saplings and stems 10–19 cm and 20–29 cm in diameter.
- Leaf area index increased significantly from spring to summer. The increase was least on external reference grids (11%) and greatest on gap release grids (66%). The substantial seasonal variations highlight the importance of the timing of LAI measurement.
- Litter loads reflected time since fire, and generally increased since 2006. Small wood and twig volumes increased markedly on the majority of grids and may be due to climatic factors such as major wind events in 2012 and periods of low rainfall which increase branch and twig shedding.
- Silvicultural treatments did not impact significantly on biodiversity monitored within the Blackwood Plateau FORESTCHECK grids.
- The Blackwood Plateau has a rich and diverse mycota, with a total of 358 species so far recorded. Species richness was similar in both 2006 and 2012 but composition of the fungal community was significantly different (only 37% of species were common to both years). Fruit body abundances in all treatments were significantly lower in 2012.
- The number of lichens recorded in 2011 was markedly lower (32% less) than in 2005, but is likely related to the change in monitoring protocols. The potential for using cryptogam monitoring species to assess the impacts of timber harvesting and silviculture on cryptogam communities appears to be promising.
- FORESTCHECK grids reflect levels of gum leaf skeletoniser damage seen throughout the southern jarrah forest region.
- Changes in the vascular plant communities reflect development of the understory following disturbance (harvesting and/or fire). Both species richness and abundance has

declined on the Blackwood Plateau grids since 2005. Fewer short-lived shrub and dwarf shrub species were recorded in all treatments in 2011.

- Changes in the bird community between 2005 and 2011 reflect changes in the development of the understory following disturbance. Leaf gleaning birds which utilise the tree canopy remained constant but those that utilise the understory scrub layer increased substantially since 2006.
- Doubling the trapping effort from eight nights in 2005–06 to 16 in 2012 resulted in an overall increase in captures but the capture rate per night decreased for both mammals and reptiles. Cool wet weather in spring 2012 contributed to low number of reptile captures in 2012, but to an increase in amphibian captures and species recorded.

The FORESTCHECK team is to be commended for their commitment to the project. I also extend my sincere thanks to the many volunteers who have assisted with the project. In 2012–13 new monitoring grids will be established in forest subject to harvesting under revised guidelines utilised within the current Forest Management Plan 2004–2013.

This report, and previous reports, can be viewed and downloaded from the Department of Environment and Conservation website at www.dec.wa.gov.au .

Margaret Byrne

Dr Margaret Byrne
Director, Science Division

March 2013

INTRODUCTION

Scope

This report has been compiled from chapters prepared by Science Division research staff involved in the FORESTCHECK monitoring program. It represents a summary of monitoring activities completed in the southern jarrah forest in the Blackwood District during the 2011–12 financial year.

FORESTCHECK is an integrated monitoring system that has been developed to provide information to forest managers in the southwest of Western Australia about changes and trends in key elements of forest biodiversity associated with a variety of forest management activities. Although the initial focus of FORESTCHECK has been on timber harvesting and silvicultural treatments in jarrah (*Eucalyptus marginata*) forest, the intention is to extend the scale of monitoring over time to include other forest ecosystems, fire (prescribed and wildfire), mining, the effects of forest disturbance for utility corridors (e.g. roads, power transmission lines), and the impacts of recreation uses (however, the Forest Products Commission only provides funding for FORESTCHECK that is specific to its activities).

FORESTCHECK was developed to meet a range of compliance conditions placed on the Forest Management Plan 1994–2003 through Ministerial Conditions and the Codd Report of 1999[1] and is included as an operational program in the current Forest Management Plan 2004–2013[2]. Integrated monitoring is a fundamental component of Ecologically Sustainable Forest Management (ESFM), and is necessary for reporting against the Montreal Process criteria and indicators for ESFM. In addition, monitoring forms the basis for adaptive management and adaptive management is recognised as an appropriate strategy for managing under conditions of uncertainty and change.

The Science Division of the Department of Environment and Conservation has primary responsibility for the implementation of FORESTCHECK. The development of the program took place over two years and included input from scientists and managers within the Department of Environment and Conservation, and from a number of external scientific agencies. The background to this process is described in the FORESTCHECK Concept Plan, and details of methods are provided in the FORESTCHECK Operating Plan. Annual Progress Reports, the Concept Plan and Operating Plan may be viewed on the Department's website at www.dec.wa.gov.au .

Monitoring strategy

Between 1995 and 2004 timber harvesting in jarrah forests was undertaken according to Silvicultural Guideline 1/95, which recognises three silvicultural objectives:

1. Thinning—to promote growth on retained trees.
2. The release of regeneration by gap creation, where existing advance growth is encouraged to develop unimpeded by the removal of competing overstorey.
3. Regeneration establishment by shelterwood, where seedlings are encouraged to establish and develop into the lignotuberous ground coppice stage. This is achieved by reducing the competition from the overstorey, but retaining sufficient overstorey to provide a seed source and maintain other forest values until the ground coppice is developed and capable of responding to release.

Silvicultural guidelines were revised in conjunction with the preparation of the Forest Management Plan (2004–2013) and are now available as SFM Guideline No. 1(CALM 2004[3]).

[1] Codd, M. 1999. Forest management Plans 1994–2003: Mid-Term EPA Report on Compliance
[2] Conservation Commission of Western Australia.2004. Forest management plan 2004–2013. Conservation Commission of Western Australia. 144p + maps.
[3] CALM 2004. Silvicultural practice in the jarrah forest. Dept. CALM, SFM guideline No. 1.

Gap creation and shelterwood treatments are being given priority in the initial stages of FORESTCHECK as these are the most widespread operations and involve the greatest extent of disturbance to the forest. Thinning will also be monitored where the structure of the forest dictates that this treatment is appropriate on a significant scale.

FORESTCHECK sites have been established at a number of locations throughout the jarrah forest, stratified according to recognised ecological gradients of rainfall, evapo-transpiration and soil fertility. Forest ecosystem mapping (Mattiske and Havel 1998[4], 2000[5]) provides a systematic basis for stratification of sampling. Allocation of sites also takes account of scheduled future harvesting within the jarrah forest, with priority given to those ecosystems likely to be subject to harvesting on an extensive scale in the next decade.

Each FORESTCHECK site consists of up to four sampling grids. Grids have been established in forest subject to the following treatments:

1. gap release
2. shelterwood (or selective cut)
3. coupe buffer or internal reference forest i.e. temporary exclusion areas (TEAS) between adjacent gaps or shelterwood forest
4. external reference or control forest—i.e. not recently harvested, or has had minimal harvesting, and will not be subject to harvesting in the foreseeable future.

At each location, grids are closely matched in terms of site characteristics (climate, geomorphology, soils, topography, altitude, aspect), pre-harvest forest structure and vegetation attributes in order that differences between grids reflect the effects of harvesting, rather than inherent site differences. Not all treatment types are always present in the one locality and occasionally, external reference forest has been located some distance from their harvested counterparts. Also, it may not always be possible to find gap release and shelterwood treatments together, because underlying relationships between rainfall, soil fertility and jarrah lignotuber development influence the broad pattern of silvicultural treatment across the jarrah forest, as have previous silvicultural activities.

Methodology

Monitoring of biodiversity is based on a sampling grid (see Fig. 1). The main grid is 200 m x 100 m, with a central area of 100 m x 100 m. A range of ecosystem attributes are monitored on each grid including:

- forest structure and regeneration stocking
- foliar and soil nutrients
- soil disturbance
- coarse woody debris and leaf litter
- macrofungi
- cryptogams
- vascular flora
- invertebrate fauna
- vertebrate fauna (birds, herpetofauna, and mammals).

Sampling methodologies for each set of ecosystem attributes are described in the FORESTCHECK Operating Plan, together with examples of protocols for data collection and storage.

[4] Mattiske, E.M. and Havel, J.J. 1998. Regional Forest Agreement Vegetation Complexes, Busselton-Augusta, Collie, Pemberton & Pinjarra, Western Australia [cartographic material—scale 1:250,000]. Department of Conservation and Land Management, WA.

[5] Mattiske, E.M. and Havel, J.J 2000. Vegetation Mapping in the South West of Western Australia. CALM, Perth.

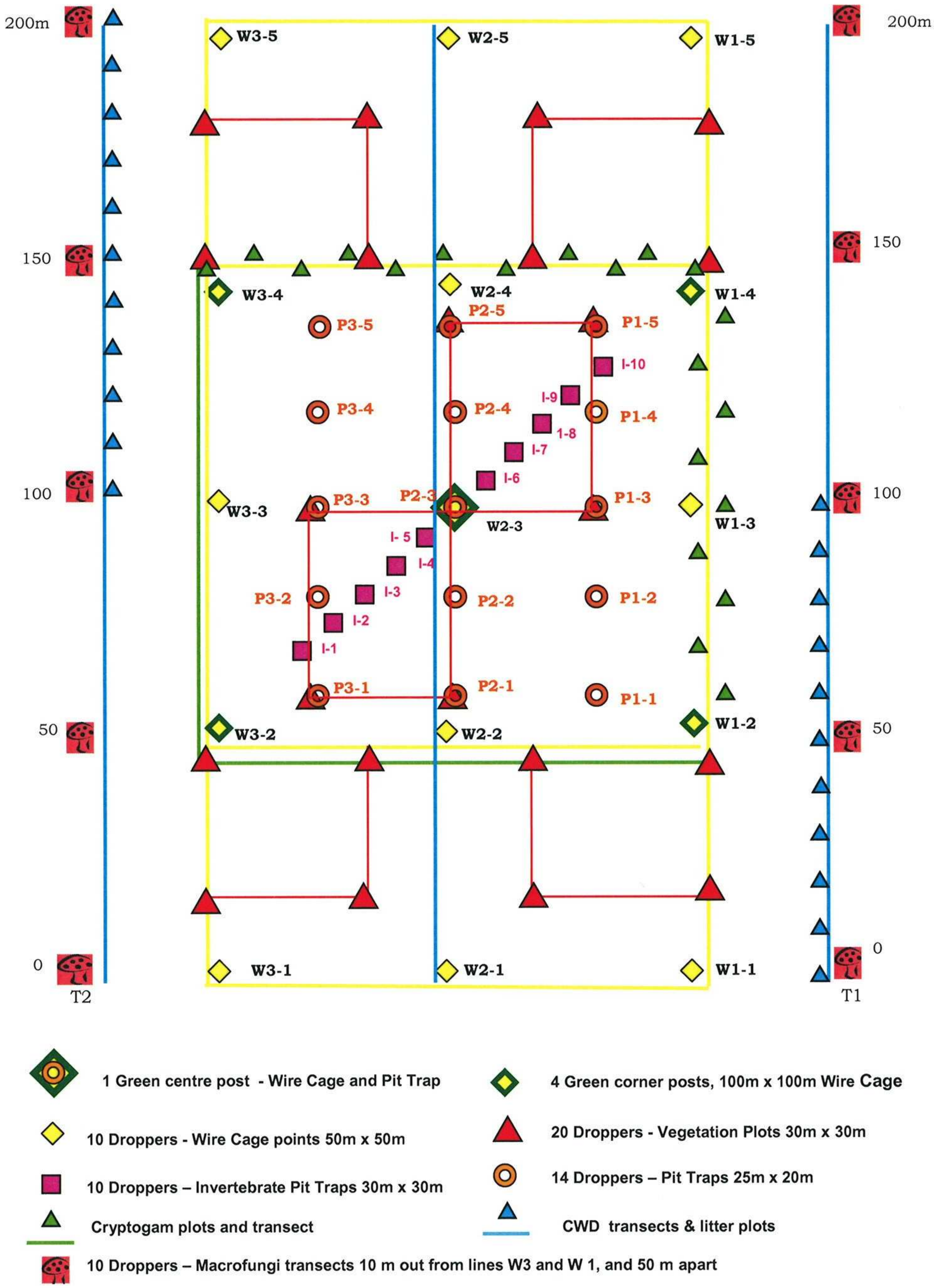


Figure 1. FORESTCHECK grid layout

Monitoring on the Blackwoood Plateau 2011–12

Eleven FORESTCHECK monitoring grids were established in jarrah forest in the Blackwood District in spring 2005. Four grids (FC38, FC41, FC43, FC46) were established in Barrabup, three in Cambray (FC44, FC42, FC47), two in Butler (FC45, FC48) and one each in St John (FC39) and Layman (FC40) forest blocks. All grids were located on the Blackwood Plateau in areas of forest adjacent the 1100 mm annual isohyet, and identified by alphanumeric codes FC38 to FC48 (Figs 2 and 3).

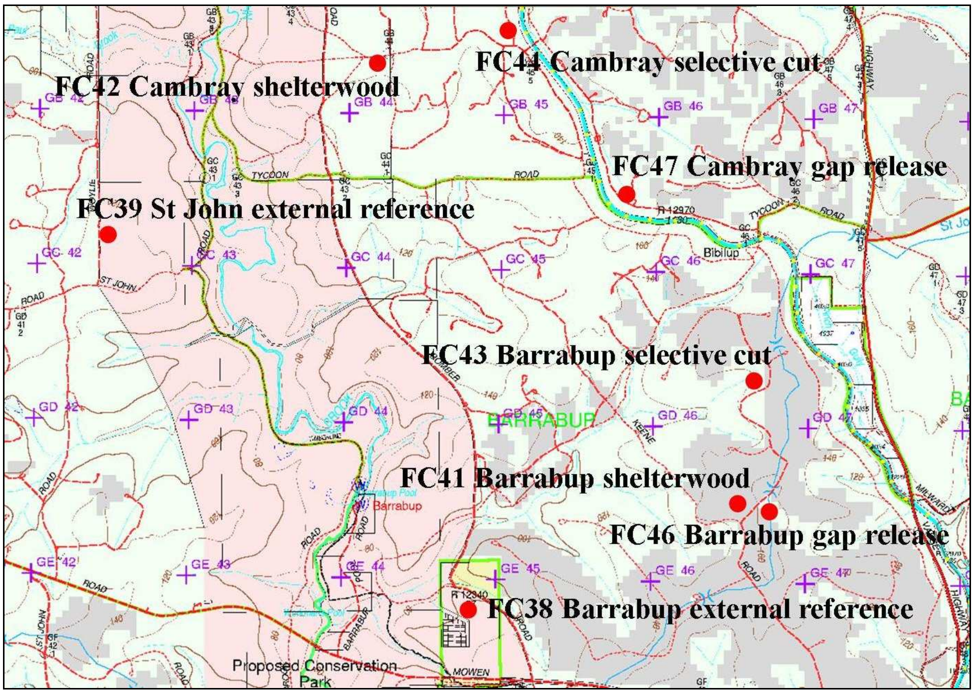


Figure 2. Locations of FORESTCHECK sampling grids established in 2006 on the eastern Blackwood Plateau.

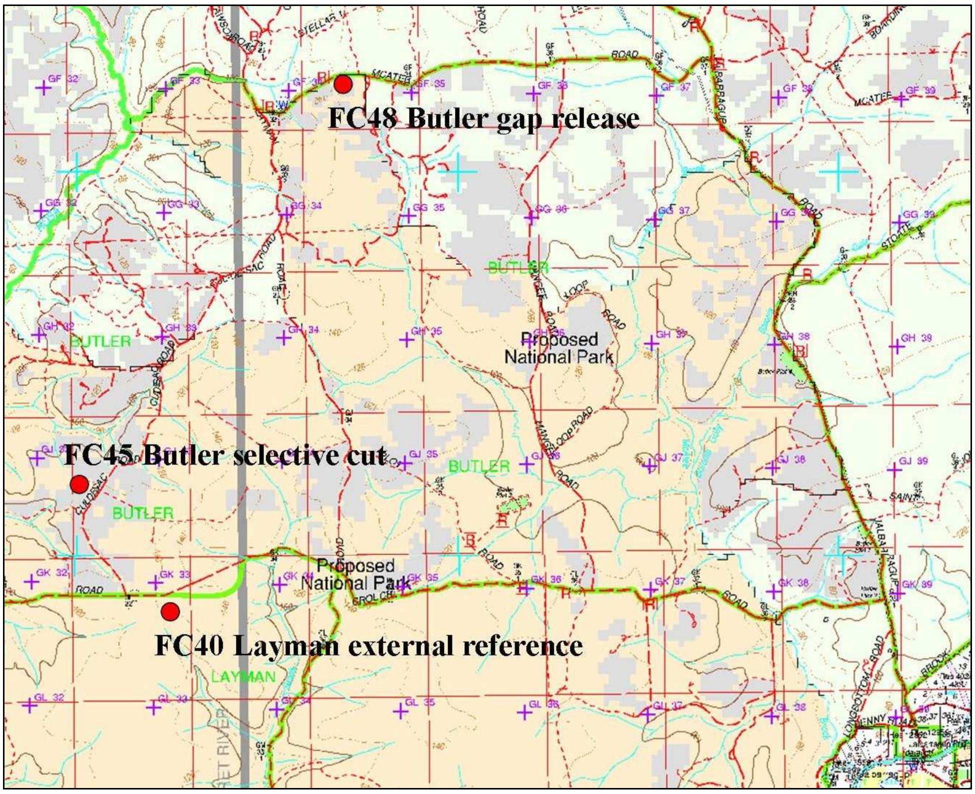


Figure 3. Locations of FORESTCHECK sampling grids established in 2006 on the western Blackwood Plateau.

All grids are located within the Kingia vegetation complex of Mattiske and Havel (1998). This complex is found in open forests of jarrah (*E. marginata* ssp. *marginata*), marri (*Corymbia calophylla*), sheoak (*Allocasuarina fraseriana*), bull banksia (*Banksia grandis*) and woody pear (*Xylomelum occidentale*) on lateritic uplands in perhumid and humid zones.

The external reference grids are situated in uncut forest but there are a small number of stumps present in the Barrabup and St John grids suggesting a number of trees had been selectively removed in the past. The Barrabup grid is located Conservation Park and the Layman grid in National Park.

The remaining grids are in forest that was harvested during the period of 1995 to 2002 and were established at sites in stands with comparable management histories. On the Blackwood Plateau a common silvicultural treatment in the past was selective cutting. Selective cutting involves the removal of individual trees in stands where the proportion of sawlogs is low. Stands where the residual number of cull trees is too great to make follow-up silviculture achievable are also recorded as having been selectively cut. Selective cutting was recognised as a silvicultural option in Guideline 1/95, which applied from 1995 up until the adoption of SFM Guideline No.1 (CALM 2004). Three selective cut grids were established, one each in Barrabup, Cambray and Butler forest blocks (Table 1).

Table 1. Location (forest block) and site attributes of each FORESTCHECK grid in the Blackwood District in 2011–12.

Treatment/grid location	Burnt		Harvested		Vegatation Complex[3]
	Year and type of burn[1]	Years since[2]	Year	Years since[2]	
External reference					
FC38 Barrabup	Sp 2002 (prescribed)	(3) 9	Uncut		Kingia
FC39 St John	Sp 1992 (prescribed)	(13) 19	Uncut		Kingia
FC40 Layman	Sp 1997 (prescribed) Sp. 2010 (prescribed)	(8) 1*	Uncut		Kingia
Shelterwood					
FC41 Barrabup	Sp 2002 (establishment)	(3) 9	2002	(3) 9	Kingia
FC42 Cambray	Sp 1996 (establishment)	(9) 15	1995	(10) 16	Kingia
Selective cut					
FC43 Barrabup	Sp 2002 (regeneration release)	(3) 9	2002	(3) 9	Kingia
FC44 Cambray	Sp 1995 (prescribed)	(9) 15	1996	(10) 16	Kingia
FC45 Butler	Sp 1997 (prescribed) Sp. 2010 (prescribed	(10) 1*	1998	(7) 13	Kingia
Gap release					
FC46 Barrabup	Sp 2002 (regeneration release)	(3) 9	2002	(3) 9	Kingia
FC47 Cambray	Sp 1996 (regeneration release)	(9) 15	1996	(9) 15	Kingia
FC48 Butler	Sp 2001 (regeneration release)	(4) 10	1998	(7) 13	Kingia

[1] Sp= silvicultural burn carried out in the spring
[2] numbers in brackets denote years since being burnt or harvested when monitored in 2005–06
[*] refers to sites that were burnt since they were first monitored in 2005–06
[3] The Kingia vegetation complex is found in open forests of jarrah (*E. marginata* ssp. *marginata*), marri (*Corymbia calophylla*), sheoak (*Allocasuarina fraseriana*), bull banksia (*Banksia grandis*) and woody pear (*Xylomelum occidentale*) on lateritic uplands in perhumid and humid zones (Mattiske and Havel 1998).

Grids were initially monitored in spring 2005 and/or autumn 2006 when the range of time since the last fire was 3–13 years. The second round of monitoring was conducted in spring 2011 and/or autumn 2012 and the range of time since the last fire was 1–19 years. The Layman external reference (F40) and the Butler selective cut (FC45) were both burnt by prescribed fire in spring 2010 (Table 1). Several major wind storms in the lower south west in 2012 (notably June and September) also contributed to increased rates of tree fall and canopy material on some grids which effect both stand basal area and coarse woody debris loads.

Grid photographs

Reference photographs of each grid were initially taken in July 2005 and presented in the FORESTCHECK Report of Progress 2005–06 (available at www.dec.wa.gov.au). In July 2012, reference photos were taken from a standard photo point at peg W2-1 looking towards the centre peg (W2-3) (refer to Fig. 1). Having a standard reference point allows for accurate changes in vegetation structure and condition to be observed in each subsequent photograph taken (Figs. 4–15).

Barrabup Grids

Figure 4. FC38 Barrabup external reference in 2006 (left) and 2012 (right)

Figure 5. FC41 Barrabup shelterwood in 2006 (left) and 2012 (right)


Figure 6. FC43 Barrabup selective cut in 2006 (left) and 2012 (right)


Figure 7. FC46 Barrabup gap release in 2006 (left) and 2012 (right)

St John and Cambray grids:


Figure 8. FC39 St John external reference in 2006 (left) and 2012 (right)

Figure 9. FC42 Cambray shelterwood in 2006 (left) and 2012 (right)

Figure 10. FC44 Cambray selective cut in 2006 (left) and 2012 (right)

Figure 11. FC47 Cambray gap release in 2006 (left) and 2012 (right)

Layman and Butler grids:

Figure 12. FC40 Layman external reference in 2006 (left) and 2012 (right)

Figure 13. FC45 Butlerselective cut in 2006 (left) and 2012 (right)

Figure 15. FC48 Butler gap release in 2006 (left) and 2012 (right)

Budget
The annual operational budget for the program is provided by the DEC's Sustainable Forest Management Division via a works agreement with the Forest Products Commission for $225,000. Salaries are funded through a service agreement with the Sustainable Forest Management Division to an amount of approximately $200,000 per annum.

2012-13 Activities
Analysis of ten years of monitoring data collected between 2001 and 2012 will begin in 2013. A comparison of the first (2001–06) and second (2007–12) rounds of monitoring will be undertaken as well as an analysis of the effects of timber harvesting on forest attributes and biodiversity using the combined data from the two rounds of monitoring.

It is proposed to install an additional set of monitoring grids in forest harvested under the guidelines of the current Forest Management Plan 2004–2013. Monitoring on these grids is scheduled to commence in autumn 2013.

FOREST STRUCTURE AND REGENERATION STOCKING

Lachlan McCaw and Verna Tunsell

Introduction

The adequacy of regeneration following harvesting and silvicultural treatment is one of the core indicators of Ecologically Sustainable Forest Management (ESFM). The current framework of regional level indicators provides for assessment of the area and per cent of harvested area of native forest effectively regenerated (Indicator 2.1.g). This is recognised as a Category A indicator that can be reported upon immediately (Commonwealth of Australia 1998).

Regeneration outcomes have for a number of years been assessed as a matter of routine on a sample of the area of forest subject to harvesting. For uneven-aged stands, there is a need to consider existing stand structure and whether there is sufficient sapling and advance growth present for re-establishment following harvesting. Under the current silvicultural guideline for jarrah-marri forest, the decision as to whether the stand should be cut to gap release or shelterwood is determined by the density of existing lignotuberous advance growth (CALM 2004).

Forest managers also require information about growth rate and species composition so that future stand conditions can be projected over time. These attributes can affect the potential of forest stands to produce wood and other products, and to achieve ecological outcomes.

A total of 48 FORESTCHECK monitoring grids were established between 2001–02 and 2005–06 across the geographic range of the jarrah forest. The distribution of grids, stratified according to DEC administrative boundaries and forest ecosystems mapped for the Regional Forest Agreement (Mattiske and Havel 2000), is as follows:

- Donnelly District (jarrah south), 10 grids
- Wellington District (jarrah north west - central), 9 grids
- Perth Hills District (jarrah north west - north), 8 grids
- Wellington District (jarrah north east), 10 grids
- Blackwood District (jarrah Blackwood Plateau), 11 grids.

Eleven monitoring grids established in jarrah forest in Blackwood District were initially assessed in autumn 2006. Grids were re-assessed in autumn 2012 with the objective of describing changes in stand structure, species composition and developmental stage of tree species present over the previous six years.

Monitoring

Assessment methods for Blackwood District grids in 2012 were as per the FORESTCHECK Operating Plan (available at www.dec.wa.gov.au), except that cut stumps were not re-measured and triangular tessellation assessment of regeneration stocking was not repeated. All trees taller than 2 m were measured along transects 100 m long by 4 m wide located between marker pegs 1-2 to 1-4 and 3-2 to 3-4 (see plot layout on p. 5). To improve the reliability of long term measurements of tree growth, mortality and tree fall all stems ≥20 cm diameter at breast height were identified with a numbered tag. The height and species of regeneration was assessed at four locations on each grid to indicate the rate of regrowth.

Projected foliage cover was recorded in spring 2011 as part of the vegetation cover assessment during vascular plant surveys. Intercepts with foliage were recorded at 240 points around the perimeter of four 30 m x 30 m vegetation quadrats using a vertical periscope fitted with a fine crosshair. Intercepts were recorded as foliage present or absent in height classes of 2–15 m and >15 m. Contacts with eucalypt foliage were recorded separately to contacts with other plant species. The initial projected foliage cover measurements for the grids were recorded in 2005.

Data management
Stem diameter measurements from 2012 were entered into the FORESTCHECK stand database and used to calculate current over-bark basal area and over-bark basal area increment for the 6-year-period from 2006 to 2012.

Validation of data in preparation for calculation of basal area increment between 2006 and 2012 revealed a small number of errors in the data presented in Table 1 of the Stand Structure and Regeneration Stocking section of the 2006 progress report. These included incorrect basal areas of jarrah and marri on the Barrabup external reference (FC38), marri on the Barrabup selective cut (FC43) and jarrah on the Butler gap release (FC48) grids. Errors arose from mis-identification of jarrah and marri, and some trees not being recorded during the 2006 assessment. Permanent numbering of the larger trees that contribute the majority of basal area will minimise the potential for errors of this kind during subsequent measurements. The database was corrected to show the true change in basal area over the period rather than change due to inconsistent measurement.

Preliminary results
Stand structure and species composition
Basal areas of eucalypts and mid-storey species are plotted in Figure 1, and basal area increment of jarrah and marri are summarised in Table 1. Data presented for the Cambray gap release (FC47) relate to Sections 3-2 to 3-4 only (refer to grid layout on p. 5), as the part of Section 1.3 to 1.4 was outside of the area treated for gap release and influenced by a retained overstorey of large mature trees.

Jarrah contributed the majority of basal area, with marri as a secondary component on all grids. *Allocasuarina fraseriana* contributed >1m^2 ha^{-1} on five grids, and *Xanthorrhoea preissii* and *Kingia australis* contributed >1 m^2 ha^{-1} on the external reference grids at Barrabup (FC38), St John (FC39) and Layman (FC40) respectively (Fig. 1). Other common mid-storey species included *Banksia grandis*, *Persoonia elliptica* and *Xylomelum occidentale*.

Eucalypt basal area increased by a small amount on the external reference grids at Barrabup and St John but declined at Layman as a result of several trees falling over following a prescribed fire in October 2010. Basal area increased on all grids in silviculturally treated forest with mean annual increments ranging from 0.15 m^2 ha^{-1} yr^{-1} in the Butler selective cut (FC45) to 1.07 m^2 ha^{-1} yr^{-1} in the Butler gap release grid (Table 1). The relative contribution of jarrah and marri to mean annual increment varied between grids, with jarrah contributing at least half the growth on gap release grids.

Stem diameter distributions for grids in each treatment are shown in Figs 2-5. The external reference grid at Barrabup showed some recruitment of jarrah and marri saplings between 2006 and 2012, while the external reference grid at Layman exhibited a decline in the number of saplings, probably as a result of prescribed fire in 2010 (Fig. 2). Stem diameter distributions remained relatively constant on the two shelterwood grids (Fig. 3). The Barrabup selective cut grid showed recruitment of saplings and in-growth of saplings into the 10-20 cm diameter class, while sapling numbers reduced at the Butler selective cut which was also burnt in 2010 (Fig. 4). Sapling numbers increased on the Barrabup gap release grid due to in-growth of ground coppice, but reduced slightly on the Cambray and Butler gap release grids due to self-thinning of small saplings and recruitment of stems into larger size classes (Fig. 5).

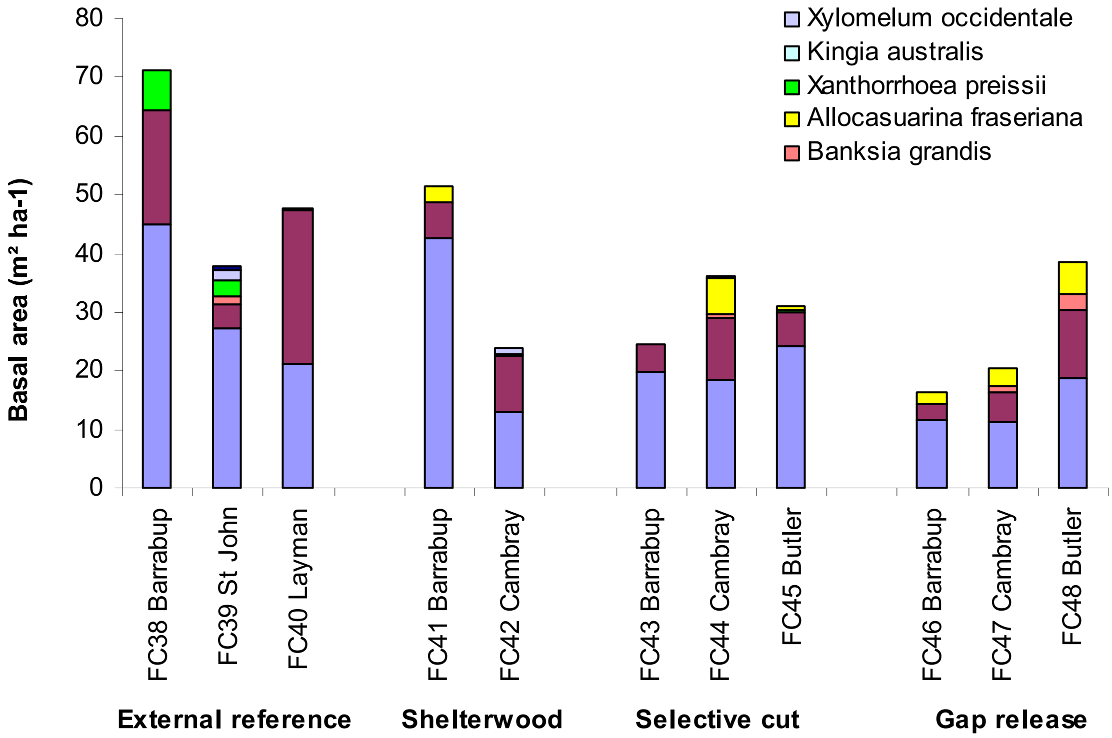


Figure 1. Basal area of jarrah, marri and mid-storey species on each grid in Blackwood District in 2012.

Table 1. Basal area in 2012 and basal area increment of live eucalypts >2 m tall over the period autumn 2006 to autumn 2012 for all FORESTCHECK grids in Blackwood District

Treatment/Grid	Basal area 2012 (m^2 ha^{-1})			Basal area increment (m^2 ha^{-1})		Mean annual increment (m^2 ha^{-1} yr^{-1})
	Jarrah	Marri	Total	Jarrah	Marri	
External reference						
FC38	44.86	19.51	64.37	1.74	0.25	0.33
FC39	27.23	4.24	31.47	0.06	-0.03	0.03
FC40	21.11	26.05	47.16	-2.75	-0.05	-0.47
Shelterwood						
FC41	42.63	5.89	48.52	3.06	2.31	0.90
FC42	13.04	9.58	22.62	0.11	1.55	0.28
Selective cut						
FC43	19.84	4.63	24.47	5.79	-0.96	0.80
FC44	18.31	10.51	28.82	0.81	1.45	0.38
FC45	24.15	5.75	29.90	0.80	0.11	0.15
Gap release						
FC46	11.50	2.95	14.45	4.33	1.33	0.94
FC47[a]	11.25	5.13	16.38	2.40	2.58	0.83
FC48	18.84	11.55	30.39	5.44	0.99	1.07

[a] Data for Sections 3-4 to 3-3 and 3-3 to 3-2 only

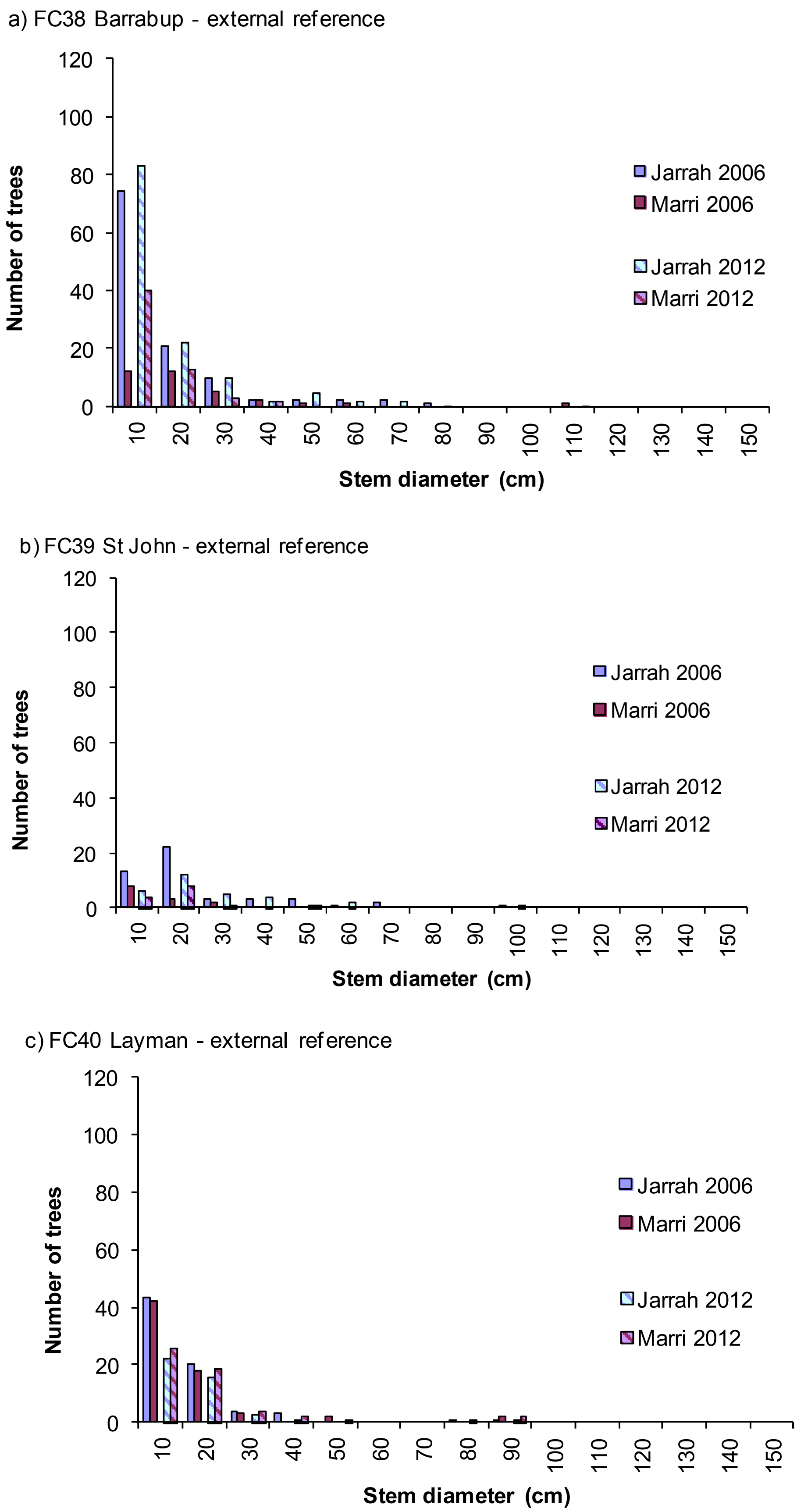
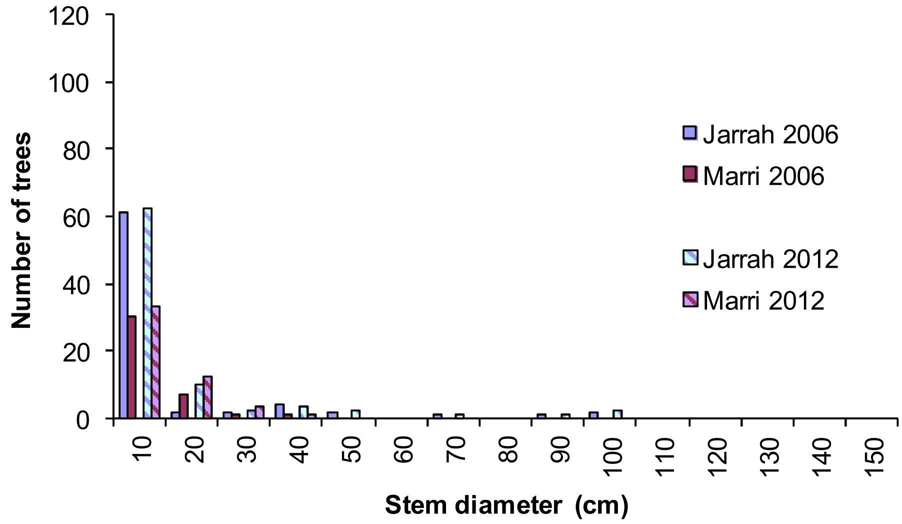


Figure 2. Stem diameter distribution by 10 cm classes (0-9 cm, 10-19 cm etc.) for three external reference grids.

a) FC41 Barrabup - shelterwood



b) FC42 Cambray - shelterwood

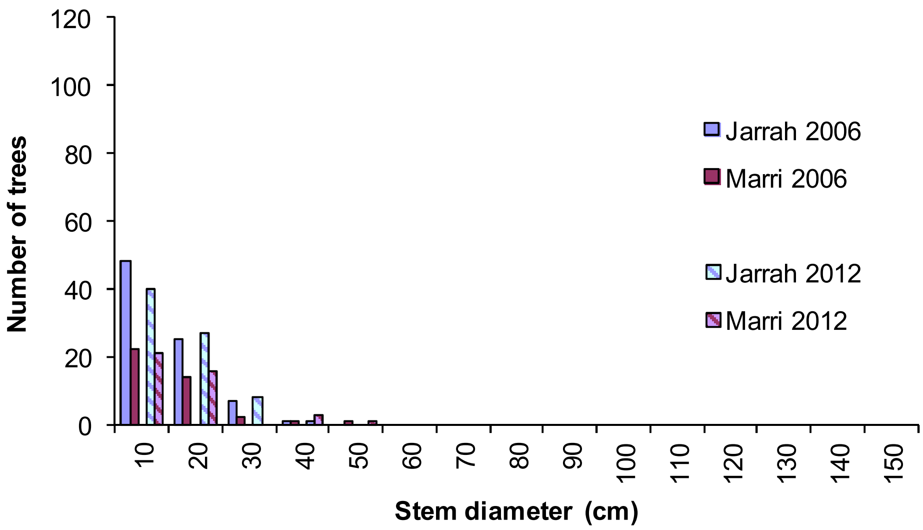


Figure 3. Stem diameter distribution by 10 cm classes (0-9 cm, 10-19 cm etc.) for two shelterwood grids.

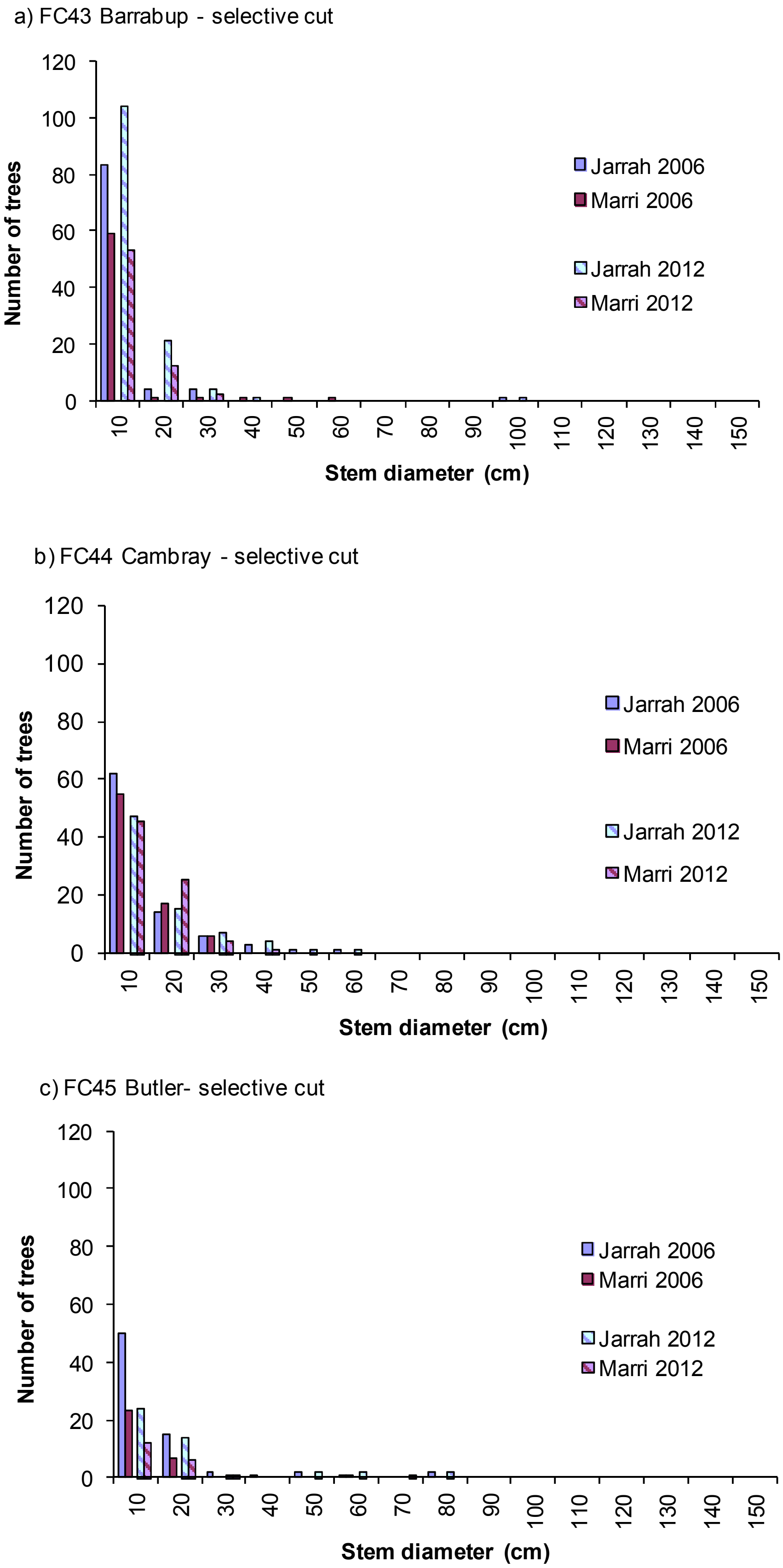


Figure 4. Stem diameter distribution by 10 cm classes (0-9 cm, 10-19 cm etc.) for three selective cut grids.

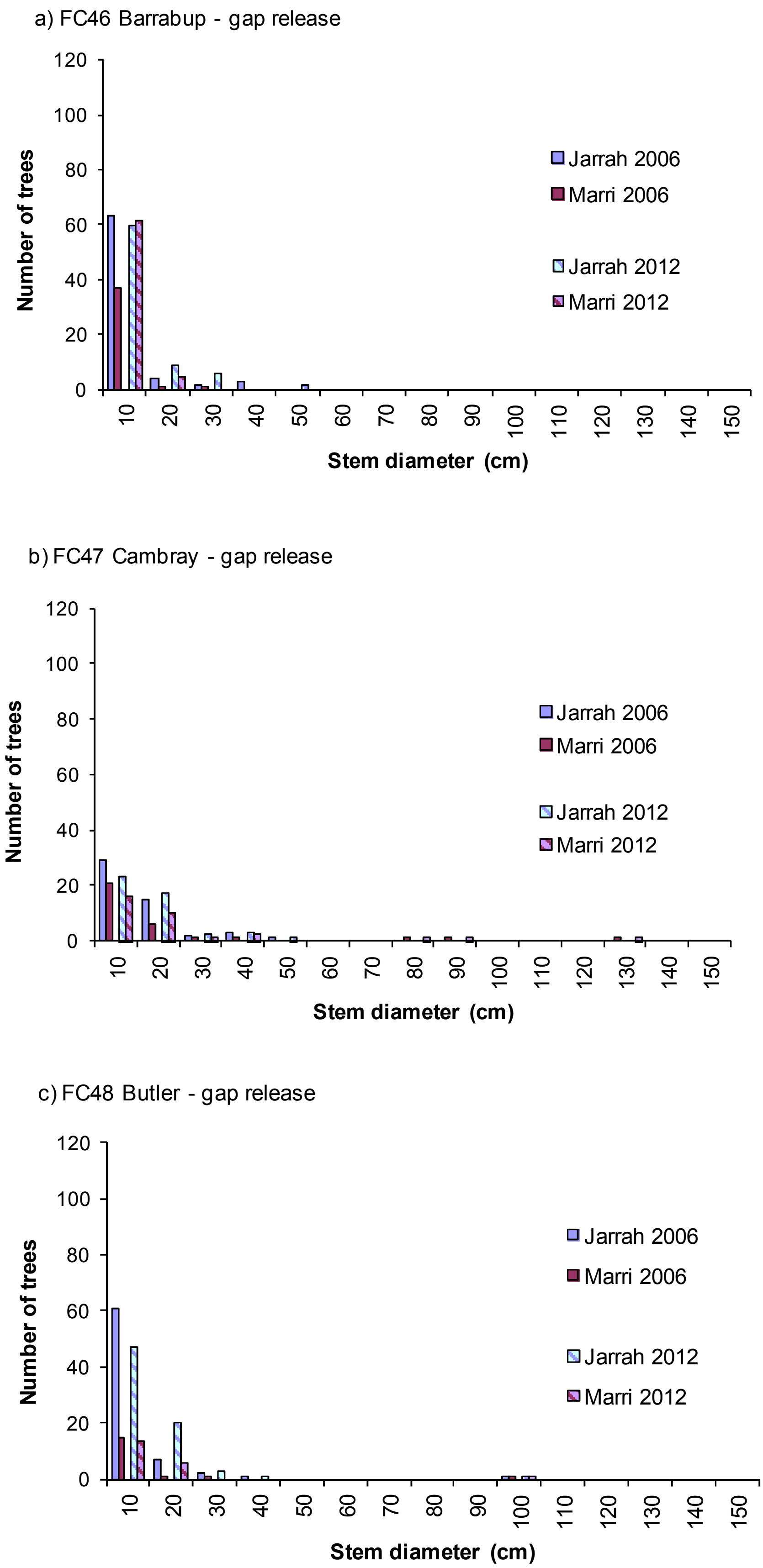


Figure 5. Stem diameter distribution by 10 cm classes (0–9 cm, 10–19 cm etc.) for three gap release grids.

Eucalypt foliage from the upper storey (>15 m height) comprised the largest proportion of projected foliage cover on external reference and shelterwood grids, whereas eucalypt foliage from the lower storey (2–15 m) dominated the projected cover on shelterwood and gap release grids, reflecting the presence of a layer of saplings (Fig. 6). Non-eucalypt foliage comprised the smallest proportion of projected cover on most grids except the Cambray selective cut which had a well developed mid-storey of *A. fraseriana* and *B. grandis.*

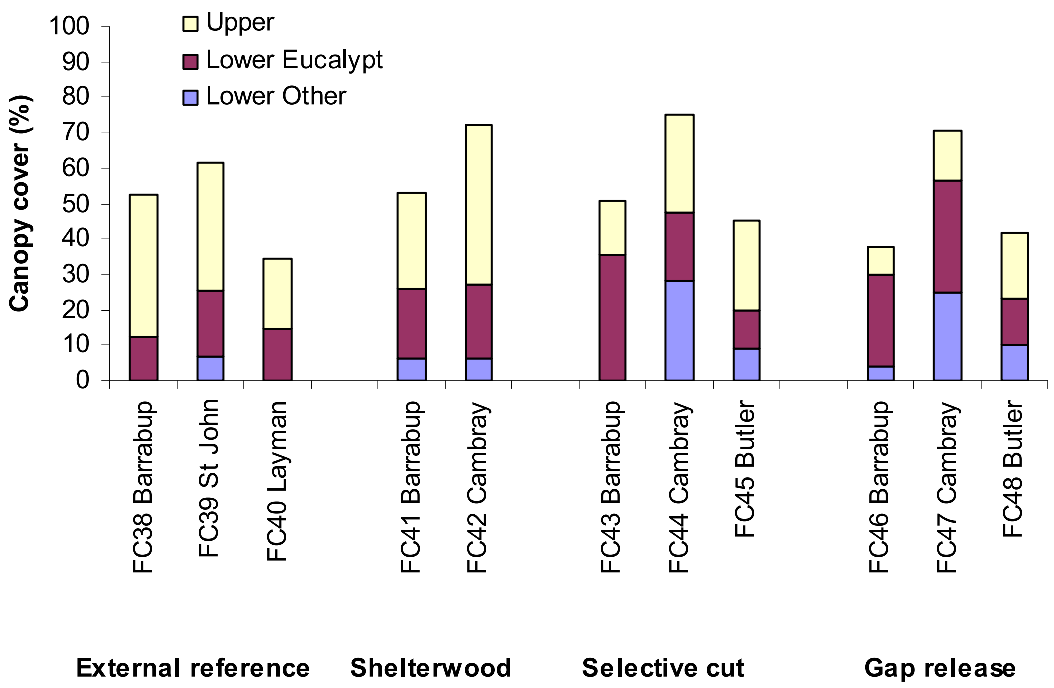


Figure 6. Projected foliage cover of eucalypts and other plants at Blackwood in 2011 divided into lower (2–15 m) and upper (>15 m) storeys.

Projected cover changed little between 2005 and 2011 on the external reference grids at Barrabup and St John but reduced at the Layman grid, probably due to the October 2010 fire which burnt some saplings back to the lignotuber and reduced the density of understorey and mid-storey layer (Fig. 7). Projected cover changed little at the Butler selective cut. Total projected foliage cover on the other harvested grids increased since 2005, with the greatest increases recorded on the Barrabup shelterwood, the Barrabup selective cut and the gap release grids at Barrabup and Cambray.

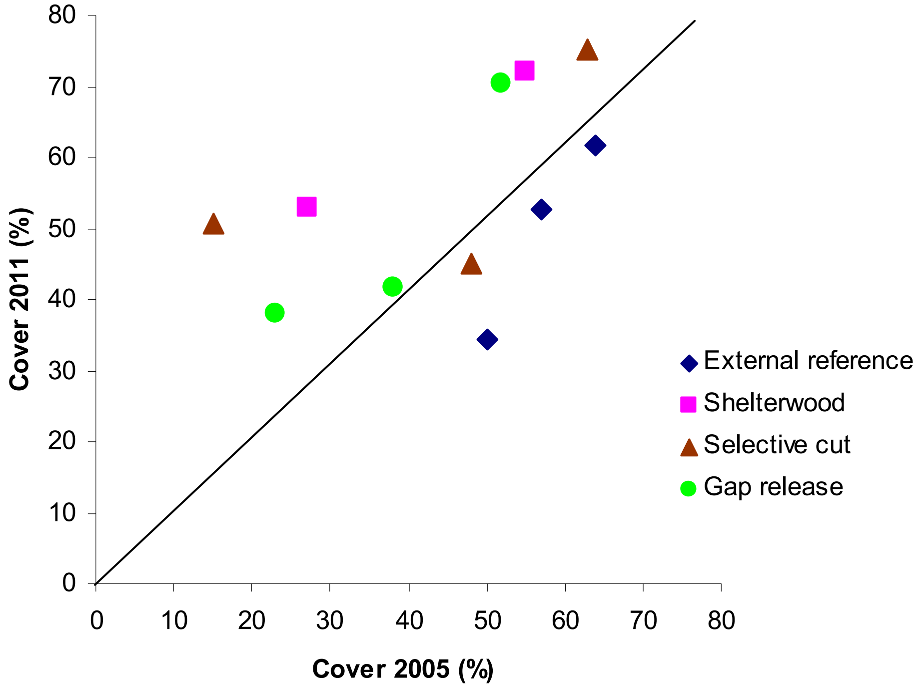


Figure 7. Scatterplot comparing projected foliage cover measured on grids at Blackwood in 2005 and 2011 (1:1 line shown).

Discussion

External reference grids exhibited only small changes in basal area and stand structure between 2006 and 2012, with the most evident changes caused by a prescribed fire at Layman block in October 2010. There was also evidence of a modest level of recruitment of saplings at the Barrabup external reference grid as lignotuberous ground coppice grew tall enough to be included in the sapling cohort >2 m tall. Silviculturally treated grids exhibited good growth with basal area increments ranging from 0.15–1.07 m^2 ha^{-1} yr^{-1} and recruitment of saplings and stems 10-19 cm and 20-29 cm in diameter. Grids in Barrabup block showed consistently good growth across all silvicultural treatments.

Periodic re-measurement of monitoring grids provides a valuable time series of rigorous and repeatable observations, and contributes to a better understanding of the response of jarrah forest ecosystems to climate and disturbance factors. Completion of the second round of measurements on all 48 FORESTCHECK grids has made possible the calculation of periodic growth on grids subject to different silvicultural treatments (Fig. 8). Growth on external reference grids was small, as would be expected for mature stands dominated by large old trees. Forest subject to shelterwood silviculture and selective cutting had a mean annual basal area increment of 0.37 m^2 ha^{-1} yr^{-1}, with jarrah comprising slightly more than half of this growth. Growth in grids cut to gap release was twice that of shelterwood and selectively cut grids with a mean annual basal area increment of 0.74 m^2 ha^{-1} yr^{-1}. There was considerable variability of basal area increment within silvicultural treatment groups, and this is likely to result from the geographic spread of the grids, the number of years since regeneration and variability in seasonal climatic conditions during the six years between measurements. Growth in stands cut to gap release would be predominantly on smaller trees (stem diameter <20 cm) while growth in shelterwood and selectively cut stands would result both from recruitment of saplings, and enhanced diameter growth of established trees released from competition.

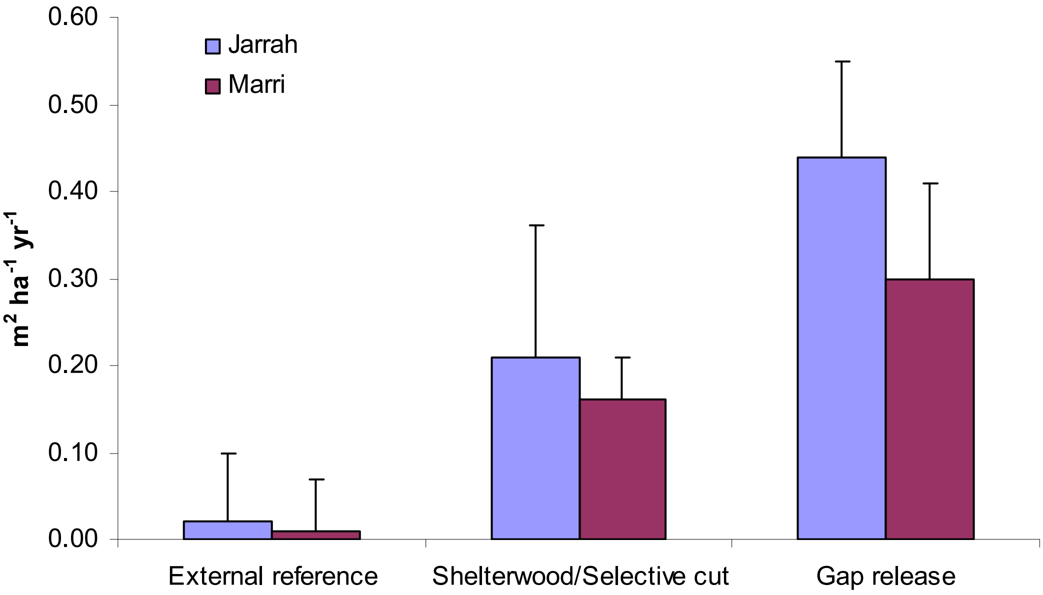


Figure 8. Mean basal area increment of jarrah and marri determined for grids in external reference (n=19), shelterwood/selective cut (n=15) and gap release (n=14) forest over 6 year period. Bars indicate standard errors.

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LEAF AREA INDEX

Kim Whitford, Deb Feeniks and Allan WIlls

Introduction

Leaves strongly influence forest growth and water use through their primary role in transpiration, rainfall interception and photosynthesis. Stand leaf surface area also reflects stand health and vigour. Across a stand, leaf area is commonly measured as leaf area index (LAI) the one-sided area of foliage per unit ground area (Watson 1947). This key biophysical attribute of forests is valuable for modelling forest growth and water use, and for monitoring burn severity, stand health, and growth and development after harvesting.

In this part of the FORESTCHECK monitoring program we aim to determine the LAI of FORESTCHECK grids and monitor changes in LAI over time. LAI was measured in late winter through spring, and in late January to early February. Based on Loneragan's (1971) description of the typical leaf cycle in jarrah, which stated that leaves mature in January and thicken and harden in February, we assumed that LAI would reach a maximum in late January through February after the flush of new leaves, and a minimum in late winter through spring, just prior to the new leaf flush. The period January to February was also preferred as it is a time of least cloud cover and low soil moisture which is favoured for remote sensing of canopy condition.

This component of FORESTCHECK is intended to:

- provide annual monitoring of LAI across the 48 FORESTCHECK grids
- provide comparative measures of LAI across the various silvicultural treatments and in uncut forest
- analyse trends within and between the treatments over time and particularly with time since the last harvest
- provide data for assessment of forest health
- describe the annual cycle of LAI in the jarrah forest
- provide a covariate potentially related to other components of biodiversity monitored in FORESTCHECK.

Field and Laboratory Monitoring

Monitoring of LAI commenced in 2011 using two indirect methods for estimating LAI; digital cover photography (DCP) (Macfarlane et al. 2007) and remote sensing of the Normalized Differential Vegetation Index (NDVI) determined from Landsat 5 Thematic Mapper imagery.

LAI was determined on 22 FORESTCHECK grids using DCP in spring 2011 and on 36 grids in February 2012. Then, using a calibration equation between DCP and NDVI from Landsat 5 Thematic Mapper imagery (MacFarlane, pers. comm.), LAI was estimated for all 48 FORESTCHECK grids for January 1988, 1990, 2004, 2005, 2006, 2007, 2008, 2009, 2010 and 2011. Remote sensing work commenced in 2011 continues but has not yet been finalised and no new results from remote sensing are presented.

In addition to the monitoring of LAI on FORESTCHECK grids, work commenced on monitoring the annual cycle in LAI at a single site in the northern jarrah forest in order to clarify the annual cycle of LAI. The aim is to identify when LAI reaches its maximum and minimum, the times of the year when LAI is relatively stable, and which months are best for monitoring LAI. For this component of the study we monitored LAI seven times over 10 months at seven fixed points where the maximum LAI ranged from approximately 1.1 to 2.3. At each of these seven fixed points the DCP camera was oriented with a compass while mounted on a steel pipe concreted into the ground, so that the same area of the canopy was consistently photographed on each occasion. This work was undertaken at the Inglehope thinning trial, east of Dwellingup. Although this site is not a FORESTCHECK location it provides a range of LAI at a convenient single location, and is thus useful for examining the annual cycle of LAI in the northern jarrah forest.

Results and Discussion

Digital cover photography

Figure 1 shows the LAI for 22 FORESTCHECK grids monitored using DCP between May and October 2011 (referred to as 'spring 2011' LAI) and 36 grids monitored in late January and in February 2012 (referred to as 'summer 2012'). LAI in spring 2011 ranged from 0.49 to 1.62 with a mean of 1.14 ± 0.07 (Table 1). LAI in summer 2012 ranged from 0.66 to 2.28 with a mean of 1.40 ± 0.06. Note that more grids were monitored in summer than in spring. The seasonal increase in LAI indicated by these measurements is consistent with the annual cycle in leaf area described by Loneragan (1971).

In spring 2011 the mean LAI for grids in the gap release treatment was significantly different from the external reference and coupe buffer, but not significantly different from shelterwood (Tukey's HSD, $p<0.05$, fig. 2). No selective cut grids were monitored in spring 2011.

In summer 2012 there was no significant difference between the treatment means of LAI (ANOVA $p = 0.05$, fig. 3). These treatment means did not vary greatly for treatments with reasonable numbers of replicate grids (external reference LAI = 1.44, n = 14; gap release LAI = 1.34, n = 8; shelterwood LAI = 1.40, n = 8). The mean LAI for the subset of external reference grids that had never been harvested was 1.55 ± 0.15 (n = 8). This may indicate that never harvested grids carry greater LAI than harvested grids. However, the difference was not significant and the sample was small and may not account for factors other than harvesting that influence LAI, such as site fertility and rainfall. Although mean LAI was elevated for the coupe buffer treatment (LAI = 1.71, n = 3) and reduced for the selective cut treatment (LAI = 1.10, n = 3) both treatments had few replicates, were geographically restricted and consequently do not provide a good basis for comparison with other treatments.

The seasonal increase in LAI from spring to summer was determined by comparing spring and summer data from the same grid. The mean seasonal increase in LAI from spring 2011 to summer 2012 was 0.38, a 33% increase. This seasonal variation is a substantial change in LAI which highlights the importance of the timing of LAI measurement. The seasonal increase in LAI was least on grids that had never been harvested where LAI increased from 1.39 in spring to 1.55 in summer, a seasonal increase of 0.15 or 11%. Never harvested stands should be fully stocked and the change in LAI should predominantly reflect seasonal variation with little or no component of LAI attributable to stand growth; i.e. changes in stand structure or increases in basal area. The seasonal increase in LAI was greatest on the gap release treatment, which had a statistically significant increase in LAI of 0.55 or 66% (t-test $p < 0.05$). The coupe buffer, external reference and shelterwood treatments all had intermediate seasonal increases in LAI of 0.31, 0.32 and 0.34 respectively; increases of 22% to 30% which were not statistically significant (t-test, $p = 0.05$). The substantial increase in LAI on the gap release treatment, which contrasts sharply with the small change on the never harvested grids, is most likely a response to the intense harvesting of this treatment which substantially reduces stand basal area, increasing water and nutrient availability. This large seasonal increase in LAI may also reflect a longer term trend of increasing LAI on gap treatments as they replace the leaf area removed in this relatively intensive harvesting.

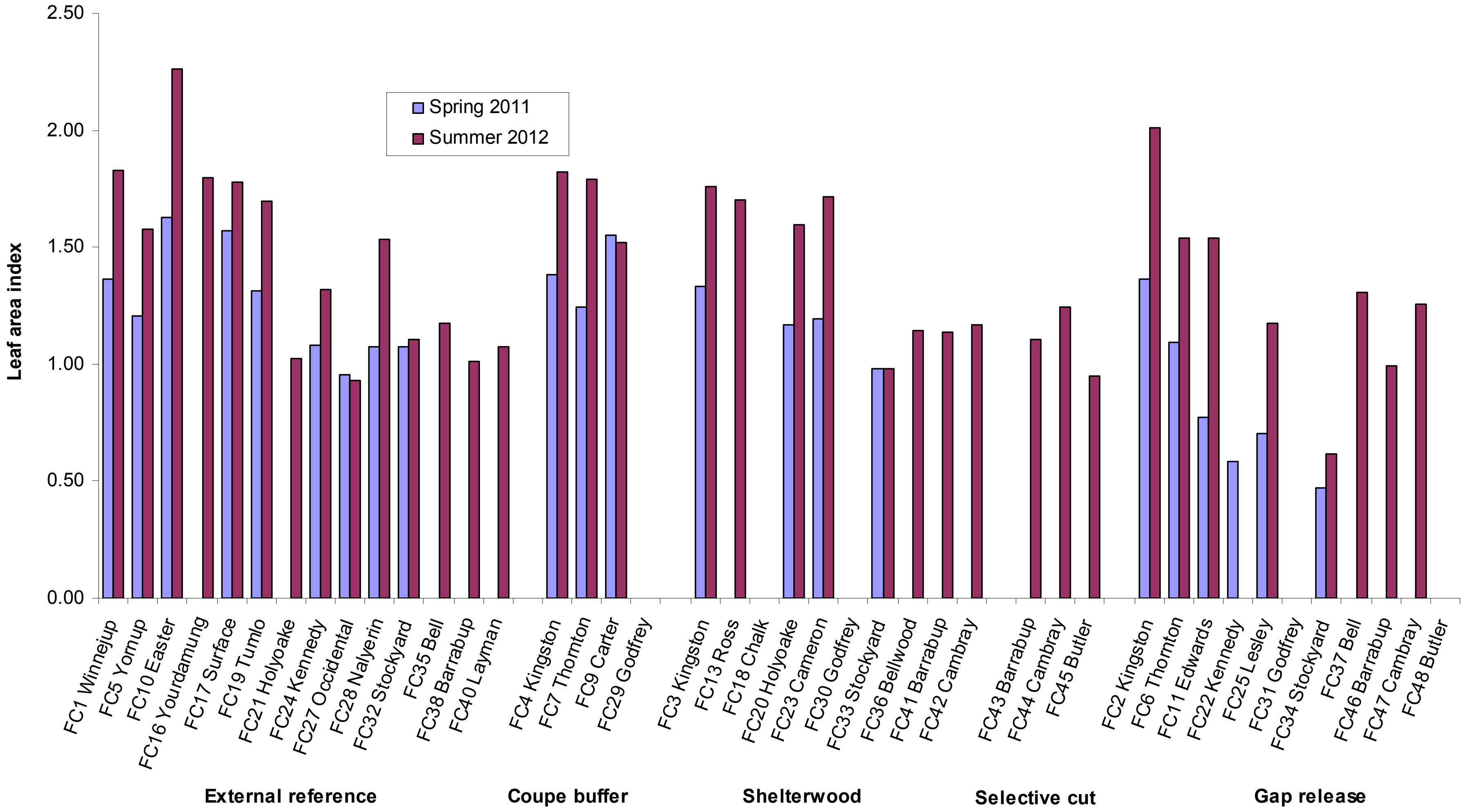

Figure 1. Leaf area index of FORESTCHECK grids in spring 2011 and late summer 2012 estimated from Digital Cover Photography.

Table 1. Results from Digital Cover Photography of the FORESTCHECK grids monitored in spring 2011 and late summer 2012. Grids are grouped by treatment type. LAI = leaf area index.

Grid	Location/ treatment	Year or decade of most recent harvest	Date of spring photo	LAI spring 2011	N°. of spring photos	Date of summer photo	LAI summer 2012	N°. of summer photos	Change in LAI spring to summer
	External reference								
FC1	Winnejup	1940–49	6/10/11	1.36	91	22/2/12	1.83	92	0.47
FC5	Yornup	1940–49	5/10/11	1.21	117	24/2/12	1.58	117	0.37
FC10	Easter	never	6/10/11	1.62	91	23/2/12	2.28	91	0.66
FC16	Yourdamung	never				2/2/12	1.80	91	
FC17	Control	never	4/10/11	1.57	91	8/2/12	1.78	90	0.20
FC19	Tumlo	never	3/10/11	1.31	91	2/2/12	1.70	92	0.39
FC21	Holyoake	never				9/2/12	1.03	91	
FC24	Kennedy	1920–29	18/07/1	1.09	91	1/2/12	1.32	91	0.24
FC27	Occidental	1930-39	30/09/1	0.95	118	10/2/12	0.98	117	0.02
FC28	Nalyerin	never	7/10/11	1.07	117	27/2/12	1.56	117	0.48
FC32	Stockyard	1950–59	4/10/11	1.08	117	7/2/12	1.10	117	0.03
FC35	Bell	never				31/1/12	1.17	117	
FC38	Barrabup	no				15/2/12	1.01	111	
FC40	Layman	never				15/2/12	1.08	118	
	Mean ± se			*1.25 ± 0.08*			*1.44 ± 0.11*		*0.32*
	Coupe buffer								
FC4	Kingston	1970	6/10/11	1.40	117	22/2/12	1.82	104	0.42
FC7	Thornton	1940-49	5/10/11	1.24	91	23/2/12	1.79	92	0.54
FC9	Carter	1940-49	5/10/11	1.55	117	23/2/12	1.52	118	-0.03
	Mean ± se			*1.40 ± 0.09*			*1.71 ± 0.10*		*0.31*
	Shelterwood								
FC3	Kingston	1996	6/10/11	1.33	117	22/2/12	1.76	117	0.43
FC13	Ross	1992				27/2/12	1.70	118	
FC20	Holyoake	1995	18/05/1	1.16	91	1/2/12	1.59	91	0.43
FC23	Cameron	1989	3/06/11	1.18	91	1/2/12	1.72	92	0.54
FC33	Stockyard	1998	28/09/1	0.99	117	7/2/12	0.96	117	-0.03
FC36	Bell	1996				31/1/12	1.14	118	
FC41	Barrabup	2002				14/2/12	1.14	90	
FC42	Cambray	1995				14/2/12	1.17	117	
	Mean ± se			*1.16 ± 0.07*			*1.40 ± 0.11*		*0.34*
	Selective cut								
FC43	Barrabup	2002				15/2/12	1.10	116	
FC44	Cambray	1995				14/2/12	1.24	117	
FC45	Butler	1997				15/2/12	0.95	117	
	Mean ± se						*1.10 ± 0.08*		
	Gap release								
FC2	Kingston	1996	6/10/11	1.36	117	24/2/12	2.03	116	0.66
FC6	Thornton	1991	5/10/11	1.09	117	23/2/12	1.54	118	0.45
FC11	Edwards	1994	14/09/1	0.77	91	8/2/12	1.54	91	0.76
FC22	Kennedy	1988	19/05/1	0.58	91				
FC25	Lesley	1997	30/09/1	0.70	117	10/2/12	1.42	115	0.71
FC34	Stockyard	1998	28/09/1	0.49	117	2/2/12	0.66	116	0.17
FC37	Bell	1996				31/1/12	1.31	101	
FC46	Barrabup	2001				14/2/12	0.99	118	
FC47	Cambray	1995				14/2/12	1.26	118	
	Mean ± se			*0.83 ± 0.14*			*1.34 ± 0.14*		*0.55*
	Overall mean LAI ± se			**1.14 ± 0.07**			**1.40 ± 0.06**		**0.38**

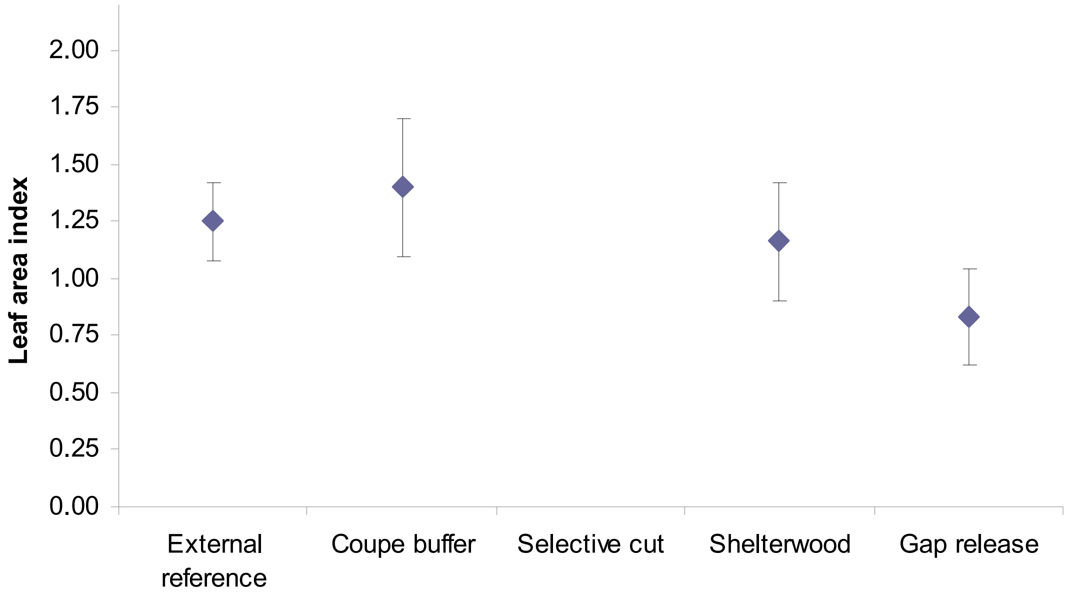

Figure 2. Treatment mean leaf area index from 22 FORESTCHECK grids in spring 2011. Error bars are 95% confidence intervals for the least squares means. No selective cut grids were monitored in spring 2011.

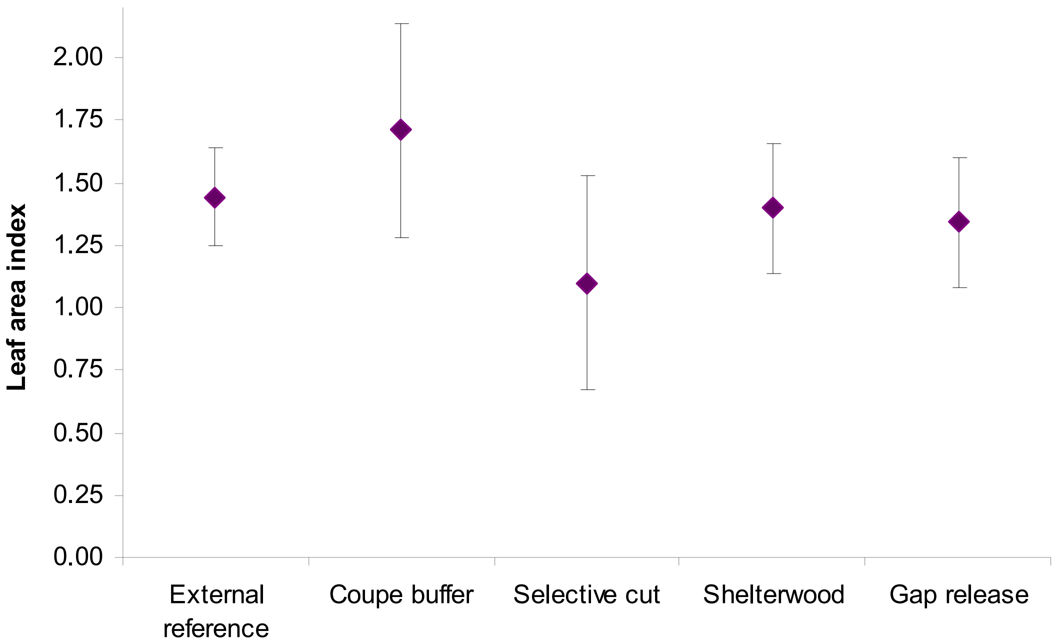

Figure 3. Treatment mean leaf area index from 36 FORESTCHECK grids in summer 2012. Error bars are 95% confidence intervals for the least squares means.

Annual cycle in leaf area index

Figure 4 shows the values of LAI determined seven times over ten months for seven fixed canopy measurement points at Inglehope. This site was selected as being potentially representative of the seasonal variation in LAI in the intermediate rainfall zone of the northern jarrah forest. Storm damage reduced leaf area at measurement points 4 and 27 on 24 September 2012.

From a minimum at the first measurement on 11 November 2011, LAI rose relatively quickly through the months of November, December, January and February. The response varied between the measurement points, but generally the rate of LAI increase declined through March and April. LAI reached a maximum in late April, May or early June and declined in the following months; indicating a minimum occurring in October or November 2012, just prior to the new leaf flush. The response for these sites is consistent with that determined from the mean LAI for two monitoring dates on the FORESTCHECK grids (Fig. 4).

Based on visual observation of 40 year old pole trees over five years, Loneragan (1971) described the typical leaf cycle in jarrah, stating that; "Early in February the last of the new tender leaves develop fully in size. They mature, thicken and harden during the summer drought before the end of March. Without pronounced changes in leaf growth the crown settles down until the next spring. Although other small flushes have been observed early in the spring following warm weather, and early in the autumn following good summer rains, the main flush following a light flowering for jarrah trees is the observed sequence".

In 2012 at Ingelhope, the maximum stand LAI occurred in late April, or May or early June, and the minimum LAI occurred about October. Visual inspection of the photographs confirm that the responses shown in Figure 4 are real and not an artefact caused by factors that affect the analysis of the DCP photographs; i.e. lighting, tree movement, and variations in camera orientation. Photographs clearly show the expansion and growth of new leaves into winter 2012, confirming that LAI at Ingelhope increased to reach a maximum in winter 2012. This indicates that the time we took the DCP photos (February) may not be the best time to monitor maximum LAI. While September/October is the best time to monitor the minimum LAI, the full seasonal range of LAI may be best captured by monitoring maximum LAI in May/June—later than the current monitoring period.

This observation of maximum LAI occurring in winter is at variance with Loneragan's (1971) description which implied that a maximum LAI occurred in late January, February or March. This possible shift in the timing of maximum LAI in jarrah may relate to reduced annual rainfall over the last 30 years and an associated decline in groundwater levels. In addition to reduced annual rainfall, Bates *et al.* (2008) reported a reduction in early winter rain and a progressive increase in mean annual temperatures in south-west Western Australia in all seasons except summer. All these factors could influence the timing of leaf flush, leaf development and leaf fall, altering the seasonal timing of maximum annual LAI. Further observation of the annual cycle of LAI is needed to characterise the seasonal cycle of LAI, identify the best time to monitor LAI and determine how much this varies annually. The timing of measurement is also important when considering measurement of the impact of defoliating insects. Maximum defoliation in affected stands may not coincide with the peak or trough in LAI of unaffected stands.

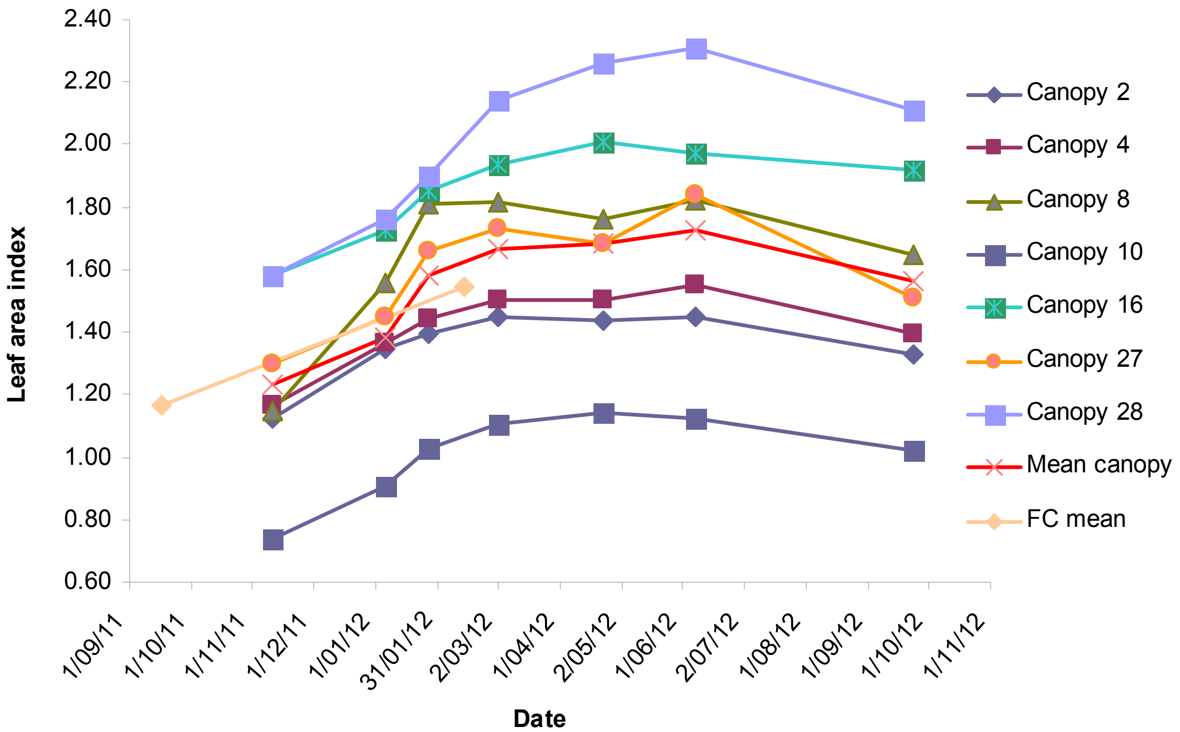

Figure 4. The seasonal change in leaf area index (LAI) over ten months across seven fixed canopy measurement points at Inglehope east of Dwellingup in the northern jarrah forest, and the mean LAI for FORESTCHECK grids in spring 2011 and summer 2012 (FC mean).

Conclusions

Main observations resulting from LAI measurements on Ingelhope sites and Blackwood Plateau FORESTCHECK grids in 2011 and 2012 were:

- LAI in spring 2011 ranged from 0.49 to 1.62 with a mean of 1.14 ± 0.07. LAI in summer 2012 ranged from 0.66 to 2.28 with a mean of 1.40 ± 0.06.
- In spring 2011 the mean LAI for the gap release treatment was significantly different from that of coupe buffer and external reference but not significantly different from the shelterwood (Tukey's HSD, $p<0.05$).
- There was no significant difference between the treatment means for LAI in summer 2012 (ANOVA $p = 0.05$).
- The mean seasonal increase in LAI from spring 2011 to summer 2012 was 0.38, a 33% seasonal increase in LAI.
- The seasonal increase in LAI was least on grids that had never been harvested where LAI increased from 1.39 in spring to 1.55 in summer, a seasonal increase of 0.15 or 11%.
- The seasonal increase in LAI was greatest on the gap release treatment, which had a statistically significant increase in LAI of 0.55 or 66% (t-test $p < 0.05$).
- The coupe buffer, external reference and shelterwood treatments all had intermediate seasonal LAI increases of 0.31, 0.32 and 0.34 respectively, increases of 22% to 30% (not significant, t-test $p = 0.05$).
- These seasonal variations are substantial changes in LAI which highlight the importance of the timing of LAI measurement.
- At a single site in the northern jarrah forest where LAI was monitored repeatedly over ten months we observed that the minimum LAI occurred in September/October and the maximum LAI occurred in May/June. This maximum LAI occurred in winter, later than the maximum indicated by Loneragan (1971).

Further work is required to characterise the seasonal cycle of LAI and determine if LAI can be measured once annually and the best time for this measurement and to refine the use of NDVI for monitoring LAI.

Acknowledgements
Thank you to Craig Macfarlane for providing the DCP software.

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COARSE WOODY DEBRIS, SMALL WOOD AND TWIGS, AND LITTER

Richard Robinson and Lachie McCaw

Introduction

Coarse woody debris (CWD) is defined as woody plant material larger than 2.5 cm in diameter. Small wood and twigs (SWT) is woody material 1–2.5 cm in diameter, and litter is dead leaves and other dead fine vegetative material less than 1 cm in diameter.

Wood and leaf litter on the forest floor provides habitat for many fungi, invertebrates, small reptiles, and mammals. The litter layer also affects soil moisture, and in conjunction with micro-organisms, influences soil structure. CWD, SWT and litter are important structural and biological components of forest ecosystems. Disturbances such as logging and burning affect the volumes and types of debris that occur in forests. This component of the FORESTCHECK monitoring program determines the amount of debris on each of the FORESTCHECK grids and monitors various attributes of this debris.

This component of FORESTCHECK is intended to:

- measure and record the amount of CWD, SWT, and litter on the ground in the various managed jarrah forest treatments (i.e. gap release and shelterwood) and in uncut forest
- analyse trends within and between the treatments over time
- provide data for analysis of distribution patterns of other organisms such as invertebrates, small mammals, fungi and cryptogams.

Litter samples were collected from 11 plots, each 0.05 m^2, along two 100 m transects on each grid (22 samples in total). SWT samples were collected from 22 plots, each 1 m^2, directly adjacent the litter plots. All samples were oven dried for 24 hrs and weights used to determine loads in tonnes per hectare. The CWD assessment was revised in 2008 (Whitford *et al*. 2008) in order to collect additional information. Amounts of CWD were determined along three 200 m transects on each grid using the methods of van Wagner (1968) and stages of decay for logs greater than 20 cm diameter were determined using methods outlined in Whitford *et al*. (2008). The re-assessment of all grids was commenced in 2008–09 (see FORESTCHECK Report of Progress 2008–09) and completed in 2009–10. Six grids which had been burnt since their initial measurements were also re-assessed in 2009–10 (see FORESTCHECK Report of Progress 2009–10, available at www.dec.wa.gov.au).

Because fire has a major impact on CWD, by consuming existing as well as creating additional CWD, the re-assessment of grids which had been burnt since their initial assessment was also commenced in 2009-10. Post-fire reassessment re-establishes the CWD baseline loads on recently burnt grids and will also aid in creating a dataset to assess the long-term impact of fire on CWD dynamics. Post fire re-assessment includes all measurements and attributes detailed in Whitford *et al*. (2008) plus assessment of scorch height, whether or not individual logs were burnt, and the degree of charring.

Field and Laboratory Measurements

No additional data on CWD was collected in 2012. SWT and litter assessments were undertaken on the Blackwood Plateau grids between 21 September and 15 November 2012. Twenty two samples each of SWT and litter were collected from each FORESTCHECK grid as per the methods detailed in the FORESTCHECK Operating Plan (available at www.dec.wa.gov.au). Samples were oven dried, weighed in grams and then converted to tonnes per hectare (t ha^{-1}).

SWT and litter samples were initially collected from the Blackwood Plateau grids in 2006, and the time since fire across all grids at that assessment was 3–13 years. In spring 2010, the Layman external reference (FC40) and the Butler selective cut (FC45) grids were burnt by prescribed fire. In 2012, the time since fire ages across the grids was 2–19 years.

Results and Discussion

Litter

Litter accumulation is influenced by a variety of factors including stand structure and density, the extent of fuel consumption during previous fires, time since previous fire and reduction in canopy density by defoliating insects. In 2012, litter loads on grids within and between treatments were generally variable and reflected time since fire. The grids with the lightest litter loads were the Layman external reference (FC40) and the Butler selective cut (FC45), which were burnt two years previously (Fig. 1).

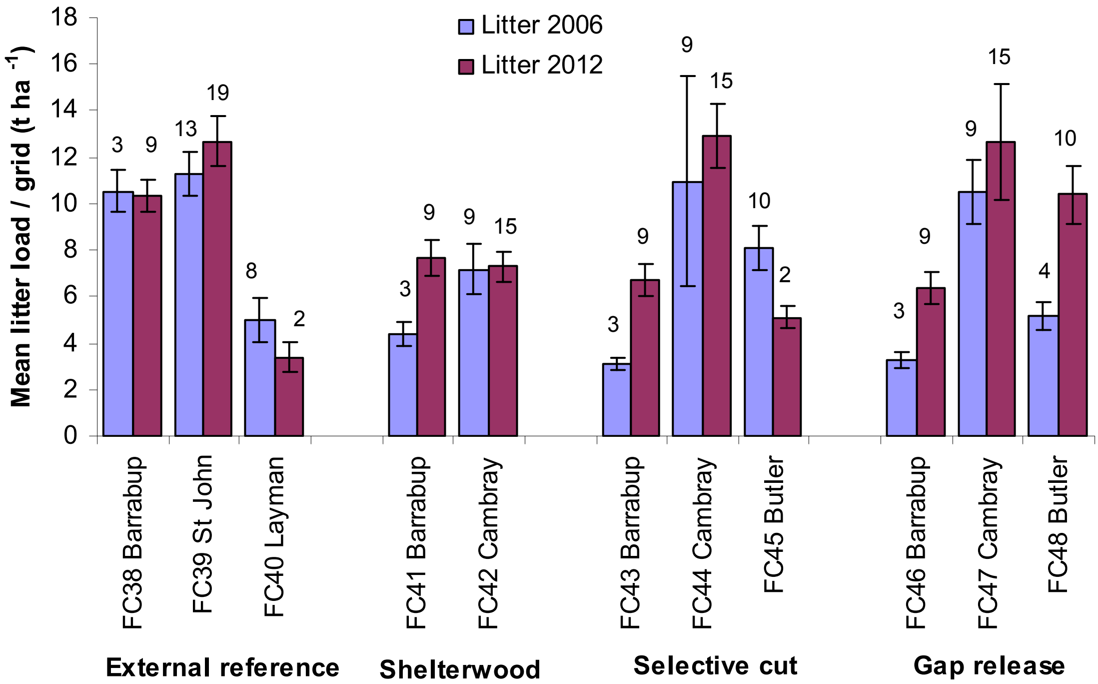

Figure 1. Mean litter loads (t ha^{-1} ± se) calculated at each FORESTCHECK grid at the Blackwood Plateau in 2006 and 2012. Numbers above columns indicate years since fire.

Litter loads on the grids were generally higher in all treatments in 2012 compared to 2006, except on the Barrabup external reference (FC38) which was similar to that in 2006, and on the Layman external reference and Butler selective cut grids where it was lower due to the 2010 prescribed fire. Generally there was a greater increase in litter loads on harvested grids than on unharvested grids.

Small wood and twigs

The amount of SWT on all sites was low (Fig. 2) compared to that of the litter (Fig. 1). SWT loads increased markedly on all grids except the Barrabup gap release (FC46) since 2006. Loads on the Layman external reference and Butler selective cut were higher in 2012 by about 2.5 times, despite having been burnt two years previously and having times of eight and 10 years since fire in 2006. The increase may be due to accelerated small branch shedding following the driest year on record occurring in 2010 (BoM 2010) followed by a dry autumn in 2011 (this trend was also noted at the Wellington East grids in 2011—see FORESTCHECK Report of Progress 2010–11). Several major wind storms in the lower south west in 2012 (notably June and September) also contributed to increased rates of twig and small branch fall.

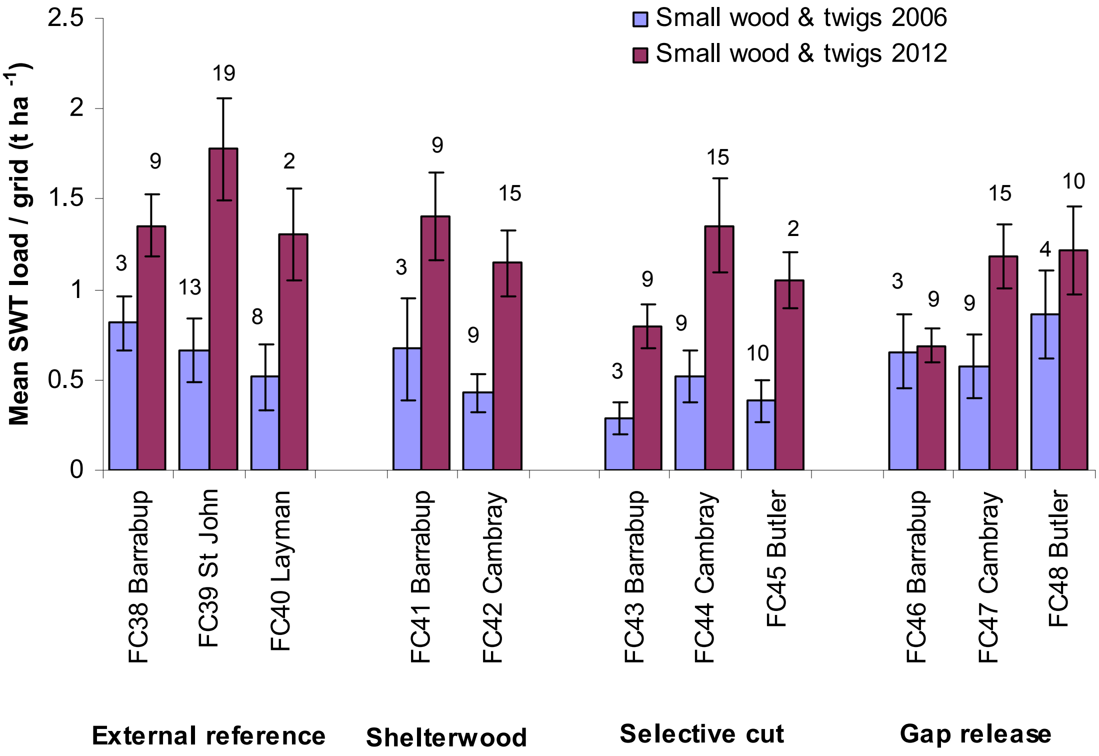

Figure 2. Mean loads (t ha^{-1}) of small wood and twigs measured at each FORESTCHECK grid at Blackwood Plateau in 2006 and 2012. Numbers above the columns indicate years since burnt.

Conclusions

Broad observations resulting from litter and SWT sampling at Blackwood Plateau in 2012 include:

- litter loads reflected time since fire, and generally increased since 2006
- SWT volumes have increased markedly on all grids except the Barrabup gap release since 2006
- increased branch and twig shedding may be due to climatic factors such as periods of low rainfall and major wind events.

Acknowledgements

Thank you to Graeme (Tub) Liddelow and Maddi Read for field assistance with sample collection.

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MACROFUNGI

Richard Robinson, Katrina Syme and Nadine Rea

Introduction

Fungi are considered one of the most important forest organisms in terms of both biodiversity and forest function. Soil, litter and wood inhabiting fungi play major roles in decomposition and nutrient cycling. Mycorrhizal fungi enhance nutrient uptake of plants and may enhance plant resistance to some pathogens. In addition, underground truffle-like fungi are an important food source for native animals, especially following disturbance such as fire.

Recent research on fungi in Western Australia's southern forests has shown that fungal communities respond to fire and other forest management activities and species assemblages change with time since disturbance. Knowledge on fungal diversity and the ecological roles that fungi play is of vital importance to forest managers making decisions regarding sustainable forest management.

The objective of this component of the FORESTCHECK program is to:

- monitor and record the species of macrofungi in the various silvicultural treatments of managed jarrah forest (shelterwood, selective cut and gap release) and in uncut reference forest
- analyse trends in species composition, richness and abundance and substrate utilisation over time
- generate detailed descriptions of unknown or unnamed species.

Field Survey

Eleven FORESTCHECK grids, including three external reference grids (FC39, FC39, FC40), two shelterwood (FC41, FC42), three selective cut (FC43, FC44, FC45) and three gap release treatments (FC46, FC47, FC48), were installed in the Jarrah Blackwood Plateau ecosystem in the Blackwood District in 2004. These plots were initially monitored for macrofungi in autumn 2006, and results were included in the FORESTCHECK Report of progress 2005–06 (available at www.dec.wa.gov.au).

The second round of macrofungal monitoring in Blackwood Plateau was undertaken in 2012. Two surveys were conducted, the first from 12–20 June and the second from 11–19 July. Surveys are conducted when the soil dryness index (SDI) indicates suitable conditions for fruit body development. SDI uses daily temperature, rainfall and evapotranspiration rates to determine a value that reflects the moisture content of surface soil, deep forest litter and woody debris (i.e. the major fungal habitats) and the value reflects the amount of rain (mm) needed to bring the soil back to field capacity (Burrows 1987). Prior research and previous FORESTCHECK surveys indicate that the soil dryness index (SDI) should be below 50 and falling to provide favourable conditions for the initiation of macrofungal fruit body development; and maximum species diversity is generally encountered when the SDI first falls to zero (Robinson 2007). During the first survey in 2012 the SDI was at 50 and declined to 30 and during the second survey, 3 weeks later, the SDI was steady between zero and 5 (Fig 1). In 2006, when the grids were initially monitored at Blackwood Plateau, the SDI was 140 and 115 at the start of each survey (15–26 June and 10–17 July respectively) and did not fall to zero until 7 August, 2 weeks after surveys were completed.

During each survey in 2012, all 11 grids were monitored. All macrofungal species and their abundance were recorded along 2 x 200 m transects on each grid. All new or previously unrecorded taxa were photographed *in situ* and vouchers collected.

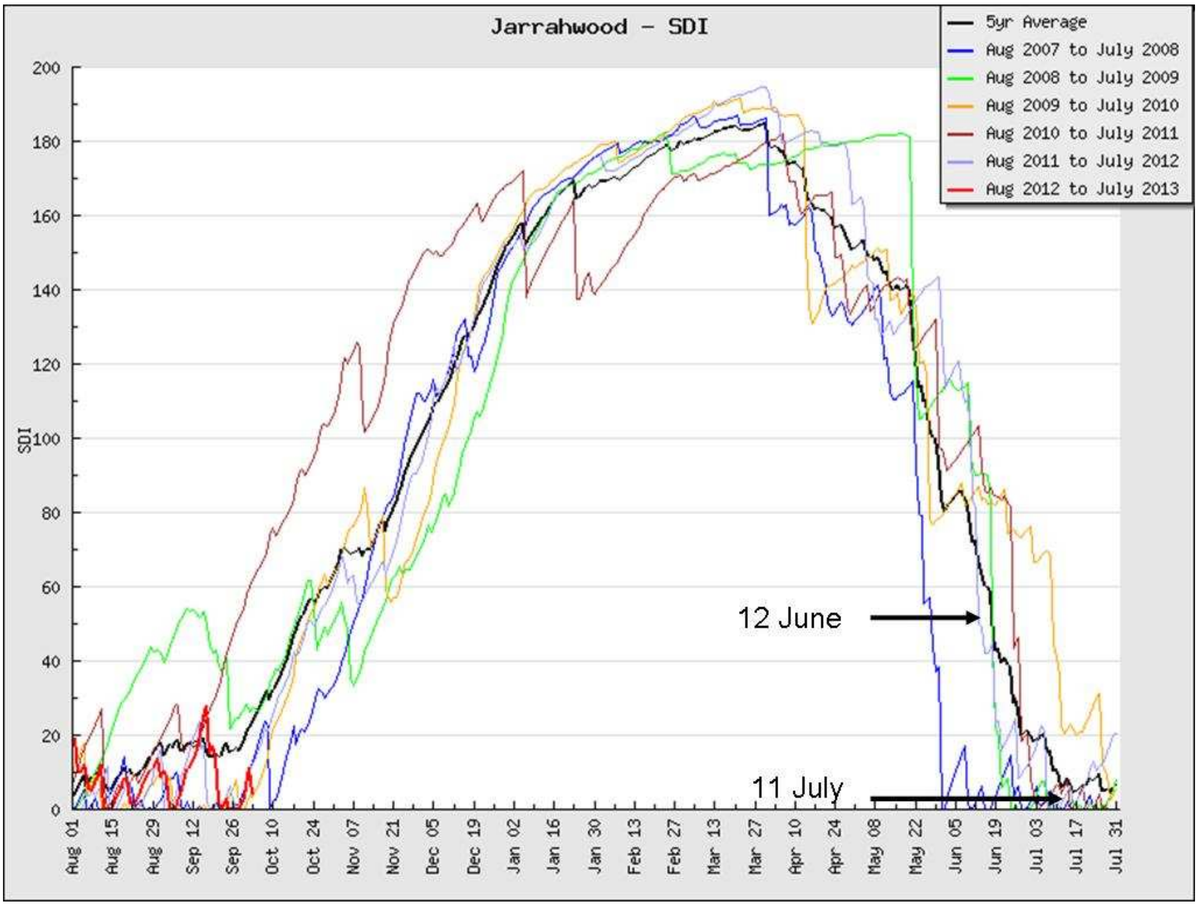

Figure 1. Daily soil dryness index (SDI) from the Jarrahwood automatic weather station during the period August 2007 to September 2012 (Bureau of Meteorology). The SDI at the start of each FORESTCHECK macrofungi monitoring period in 2012 is indicated by the black arrows on the mauve coloured line.

Preliminary Results and Discussion

Voucher specimen examination and processing

In the laboratory, voucher specimens were kept in a refrigerator at 5ºC. Processing of each voucher collection was completed on the day of collection. Detailed descriptions of the macroscopic characters of the fresh specimens were compiled for each collection that represented a putative new species or represented noticeable variation in species concepts already determined. All collections were then air dried at 35º C. At the completion of the field surveys, some dried specimens were examined microscopically and detailed measurements of basidia, spore and hyphal structure were undertaken to aid in verifying their identity and to confirm a number of other unnamed species. A species list has been compiled (Appendix 1). In total, 89 voucher collections were made representing 73 species. A total of 40 taxa were determined to be new records for FORESTCHECK. Voucher specimens are currently being entered onto the PERTH (WA Herbarium) database and are housed in the Tony Annells Herbarium at the Manjimup Research Centre. In order to verify identifications and keep pace with taxonomic revision of many species, taxonomic studies of specimens within the FORESTCHECK collection is an ongoing process.

Total species richness and abundance in 2012

A total of 242 species of macrofungi and 9,036 fruit bodies were recorded on the Blackwood Plateau monitoring grids in 2012 (Appendix 1). Of these, 41 species (17%) were recorded for the first time in FORESTCHECK. One hundred and forty one species were recorded in the June survey and 177 in the second survey in July. Only 32% of the total species were recorded in both surveys (Fig. 2). This demonstrates the temporal differences in fruit body development throughout the fruiting season and the complications associated with analysing macrofungal communities in survey projects. It also demonstrates the importance of standardising survey methods and the value of intensive long-term survey for monitoring macrofungal communities.

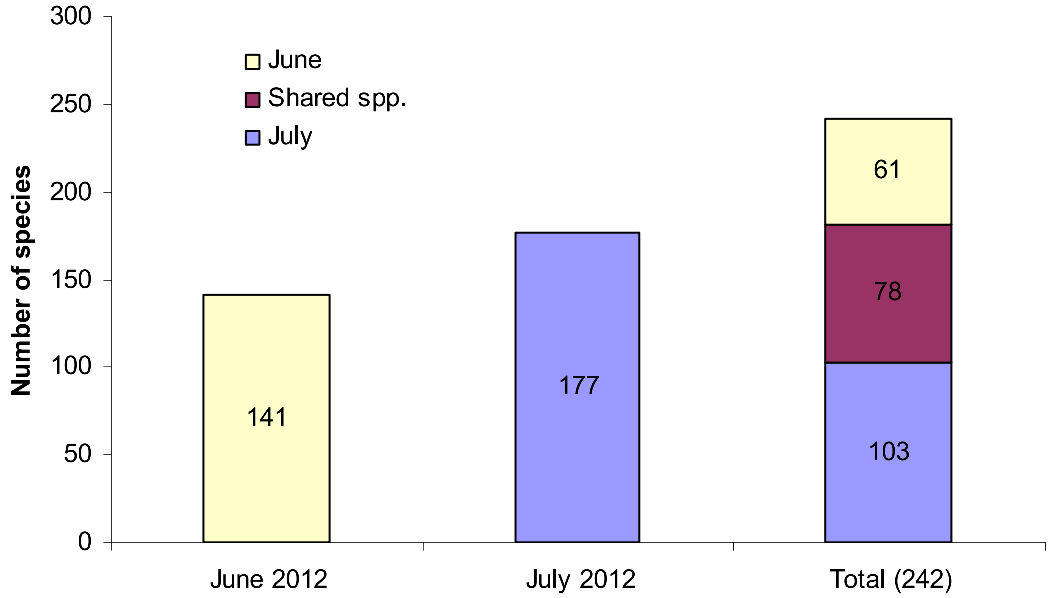

Figure 2. Total number of species recorded in June and July surveys on the Blackwood Plateau FORESTCHECK monitoring grids in 2012.

Species richness and abundance of fruit bodies on each grid varied within and between treatments with harvested grids generally having higher numbers of species and fruit bodies (Fig. 3).

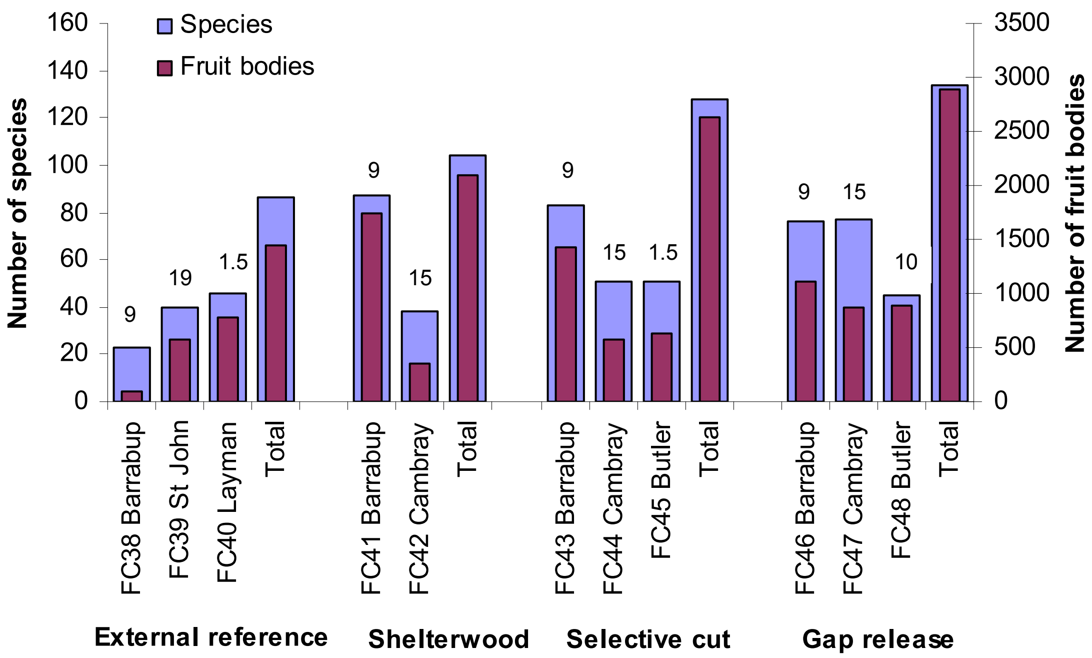

Figure 3. Total number of species recorded on each FORESTCHECK monitoring grid at Blackwood Plateau in 2012. Numbers above columns indicate the years since the last fire.

Time since fire did not appear to influence species richness or abundance, but it was interesting to note that the recently burnt (1.5 years previously) Layman external reference grid (FC40) had a higher species richness and fruit body abundance recorded than the Barrabup (FC38) and St John (FC39) grids which had not been burnt for 9 and 19 years respectively. Fruit body abundance on the Barrabup external reference was very low (Fig. 3).

Comparison with previous monitoring at Blackwood Plateau and other regions
Blackwood Plateau data from both the 2006 and 2012 surveys was analysed and compared with respect to mean species richness and abundance per treatment and the mean number of species fruiting on the various substrates (soil, litter and wood). Differences in numbers of species associated with macrofungal communities recorded on each treatment on each of the survey dates were also examined. Finally, total species richness and abundance recorded for all macrofungal surveys conducted at each FORESTCHECK location between 2002 and 2012 was compared.

Species richness and abundance

Survey years

Overall 358 species of macrofungi have been recorded on the Blackwood Plateau monitoring grids. The total number of species was very similar in both 2006 (250) and 2012 (242) (Fig. 4), but the abundance of fruit bodies was about one-third lower in 2012 compared to 2006 (9,036 and 13,578 respectively). About 37% were common to both survey years. The high abundance of fruit bodies recorded in 2006 is unexpected, as conditions were noticeably drier than those encountered in 2012.

Despite similar numbers of species recorded in both survey years, the number of species recorded in each treatment was generally lower in 2012, except in the selective cut treatment (Fig. 5). This suggests that more species were common across treatments in 2012. The proportion of species common to both survey years in each treatment ranged from 22.5% in the external reference, 30% in the sheltwerood, 28% in the selective cut and 34% in the gap release treatment.

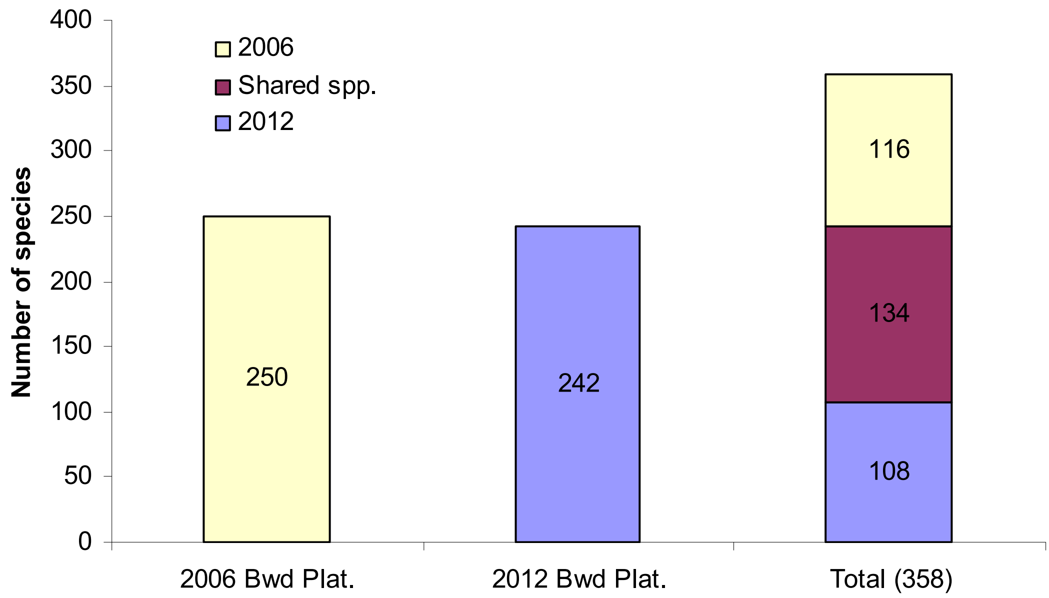

Figure 4. Number of species of macrofungi recorded at Blackwood Plateau in 2006 and 2012 and the number of species common to both survey years.

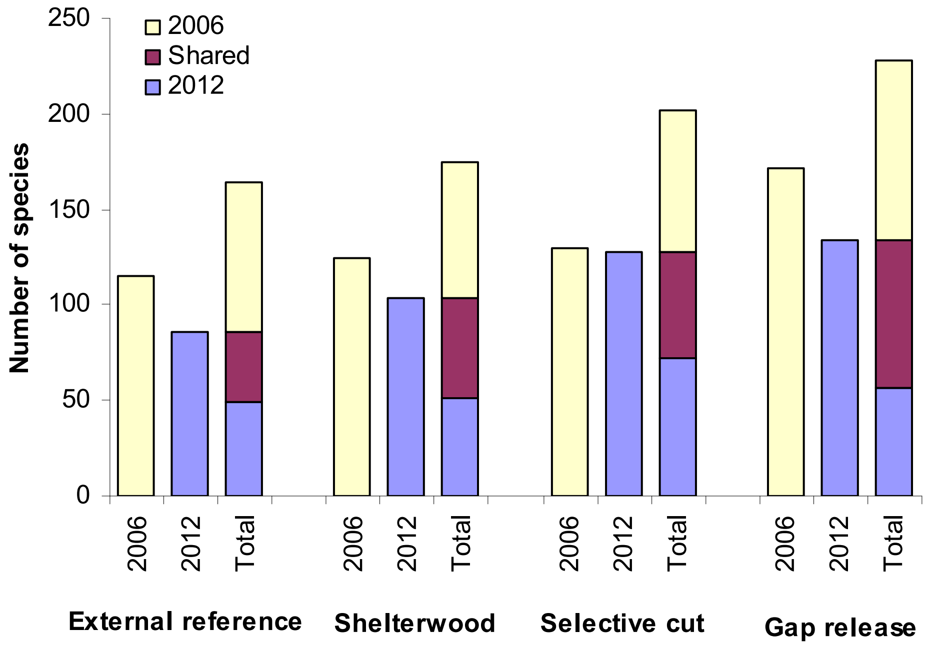

Figure 5. Number of species of macrofungi recorded in each treatment at Blackwood Plateau in 2006and 2012 and the number of species in each treatment common to both survey years.

Mean species richness was similar in harvested treatments but species richness in the external reference treatment was lower than that in the gap release in both survey years (Fig. 6). Fruit body abundances were variable within and between treatments in both years but, similar to the species richness, fruit body abundance in the external reference treatment was lower than in the gap release (Fig. 7). Similar trends were evident when data from both survey dates were combined.

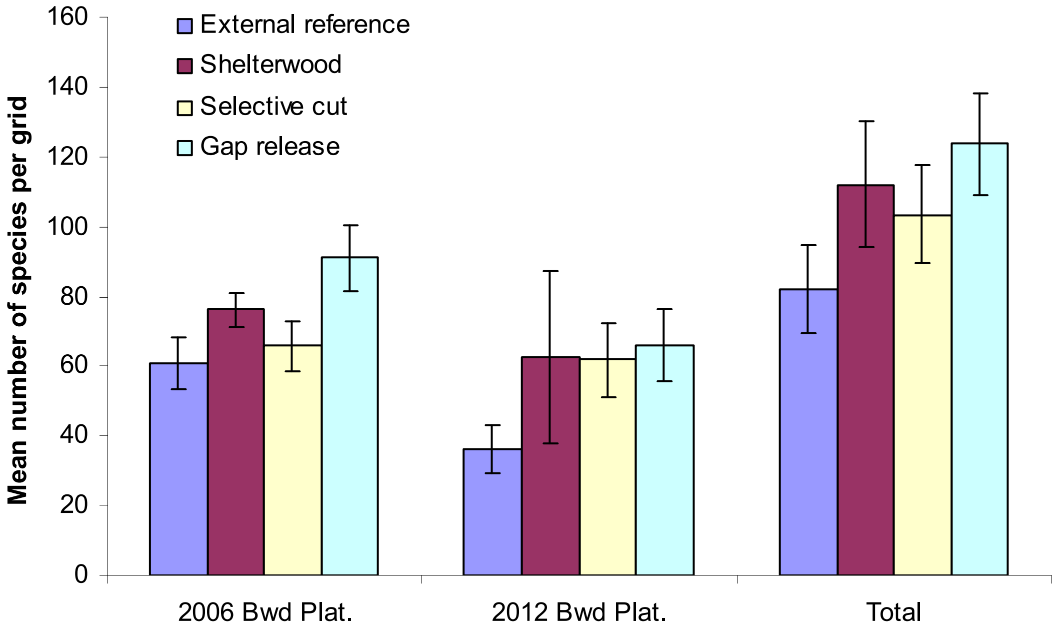

Figure 6. Mean number of species per grid (± se) in each treatment at Blackwood Plateau in 2005 and 2012.

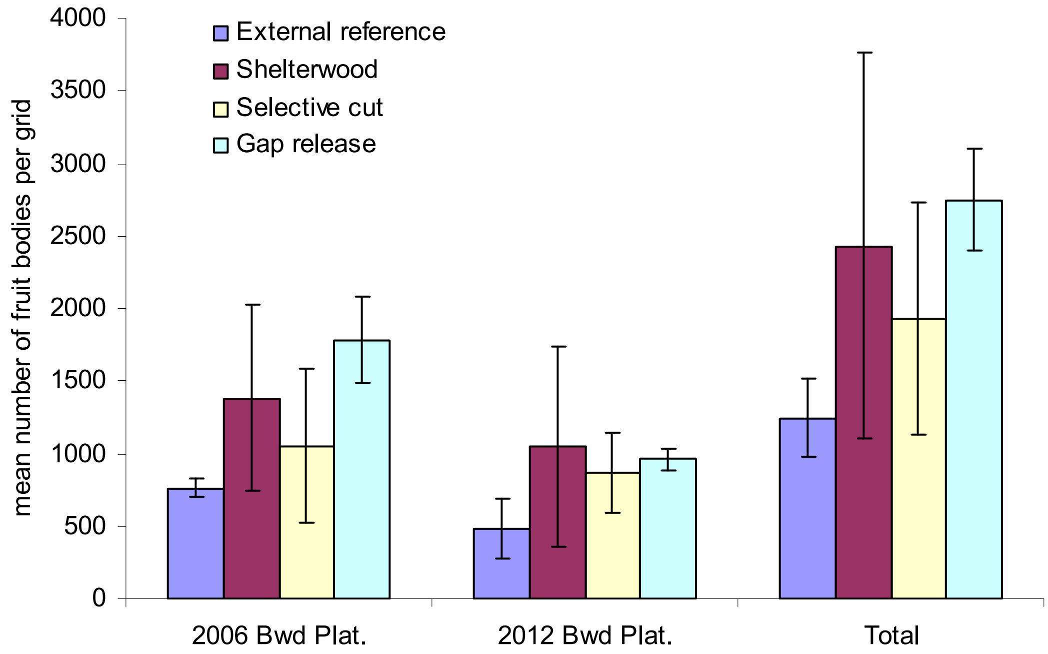

Figure 7. Mean number of fruit bodies per grid (± se) in each treatment at Blackwood Plateau in 2006 and 2012.

Donnelly appears to be the most species rich location, followed by the dry Wellington East location and the wet Blackwood Plateau where similar numbers of fungi were recorded in 2005, 2006, 2011 and 2012. The Perth Hills location was the poorest for both species richness and abundance (Fig. 8). Abundance generally reflected species richness, except at Wellington 1 in 2003, where abundance appeared to be higher in relation to the number of species recorded. In general, more species of large robust fungi were recorded at Wellington East and very few smaller, more delicate species. This may be a reflection of the drier more open environment.

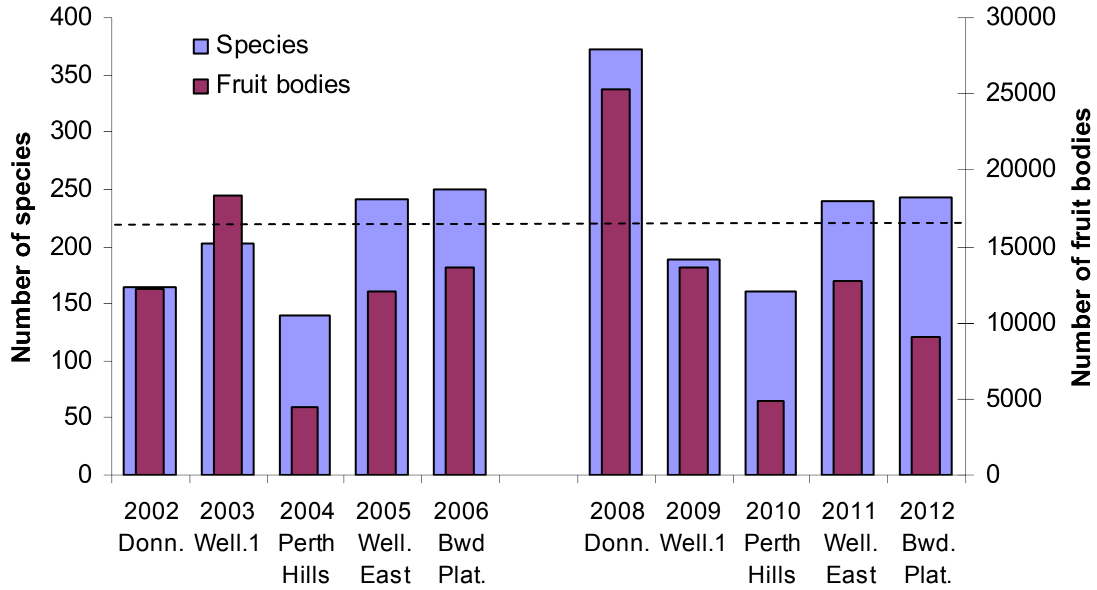

Figure 8. Total number of species and fruit bodies recorded at each FORESTCHECK location from 2002 to 2012. The dotted line represents the average number of species recorded per year (220).

Substrates

The three major habitats for fungi are soil, litter and wood. A small number of parasitic fungi fruit on their host and lichenised fungi fruit with their algal partner. The majority of macrofungi recorded at Blackwood Plateau in both years fruited on soil, but fewer species were recorded on soil in all treatments in 2012 (Figs 9 and 10). The mean number of species recorded on litter and wood was similar on each substrate in each treatment in both 2006 and 2012. In both years, more species were recorded fruiting on wood in harvested treatments. This likely reflects the increased amounts of coarse woody debris on harvested grids.

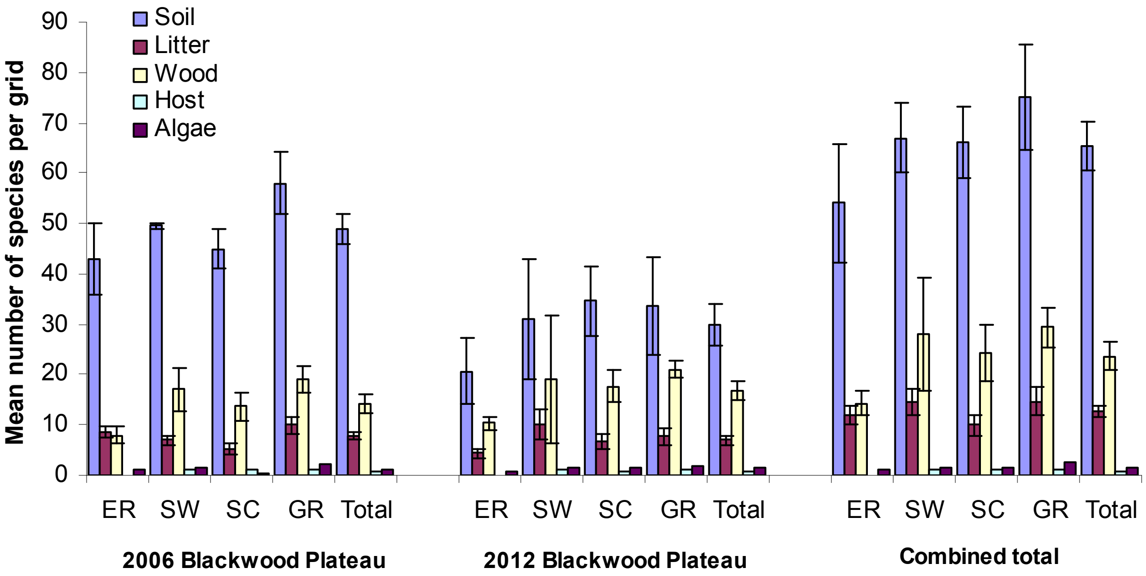

Figure 9. Mean number of species per grid (± se) recorded fruiting on soil, litter and wood on the Blackwood Plateau FORESTCHECK grids in 2006 and 2012.

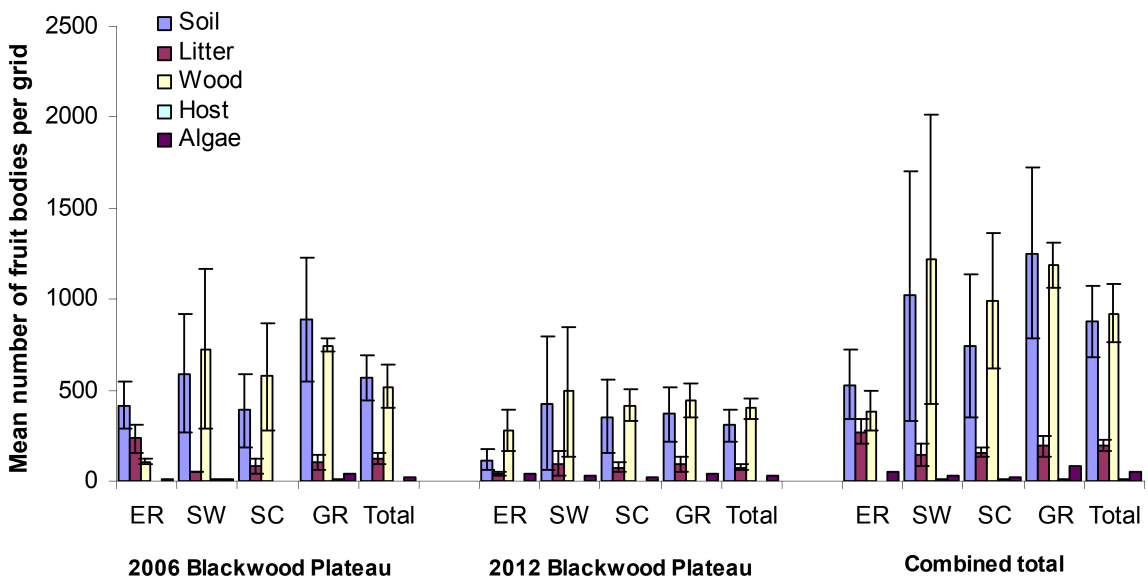

Figure 10. Mean number of fruit bodies per grid (± se) recorded fruiting on soil, litter and wood on the Blackwood Plateau FORESTCHECK grids in 2006 and 2012.

Trophic status

Fungi are associated with two of the most beneficial ecological processes involved in ecosystem functioning; the formation of mycorrhizae and decomposition. The vast majority (97.5%) of species recorded in 2012 were involved in these two roles. In 2012, the mean number of mycorrhizal species per grid in all treatments was lower than that recorded in 2006 (Fig. 11). The total number of mycorrhizal species recorded in 2006 was 112, with 99 in 2012. In both survey years there were more species of saprotrophic fungi recorded in harvested grids which was also evident when data from both years were combined. The total number of saprotrophic species was similar in both sample years, 131 in 2006 and 137 in 2012.

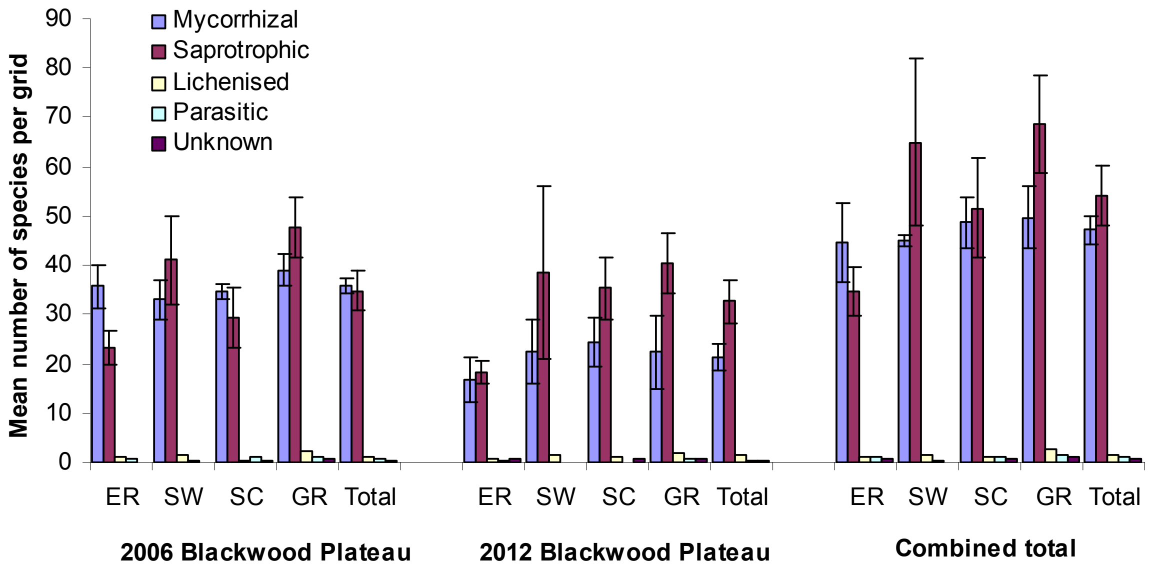

Figure 11. Mean number of mycorrhizal, saprotrophic, lichenised and parasitic species of macrofungi per grid (± se) recorded on the Blackwood Plateau FORESTCHECK grids in 2006 and 2012.

The mean number of mycorrhizal species per grid was markedly lower in all treatments in 2012, suggesting that the assemblage of these species was different between treatments. In both sample years and overall, saprotrophic species produced more fruit bodies than mycorrhizal species (Fig. 12), but the mean number of fruit bodies per grid in harvested treatments was generally lower in 2012. The number of fruit bodies in harvested treatments was generally higher than in the external reference treatment for both mycorrhizal and saprotrophic fungi.

Cortinarius and *Amanita* were the most diverse and abundant mycorrhizal genera in both survey years. In 2006, 45 species of *Cortinarius* produced 1449 fruit bodies, but in 2012 only 34 species were recorded and 204 fruit bodies counted. Only 15 species of *Cortinarius* were recorded in both sample years. Four species within the *Cortinarius* (*Dermocybe*) *clelandii* complex (Fig. 13) were recorded in 2006 (106 fruit bodies counted) but none were recorded in 2012. Similarly, five species of the mycorrhizal genus *Phellodon* were recorded in 2006 (423 fruit bodies counted) and none in 2012 (Fig. 13). *Cortinarius dermocybe* and several *Phellodon* species are generally common throughout the jarrah forest.

Mycena subgallericulata and *Calocera guepinioides* (Fig. 14) were the most abundant saprotrophic species in 2006, with 1065 and 984 fruit bodies recorded throughout all treatments. However, in 2012 only 226 *M. subgallericulata* fruit bodies were recorded. Low numbers of saprotrophic species was typical of many species recorded in 2012 (see Appendix 1) but *C. guepioioides* was one of the few species that were more abundant in 2012.

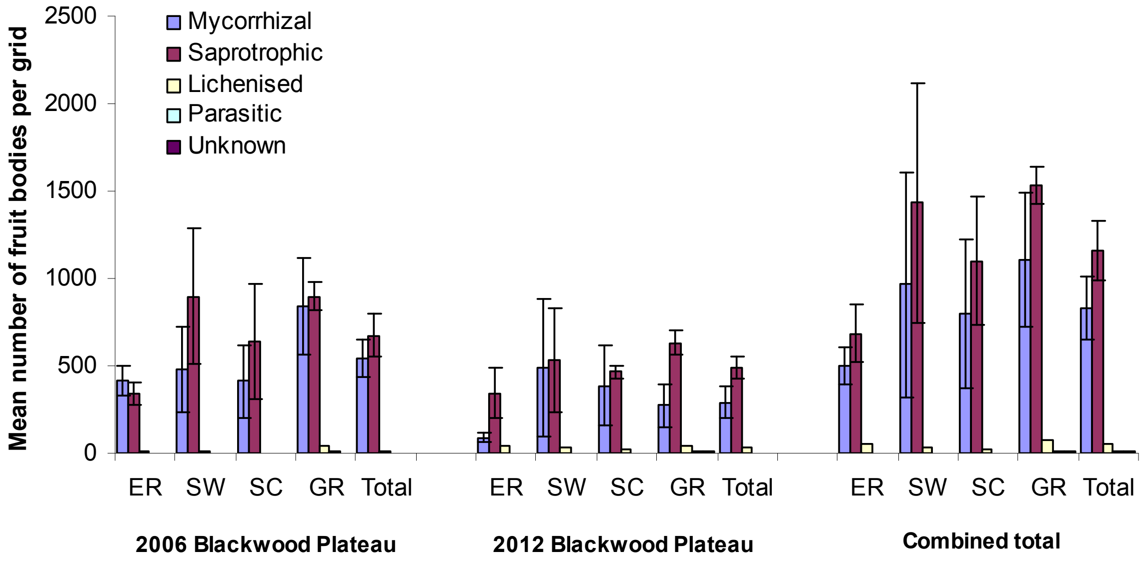

Figure 12. Mean number of mycorrhizal, saprotrophic, lichenised and parasitic macrofungal fruit bodies per grid (± se) recorded on the Blackwood Plateau FORESTCHECK grids in 2006 and 2012.

Figure 13. *Cortinarius* (*Dermocybe*) *clelandii* (left:) and *Phellodon* sp. 621 (right) were common in 2006, but not recorded in 2012.

Figure 14. *Mycena subgallericulata* (left) was prolific in 2006 but recorded in low numbers in 2012, while *Calocera guepinioides* (right) was one of the few saprotrophic species more abundant in 2012.

The reason for the low number of fruit bodies in 2012 (or conversely the high numbers in 2006) and the absence of otherwise common species is unknown, but likely associated with climate and yearly variation in fungal fruiting behaviour.

Few macrofungi are parasitic or lichenised. *Armillaria luteobubalina* (Fig. 15) is a common parasitic species found throughout jarrah forest, being more prevalent in the wetter southern regions. It infects both tree and understory species. *Licenomphalia chromacea* (Fig. 15) is a common lichenised fungus, and fruits prolifically from algal mats on either bare soil or on well-decayed wood and stumps. Both species were recorded in similar numbers in both sample years.

Figure 15. *Armillaria luteobubalina* fruit bodies (left) at the base of a dead understorey shrub and *Lichenomphalia chromacea* (right) fruiting from an algal mat on open sandy soil.

Species accumulation across all locations
The total number of species of macrofungi recorded on FORESTCHECK monitoring grids between 2002 and 2012 is 699. The number of species has steadily increased from 160 by an average of 59 species per year. The largest increase was 113 from 2006 to 2008, and the lowest was 15 from 2009 to 2010 (Fig. 16).

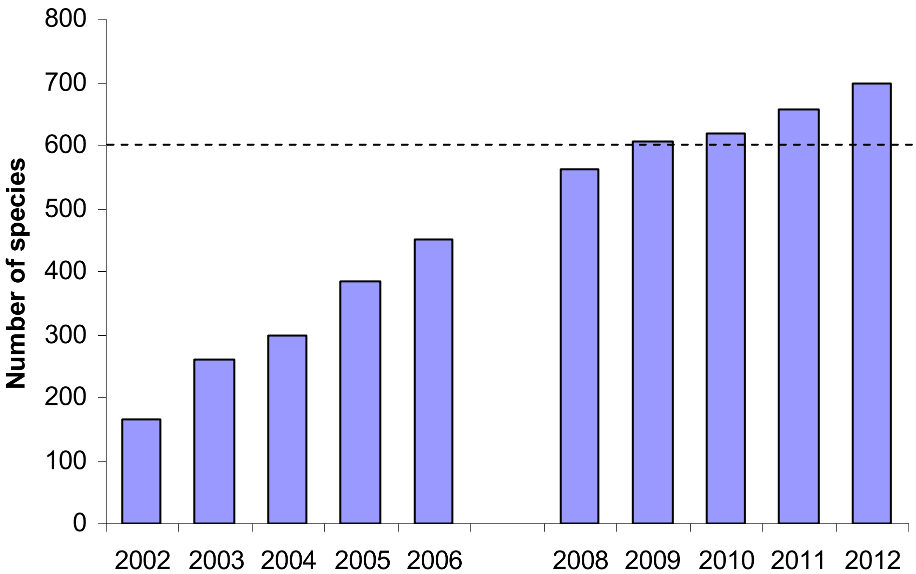

Figure 16. Species accumulation for macrofungi recorded on FORESTCHECK grids from 2002–2012.

The accumulation curve began to plateau after 2009 at about 600 species. The average annual increase from 2010–12 was about 30 species per year compared to 73 per year for the period 2002 to 2009. The average annual accumulation during the first monitoring period of

FORESTCHECK locations (2002 to 2006) was 90 species per year and 50 during the second monitoring period (2008 to 2012). In 2012, 41 new species were recorded.

The annual accumulation is closely related to survey intensity and is expected to decrease further if monitoring continues on the same grids. However, if in the future new FORESTCHECK grids are introduced at different locations in different vegetation complexes, the accumulation would be expected to increase again.

Conclusions

The main observations made following monitoring of macrofungi in the Jarrah Blackwood Plateau ecosystem in the Blackwood District were:

- A total of 699 species of macrofungi have so far been recorded in FORESTCHECK and species accumulation continues to increase.
- The Blackwood Plateau has a rich and diverse mycota, with a total of 358 species so far recorded.
- 242 species were recorded at Blackwood Plateau in 2012, similar that recorded in 2006 (250). However, only 134 species (37%) were recorded in both years. Forty one species recorded in 2012 were recorded for the first time for FORESTCHECK.
- Mean species richness per grid was lower in all treatments in 2012, with the external reference treatment having lower species richness than the gap release in both survey years.
- The abundance of fruit bodies was consistently lower in all treatments in 2012, with the overall abundance in 2012 being 1/3 less than that in 2006.
- The majority of species fruited on soil followed by litter then wood in both years, but the number of fruit bodies recorded on soil and wood was similar.
- The total number of mycorrhizal species recorded in 2012 was slightly lower than that in 2006, but the mean number of species per grid in treatments was markedly lower in 2012. Total saprotrophic species and their mean numbers of species per grid in treatments were similar in both 2006 and 2012.
- The reason for the lower abundance and absence of common mycorrhizal species from 2012 surveys is unknown, but likely related to different climatic conditions and variation in macrofungal fruiting patterns.

Acknowledgements

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References

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Robinson, R.M. 2007. Assessing the risk of fire assists fungal survey in the southwest of Western Australia. *Proceedings of the 16th Biennial Australasian Plant Pathology Society Conference. 24–27 September 2007, Adelaide, SA., p. 86*.

Appendix 1. List of macrofungi and their abundance recorded at Blackwood Plateau in 2006 and 2012.

Species number	Species name	Treatments 2012				2012	2006
		Ref	SW	SC	GR	Total	Total
0	Agaric unidentified	1		5	35	41	11
38	*Agaricus* sp. small (R.M. Robinson & R.H. Smith FC42)			2		2	
71	*Agaricus* sp. small flat red stain (R.M. Robinson & R.H. Smith FC123)			1		1	
240	*Agaricus* sp. small with red brown fibrils (R.M. Robinson & R.H. Smith FC407)				1	1	1
120	*Aleuria rhenana* Fuckel						9
126	*Aleurina ferruginea* (W. Phillips) W.Y. Zhuang & Korf				1	1	4
206	*Amanita ananiceps* (Berk.) Sacc.			6		6	1
395	*Amanita basiorubra* A.E.Wood						2
186	*Amanita brunneibulbosa* O.K.Mill.	14	2	9	6	31	11
588	*Amanita fibrillopes* O.K. Mill.		1		1	2	2
906	*Amanita* sp. ivory with yellow veil (R.M. Robinson FC1798)			5		5	
360	*Amanita* sp. large, grey white cap, no veil (R.M. Robinson & R.H. Smith FC706)			1		1	
396	Amanita sp. light brown cap, brown scales on stem (R.M. Robinson FC1797)	3				3	
903	*Amanita* sp. orange brown (R.M. Robinson FC1794)	4				4	
904	*Amanita* sp. small ivory cap, long blunt basal bulb (R.M. Robinson FC1795)	1				1	
45	*Amanita* sp. white deeply rooted (R.M. Robinson, R.H. Smith & K. Pearce FC377)						4
371	*Amanita* sp. white with saccate volva (R.M. Robinson & R.H. Smith FC741)			1		1	
519	*Amanita* sp. yellow brown cap and long stem with constricted bulb (R.M. Robinson & R.H. Smith FC960)						3
320	*Amanita* sp. yellow buff robust fruit with bulbous base (R.M. Robinson & R.H. Smith FC592)						2
925	*Amanita* sp. yellow veil (R.M. Robinson FC1857)			2		2	
531	*Amanita* spp. unidentified	9	1	4	3	17	6
196	*Amanita umbrinella* E.J.Gilbert & Cleland		1	2	1	4	2
6	*Amanita xanthocephala* (Berk.) D.A.Reid & R.N.Hilton	1	2	9	1	13	107
418	*Amylotrama* (Hysterogaster) sp. citrus (R.M. Robinson WFM153)	1				1	
629	*Amylotrama* (*Hysterogaster*) sp. yellow with olive gleba (R.M. Robinson & J. Fielder FC1190)						2
180	*Armillaria luteobubalina* Watling & Kile	1			18	19	29
188	*Austroboletus laccunosus* (Kuntze) T.W.May & A.E.Wood	2				2	2
200	*Austroboletus occidentalis* Watling & N.M.Greg.	1	3	2	4	10	7
522	*Austropaxillus* aff. *infundibuliformis* (Cleland) Bresinsky & M.Jarosch		1	1	3	5	5
179	*Austropaxillus macnabbii* (Singer, J. García & L.D. Gómez) Jarosch		2	1		3	14
291	*Austropaxillus* sp. orange-brown (R.M. Robinson, R.H. Smith & K. Pearce FC 546)						43
392a	*Banksiamyces toomansis* (Berk. & Broome) G.W. Beaton - quercifolia						37
103	*Boletellus obscurecoccineus* (Höhn.) Singer	1		7	1	9	14
29	*Boletus* sp. Boletus speciosa group - dull maroon, light stain (R.M. Robinson & R.H. Smith FC28)				1	1	1
210	*Boletus* sp. Boletus speciosa group - orange pores (R.M. Robinson, R.H. Smith & K. Pearce FC344)		1			1	
345	*Boletus* sp. light yellow (R.M. Robinson & L. McGurk FC660)						4
628	*Boletus* sp. slippery dark brown cap (R.M. Robinson & J. Fielder FC1186)						2
358	*Boletus* sp. viscid brown cap with yellow marshmallow pores NC						1
607	*Boletus* sp. yellow brown, stains blue (R.M. Robinson & J. Fielder FC1102)				1	1	
99	*Boletus* sp. yellow red with blue staining flesh (R.M. Robinson & R.H. Smith FC398)			1	3	4	13
304	*Byssomerulius corium* (Pers. : Fr.) Parmasto				19	19	
9	*Calocera guepinioides* Berk.	38	366	401	179	984	557
187	*Campanella gregaria* Bougher	100		25		125	72
319	*Clavaria* (?*Clavulinopsis*) sp. grey brown with black tips (R.M. Robinson & R.H. Smith FC758)			6		6	7
81	*Clavulina* aff. *cinerea* (Bull. : Fr.) J.Schröt.						1
344	*Clavulina* sp. cream, fluffy tips (R.M. Robinson & L. McGurk FC658)	2			9	11	

Species number	Species name	Treatments 2012				2012	2006
		Ref	SW	SC	GR	Total	Total
143	*Clitocybe* aff. *clitocyboides* (Cooke & Massee) Pegler				1	1	
15	*Coltricia cinnamomea* (Jacq.) Murrill	15	53	76	37	181	249
532	*Coltriciella dependens* (Berk. & M.A.Curtis) Murrill	12	35	16	8	71	72
662	*Coprinus* sp. mealy scaled cap (on burnt soil)'NC		1			1	
899	Corticioid. Black rubbery skin. (R.M. Robinson FC1786)		5			5	
921	Corticioid. Burnt orange powdery skin (R.M. Robinson FC1819)		9		2	11	
615	Corticioid. Creamy grey maze (R.M. Robinson FC1134)				4	4	
623	Corticioid. Creamy pimpled resupinate skin with orange margin and attachment (R.M. Robinson & J. Fielder FC1160)						1
718	Corticioid. Creamy yellow lumpy skin (R.M. Robinson FC1778)		8			8	
835	Corticioid. Grey fluff (R.M. Robinson & K. Syme FC1632)	7				7	
838	Corticioid. Olive grey (R.M. Robinson FC1642)				5	5	
593	Corticioid. Pinkish beige skin (R.M. Robinson & J. Fielder FC1067)						40
923	Corticioid. Pinkish beige, pruniose (R.M. Robinson FC1845)	4				4	
901	Corticioid. Pinkish orange waxy crust (R.M. Robinson FC1788)	8	12	4		24	
683	Corticioid. Thin creamy maze BFF0066 (Sp. 454a) FC1250				5	5	
582	Corticioid. White parchment (R.M. Robinson & J. Fielder FC1047)		4			4	3
158	*Cortinarius* aff. *microarcherii* Cleland	5				5	
314	*Cortinarius archerii* Berk.				1	1	13
115	*Cortinarius austrofibrillosa* Grgur.			1		1	40
173a	*Cortinarius basirubescens* Cleland & J.R.Harris (red cap)	2	4		2	8	18
173b	*Cortinarius basirubescens* Cleland & J.R.Harris (brown cap)						92
357	*Cortinarius sinapicolor* Cleland	6	4	4	1	15	23
234	*Cortinarius* sp. yellow tan (R.M. Robinson, R.H. Smith & K. Pearce FC393)				3	3	
68	*Cortinarius* sp. brown (R.M. Robinson & R.H. Smith FC79)						69
355	*Cortinarius* sp. brown cap with lavender margin and stem (R.M. Robinson & R.H. Smith FC699)						1
421	*Cortinarius* sp. brown cap with lilac white stem (R.M. Robinson & J. Fielder FC1095)						72
279	*Cortinarius* sp. brown fibrillose (R.M. Robinson, R.H. Smith & K. Pearce FC521)						6
244	*Cortinarius* sp. brown umbonate (R.M. Robinson & R.H. Smith FC416)						100
73	*Cortinarius* sp. brown with purplish tints (R.M. Robinson & R.H. Smith FC434)						4
466	*Cortinarius* sp. brown with white margin (R.M. Robinson, R.H. Smith & K. Syme FC835)						1
154	*Cortinarius* sp. chestnut (R.M. Robinson & J. Fielder FC 1050)		1	7	2	10	161
382	*Cortinarius* sp. chestnut cap with yellow margin and yellow flesh (R.M. Robinson & R.H. Smith FC774)						1
500	*Cortinarius* sp. chestnut large (R.M. Robinson & R.H. Smith FC918)						19
299	*Cortinarius* sp. chocolate brown with mustard gills (R.M. Robinson & K. Pearce FC578)						6
201	*Cortinarius* sp. cream cap with orange gills (R.M. Robinson FC327)	2			2	4	
878	*Cortinarius* sp. creamy yellow fibrillose cap, white bulbous stem (R.M. Robinson FC1743)			1		1	
840	*Cortinarius* sp. creamy yellow, long stem (R.M. Robinson FC1652)			2		2	
922	*Cortinarius* sp. dark brown cap, brown gills, white fibrilose stem (R.M. Robinson & N. Rea FC1840)	9				9	
453	*Cortinarius* sp. decurrent gills and deep stem with double ring (R.M. Robinson, R.H. Smith & K. Syme FC790)				1	1	
611	*Cortinarius* sp. dry, purple grey (R.M.Robinson & J.C.Fielder FC1130)		2			2	
374	*Cortinarius* sp. golden tan (R.M. Robinson & R.H. Smith FC748)						4
348	*Cortinarius* sp. golden tan cap with long stem (R.M. Robinson & J.E.Neal FC669)						5
293	*Cortinarius* sp. grey blue, myxacium (R.M. Robinson, R.H. Smith & K. Pearce FC550)				5	5	
257	*Cortinarius* sp. honey brown (R.M. Robinson & R.H. Smith FC454)				2	2	
146	*Cortinarius* sp. Myxacium orange-brown viscid cap (R.M. Robinson & R.H. Smith FC223)	1				1	14
223	*Cortinarius* sp. orange (R.M. Robinson & J. Fielder FC1187)						31
223	*Cortinarius* sp. orange (R.M. Robinson & J.Fielder FC1016)						3
212	*Cortinarius* sp. orange brown (R.M. Robinson, R.H. Smith & K.						14

Species number	Species name	Treatments 2012				2012	2006
		Ref	SW	SC	GR	Total	Total
	Pearce FC371)						
205	*Cortinarius* sp. orange cap with yellow flesh and yellow gills (R.M. Robinson FC331)						2
596	*Cortinarius* sp. pink brown cap with apressed fibrils (R.M. Robinson & J. Fielder FC1052)						3
98	*Cortinarius* sp. pointy cap (R.M. Robinson & R.H. Smith FC134)	1	3	6		10	40
888	*Cortinarius* sp. purple brown cap, lavender stem (R.M. Robinson FC1747)		1			1	
627	*Cortinarius* sp. purple brown with glutinous stem (R.M. Robinson & J. Fielder FC1183)						30
515	*Cortinarius* sp. red brown cap with slender lavender stem (R.M. Robinson, R.H. Smith & K. Syme FC952)			1		1	
626	*Cortinarius* sp. red brown pointy cap (R.M. Robinson & J. Fielder FC1181)	14				14	250
670	*Cortinarius* sp. small fibrillose in moss (R.M. Robinson & J. Fielder BFF 84)				3	3	
609	*Cortinarius* sp. small purple umbonate cap (R.M. Robinson & J. Fielder FC1114)						2
673	*Cortinarius* sp. small red-brown with tan margin (R.M. Robinson BFF117)	2	2			4	
267	*Cortinarius* sp. snowy chestnut (R.M. Robinson & R.H. Smith FC478)				1	1	24
432	*Cortinarius* sp. tan cap with chocolate gills (R.M. Robinson & K. Syme WFM110)						13
897	*Cortinarius* sp. tan cap, pale violet stem (R.M. Robinson FC1776)		10			10	
171b	*Cortinarius* sp. vinaceous lilac (R.M. Robinson, R.H. Smith & K. Pearce FC543)	7				7	54
270	*Cortinarius* sp. viscid red brown cap with white stem (R.M. Robinson & R.H. Smith FC482)	1				1	1
273	*Cortinarius* sp. white with deep rooting stem (R.M. Robinson, R.H. Smith & K. Pearce FC498)	2		4		6	
231	*Cortinarius* sp. yellow brown cap with tan margin (R.M. Robinson & R.H. Smith FC389)			2	1	3	
237	*Cortinarius* sp. yellow with orange brown fibrils (R.M. Robinson & R.H. Smith FC403)	4			1	5	
354	*Cortinarius* sp. yellow-brown cap with lavender gills and stem (R.M. Robinson & R.H. Smith FC698)						3
184	*Cortinarius* spp. (unidentified)	12	1	16	5	34	62
7	*Cortinarius sublargus* Cleland			11		11	1
584	*Cortinarius symeae* (Bougher, Fuhrer & E.Horak) Peintner			1		1	9
147	*Cortinarius* (*Dermocybe*) *austroveneta* (Cleland) M.M.Moser & E.Horak						2
172a	*Cortinarius (Dermocybe) clelandii* (A.H.Sm.) Grgur. - yellow mycelium						12
172b	*Cortinarius (Dermocybe) clelandii* (A.H.Sm.) Grgur.- yellow mycelium - glutinous cap						9
340	*Cortinarius (Dermocybe) clelandii* (A.H.Sm.) Grgur. - mini						20
57	*Cortinarius (Dermocybe) clelandii* (A.H.Sm.) Grgur. - white mycelium)						65
809	*Cortinarius (Dermocybe) globiformis* (Bougher) Bougher & Trappe	1				1	
110	*Cortinarius (Dermocybe) kula* Grgur.						1
168	*Cortinarius (Dermocybe)* sp. jarrah (R.M. Robinson & R.H. Smith FC301)	2	4	13	2	21	143
124	*Cortinarius (Dermocybe)* sp. yellow-olive (R.M. Robinson & R.H. Smith FC182)						3
16	*Cotylidia undulata* (Fr.) P. Karst.						50
118	*Crepidotus nephrodes* (Berk. & M.A.Curtis) Sacc.		8	4	8	20	11
323	*Crepidotus* sp. rusty brown suede (R.M. Robinson & L. McGurk FC599) - *C. eucalyptica*?						1
83	*Crepidotus* sp. small creamy tan (R.M. Robinson & R.H. Smith FC99)			1		1	
21	*Crepidotus* sp. small white NC			6		6	23
686	*Crepidotus* sp. white gelatinised (R.M. Robinson FC1239)		2			2	
241	*Crepidotus variabilis* (Pers. : Fr.) P.Kumm.			7	102	109	8
148	*Crucibulum laeve* (Huds. : Pers.) Kambly	28		40		68	19
307	*Cyathus* sp. (R.M. Robinson & K. Pearce FC591)						5
289	*Dacrymyces capitatus* Schwein.			12		12	
123	*Discinella terrestris* (Berk. & Broome) Denni	42	24	53	300	419	358
622	*Discinella terrestris* (Berk. & Broome) Denni -white form (R.M. Robinson & R. Wittkuhn BFF107)*						1
243	Discomycete orange discs on marri nuts (R.M. Robinson & R.H.						13

Species number	Species name	Treatments 2012				2012	2006
		Ref	SW	SC	GR	Total	Total
	Smith FC798)						
294	Discomycete small yellow on *Banksia grandis* leaves (R.M. Robinson, R.H. Smith & K. Pearce FC557)			78		78	
902	Discomycete. Yellow ornamented (R.M. Robinson 1773)				32	32	
31	*Entoloma moongum* Grgur.			1	1	2	10
792	*Entoloma* sp. (R.M. Robinson FC1450)			1	1	2	
410	*Entoloma* sp. blue-black, marginate gills (R.M. Robinson & K. Syme WFM53)						6
198	*Entoloma* sp. brown black cap tan gills blue stem (R.M. Robinson FC323)						4
222	*Entoloma* sp. brown black with grey white gills (R.M. Robinson, R.H. Smith & K. Pearce FC374)						2
861	*Entoloma* sp. brown dimpled, tan gills, light brown stem (R.M. Robinson, K.Syme & P.Anderson WFM652)			2	3	5	
30	*Entoloma* sp. creamy white (R.M. Robinson & R.H. Smith FC29)				1	1	24
167	*Entoloma* sp. dark grey cap with blue gill edge (R.M. Robinson & R.H. Smith FC410)						3
235	*Entoloma* sp. grey brown cap with grey stem (R.M. Robinson & R.H. Smith FC399) = Sp. 194		1	7		8	1
272	*Entoloma* sp. grey brown with dimple (R.M. Robinson, R.H. Smith & K. Pearce FC497)						3
77	*Entoloma* sp. grey-brown with brown stem (R.M. Robinson & R.H. Smith FC92)						1
25	*Entoloma* sp. grey-brown/blue stem (R.M. Robinson & R.H. Smith FC23)						2
583	*Entoloma* sp. khaki brown cap with white stem (R.M. Robinson & J. Fielder FC1025)						6
78	*Entoloma* sp. olive-brown with decurrent gills (R.M. Robinson & R.H. Smith FC93)						2
153	*Entoloma* sp. small dark grey-brown (R.M. Robinson & R.H. Smith FC242)			1		1	
278	*Entoloma* sp. suede grey brown cap with dimple (R.M. Robinson, R.H. Smith & K. Syme FC996)			1		1	
606	*Entoloma* sp. Tall velvet grey brown cap (R.M. Robinson & J. Fielder FC1100)			5	4	9	
589	*Entoloma* sp. tall grey conical (R.M. Robinson & J. Fielder FC1042)						8
135	*Entoloma* sp. tall, grey-brown (R.M. Robinson & R.H. Smith FC207)			1		1	17
274	*Entoloma viridomarginatum* (Cleland) E.Horak						1
159	*Exidia glandulosus* (Bull. : Fr.) Fr.						100
41	*Fistulina spiculifera* (Cooke) D.A.Reid	1	3	5		9	8
91	*Fistulinella mollis* Watling			2		2	
19	*Fomitopsis lilacinogilva* (Berk.) J.E.Wright & J.R.Deschamps				9	9	12
136	*Fuscoporia gilva* (Schwein.) T.Wagner & M.Fisch.		10	6	12	28	1
11	*Galerina* sp. hanging gills and conic (R.M. Robinson & R.H. Smith FC11)	14	168	115	102	399	291
58	*Galerina* sp. small cap, eccentric stipe - on wood (R.M. Robinson & R.H. Smith FC63)	20	15	38	149	222	131
630	*Galerina* sp. tiny tan (R.M. Robinson & J. Fielder FC1192)		25		16	41	30
442	*Geopora* (*Sepultaria*) sp. hollow spheres (R.M. Robinson WFM126)	6				6	
919	*Glonium circumserpens* (Nyl.) Kantvilas & Coppins		26	50		76	
8	*Gymnopilus allantopus* (Berk.) Pegler	158	164	74	201	597	658
690	*Gymnopilus ferruginosus* B.J.Rees	1				1	
900	*Gymnopilus* sp. chestnut with yellow pale margin (R.M. Robinson FC1782)			1	3	4	
591	*Gymnopilus* sp. purple maroon (R.M. Robinson & J. Fielder FC1078)						2
85	*Gymnopilus* sp. slender (R.M. Robinson & R.H. Smith FC110)	236	87	204	126	653	1112
633	*Gymnopus dryophilus* (Bull. : Fr.) Murrill		1			1	1
292	*Gyroporus variabilis* sensu Bougher & Syme						2
600	*Hebeloma aminophilum* R.N.Hilton & O.K.Mill.						32
96	*Hebeloma* sp. viscid pink (R.M. Robinson & R.H. Smith FC457)						3
433	*Hebeloma westraliensis* Bougher, Tommerup & Malajczuk	5				5	
821	*Henningsomyces* sp. White (R.M. Robinson & K. Syme WFM541)				3	3	
56	*Heterotextus peziziformis* (Berk.) Lloyd	19	35	45	41	140	27
422	*Hohenbuehelia atrocaerulea* (Fr. : Fr.) Singer			3	10	13	8
87	*Hydnellum* sp. red brown (R.M. Robinson & R.H. Smith FC113)						32

Species number	Species name	Treatments 2012				2012	2006
		Ref	SW	SC	GR	Total	Total
539	Hydnoid. Creamy white toothed resupinate (R.M. Robinson & K. Syme WFM160)						1
297	*Hydnum repandum* L. : Fr.						31
924	*Hygrocybe* aff. *graminicolor* (R.M. Robinson FC1851)				3	3	
317	*Hygrocybe conica* (Schaeff. : Fr.) P.Kumm.						2
445	*Hygrocybe polychroma* Bougher & A.M.Young						12
599	*Hygrocybe* sp. olive yellow (R.M. Robinson & J. Fielder FC1058)						5
732	*Hygrocybe* sp. pallid with orange stem (R.M. Robinson FC1426)		2	1		3	
631	*Hygrocybe* sp. Yellow orange with orange stem (R.M. Robinson FC1835)	7	1			8	6
122	*Hygrocybe* sp. yellow-orange (R.M. Robinson & R.H. Smith FC858)						5
416	*Hymenochaete semistupposa* Petch						3
758	*Hymenochaete* sp. brown with yellow margin (R.MN. Robinson WFM421)				6	6	
691	*Hyphodontia barba-jovis* (Bull.) J. Erikss.		4		10	14	
895	*Hyphodontia* sp. tower teeth (R.M. Robinson FC1037b)	18	4		4	26	
100	*Hypholoma australe* O.K.Mill.						186
595	*Hypholoma* sp. (R.M. Robinson & J. Fielder FC 1049) - *H sublateritium* (Fr.) Quél.						61
108	*Hypomyces chrysospermus* Tul. & C. Tul.						16
592	*Hysterangium* sp. olive gleba (R.M. Robinson & J. Fielder FC1077)			2		2	18
1	*Inocybe australiensis* Cleland & Cheel	37	67	64	60	228	266
398	*Inocybe* fibrillosibrunnea O.K. Mill. & R.N. Hilton			1		1	
487	*Inocybe* sp. brown fibrillose cap with yellow gills (R.M. Robinson, R.H. Smith & K. Syme FC883)				1	1	2
48	*Inocybe* sp. grey (R.M. Robinson & R.H. Smith FC52)	3	14	65	28	110	48
65	*Inocybe* sp. large scaly cap (R.M. Robinson & R.H. Smith FC74)			1		1	
484	*Inocybe* sp. large umbonate firillosecap with yellow-tan gills (R.M. Robinson, R.H. Smith & K. Syme FC880)						6
226	*Inocybe* sp. orange brown (R.M. Robinson & R.H. Smith FC375) - no cystidia		1			1	
20	*Inocybe* sp. scaly cap (R.M. Robinson, R.H. Smith & K. Pearce FC334)						61
790	*Inocybe* sp. scaly orange brown cap, pink stem (R.M. Robinson & K. Syme WFM379)			2		2	
53	*Inocybe* sp. tan skirt (R.M. Robinson & R.H. Smith FC60)						26
286	*Inocybe* sp. umbonate, shaggy (R.M. Robinson & K. Pearce FC576)	1				1	4
74	*Laccaria* aff. *masoniae* G.Stev.	20	353	347	347	1067	1844
36	*Laccaria lateritia* Malençon	6		1		7	146
765	*Laccaria* sp. burnt orange (R.M. Robinson, K. Syme & J. Mccalmont WFM460)			4		4	
221	*Lactarius clarkeae* Cleland		2	1	3	6	3
142	*Lactarius eucalypti* O.K.Mill. & R.N.Hilton	4		5	9	18	34
245	*Lactarius* sp. creamy yellow (R.M. Robinson & R.H. Smith FC417)	3	6	3	3	15	4
185	*Lepiota* aff. *cristata* (Alb. & Schwein. : Fr.) P.Kumm.				3	3	4
735	*Lepiota* sp. amber drops (R.M. Robinson FC1398)	4		1		5	
862	*Lepiota* sp. creamy brown with ring (R.M. Robinson, K.Syme & P.Anderson WFM597)	4	2	8	5	19	
884	*Lepiota* sp. creamy brown with scaly stem (R.M. Robinson FC1721)		3	3	3	9	
264	*Lepiota* sp. creamy grey (R.M. Robinson & R.H. Smith FC471)	2	4	1	2	9	5
246	*Lepiota* sp. purple grey (R.M. Robinson & R.H. Smith FC419)				1	1	2
728	*Lepiota* sp. red-brown (R.M. Robinson & K. Syme FC1337)		1			1	
166	*Lepiota subcristata* Cleland			1		1	33
112	*Lichenomphalia chromacea* (Cleland) Redhead, Lutzoni, Moncalvo & Vilgalys	135	22	46	58	261	102
461	*Lichenomphalia* sp. dull yellow (R.M. Robinson & F. Tovar FC1347)						1
127	*Lichenomphalia umbellifera* (L.) Redhead, Lutzoni, Moncalvo & Vilgalys		32	19	44	95	72
425	*Lichenomphalia*sp. salmon pink (R.M. Robinson, K.S. Syme & J. Fielder WFM332)				15	15	
24	*Lycoperdon* sp. (R.M. Robinson & R.H. Smith FC22)	4	64	81	39	188	72
318	*Marasmellis* sp. small white cap on twigs and leaves (R.M. Robinson & J.E.Neal FC667)						29

Species number	Species name	Treatments 2012				2012	2006
		Ref	SW	SC	GR	Total	Total
55	*Marasmius crinisequi* F.Muell.		3	2		5	6
309	*Marasmius* sp. 223 (R.M. Robinson FF664)				1	1	41
443	*Marasmius* sp. tan (R.M. Robinson FF770, WFM129)			2		2	21
22	*Melanotus hepatochrous* (Berk.) Singer			6		6	8
643	*Merulius* (?*Phlebia*) sp. on leaves (R.M. Robinson BFF0039)	8				8	
64	*Mycena adscendens* (Lasch) Maas. Geest.						7
477	*Mycena* aff. *adonis* (Bull.) Gray				2	2	3
44	*Mycena* aff. *atrata* Grgur. & A.A.Holland. ex Grgur.	1			2	3	
327	*Mycena* aff. *maldea* Grgur.				1	1	5
134	*Mycena albidocapillaris* Grgur. & T.W.May		2	2	8	12	25
80	*Mycena carmeliana* Grgur.	13	21	47	143	224	165
312	*Mycena fuhreri* Grgur.	1			7	8	1
144	*Mycena kuurkaceae*Grgur.		5	10	4	19	151
50	*Mycena mijoi* Grgur.		1	2	7	10	10
66	*Mycena pura* (Pers. : Fr.) P.Kumm.		3	1	2	6	
523	*Mycena* sp. brown striate cap with dark umbo (R.M. Robinson & R.H. Smith FC966)			21	47	68	
308	*Mycena* sp. grey brown cap no bleach (R.M. Robinson & J. Fielder FC1038)		3	4	2	9	55
590	*Mycena* sp. grey brown with creamy brown margin (R.M. Robinson & J. Fielder FC1068)						2
565	*Mycena* sp. red gills (R.M. Robinson & K. Syme WFM374)	12				12	1
295	*Mycena* sp. small buff (R.M. Robinson & K. Pearce FC558)		2			2	
165	*Mycena* sp. small grey - bleach (R.M. Robinson & R.H. Smith FC394)	1		1	4	6	3
386	*Mycena* sp. tiny white sticky cap (R.M. Robinson & K. Syme WFM6 & WFM305)			14		14	7
88	*Mycena* sp. tiny white with decurrent gills (R.M. Robinson & R.H. Smith FF61)				18	18	17
182	*Mycena* spp. (unidentified)		2	2	2	6	9
163	*Mycena subgallericulata* Cleland	84	17	95	30	226	1065
51	*Mycena yirukensis* Grgur.	8	53	8	25	94	505
238	*Mycena yuulongicola* Grgur.	3			15	18	8
510	*Mycoacia subceracea* (Wakef.) G.Cunn.						1
413	*Nidularia deformis* (Willd. : Pers.) Fr.						8
535	*Nothojafnea cryptotricha* Rifai				4	4	35
601	*Octavianina* sp. orange (R.M. Robinson & J. Fielder FC1086)						4
213	*Omphalotus nidiformis* (Berk.) O.K.Mill.		3	1		4	
558	*Paecilomyces tenuipes* (Peck) Samson						1
104	*Panellus ligulatus* E.Horak						23
311	*Panus fasciatus* (Berk.) Pegler			2		2	3
393	*Perenniporia ochroleuca* (Berk.) Ryvarden				1	1	
455	*Peziza* sp. brown (R.M. Robinson & R.H. Smith FC799)						1
524	*Peziza thozetii* Berk.			1		1	1
598	*Phaeocollybia tasmanica* B.J.Rees & A.E.Wood						7
37	*Phellinus* sp. yellow rim (R.M. Robinson, R.H. Smith & K. Pearce FC515)						6
70	*Phellodon* aff. *niger* (Fr. : Fr.) P.Karst.						17
84	*Phellodon* sp. black slender (R.M. Robinson & J. Fielder FC1189)						149
621	*Phellodon* sp. black with silvery margin and brown grey spines (R.M. Robinson & J. Fielder FC1159)						137
479	*Phellodon* sp. black, brown spines (R.M. Robinson & R.H. Smith FC844)			1	13	14	118
435	*Phellodon* sp. brown (R.M. Robinson, R.H. Smith & K. Syme FC827)						2
634	*Phellodon* sp. flimsy silver grey (R.M. Robinson & J. Fielder FC1204)						1
101a	*Phlebia rufa* (Pers. : Fr.) M.P.Christ.	15	2			17	
160b	*Pholiota communis*(Cleland & Cheel) Grgur.			4		4	67
160a	*Pholiota highlandensis* (Peck) Quadr.	17	44	18	12	91	700
119	*Pholiota multicingulata* E.Horak	1	14	17	21	53	69
401	*Pisolithus mamoratus* (Berk.) E.Fisch.						2

Species number	Species name	Treatments 2012				2012	2006
		Ref	SW	SC	GR	Total	Total
469	*Pleuroflammula* sp. chestnut with fringed margin (R.M. Robinson FC842)		2			2	
133	*Pluteus atromarginatus* (Konrad) Kühner						5
47b	*Pluteus lutescens* (Fr.) Bres. - yellow green		2		1	3	4
585	Polypore white floccose resupinate (R.M. Robinson & J. Fielder FC1027)			3		3	10
783	Polypore white resupinate under burnt wood (R.M. Robinson, K. Syme FC1493)	4	7	8	24	43	
3	Polypore. Long white shelf (R.M. Robinson & R.H. Smith FC3)						1
896	Polypore. Thin creamy orange white resupinate (R.M. Robinson FC1774)				3	3	
668	Polypore. White resupinate with yellow margin (R.M. Robinson BFF 83)		3			3	
783	Polypore. White resupinateunder burnt wood (R.M. Robinson FC1787)	3				3	
145	*Poronia erici* Lohmeyer & Benkert				1	1	
632	*Porostereum crassum* (Lév.) Hjortstam & Ryvarden						1
236	*Postia peliculosa* (Berk.) Rajchenb.		2	1	1	4	2
155	*Protubera canescens* G.W.Beaton & Malajczuk		1			1	
59	*Psathyrella echinata* (Cleland) Grgur.				47	47	59
17	*Psathyrella* sp. (R.M. Robinson & R.H. Smith FC15)						3
177	*Psilocybe coprophila* (Bull. : Fr.) P.Kumm.	22	3	21	5	51	49
349	*Psilocybe musci* Cleland & Cheel				3	3	1
129	*Pulvinula tetraspora* (Hansf.) Rifai						54
176	*Pycnoporus coccineus* (Fr.) Bondartsev & Singer	88		52	47	187	125
52a	*Ramaria capitata* (Lloyd) Corner			5		5	1
52b	*Ramaria capitata* (Lloyd) Corner - burnt ground						116
247	*Ramaria citrinocuspidata* A.M. Young & N.A. Fechner						6
377	*Ramaria lorithamnus* (Berk.) R.H.Petersen		1	4	3	8	10
102	*Ramaria ochroceosalmonicolor* (Cleland) Corner	2	5	19	3	29	68
242	*Ramaria* sp. cream (R.M. Robinson & R.H. Smith FC414)				4	4	
86	*Ramaria* sp. orange-red with yellow stem (R.M. Robinson & R.H. Smith FC112)	2				2	5
767	*Ramaria* sp. yellow flat (burnt ground) (R.M. Robinson, K. Syme & J. Mccalmont WFM464)		3	1		4	
79	*Resupinatus cinerascens* (Cleland) Grgur.						25
258	*Rhizopogon* sp. sticky (R.M. Robinson FC258)		1			1	
181	*Rhodocollybia butyracea* (Bull. : Fr.) Lennox		1	1		2	2
811	*Rhodocybe* sp. grey with decurrent gills R.M. Robinson & K. Syme WFM508)	1	2		1	4	
209	*Rickenella fibula* (Bull. & Vent. : Fr.) Raithelh.		2			2	8
305	*Rubinoboletus phaseolisporus* T.-H. Li, R.N. Hilton & Watling [*Tylopilus* sp. yellow (R.M. Robinson & J. Fielder FC1015)]				2	2	32
69	*Russula adusta* (Pers. : Fr.) Fr.			1	2	3	1
90	*Russula* aff. *cyanoxantha* creamy grey-green (R.M. Robinson FC1565)		1			1	
89	*Russula clelandii* complex O.K.Mill. & R.N.Hilton		3	4	3	10	17
202	*Russula flocktoniae* Cleland & Cheel		2		2	4	7
90	*Russula kalimna* Grgur.	1				1	1
92	*Russula neerimea* Grgur.	2	2			4	14
178	*Russula persanguinea* Cleland			2		2	
559	*Russula* sp. peaches and cream (R.M. Robinson & K. Syme WFM186)						1
276	*Russula* sp. purple mottled (R.M. Robinson, R.H. Smith & K. Pearce FC505)						1
10b	*Russula* sp. small white (R.M. Robinson RR921WA)		4			4	
10a	*Russula* sp. white (R.M. Robinson & R.H. Smith FC8)	2			1	3	14
150	*Scutellinia* aff. m*argaritacea* (Berk.) Kuntze (*sensu* Bougher & Syme)						35
12	*Simocybe tabacina* E. Horak		23		29	52	6
306	*Sphaerobolus stellatus* Tode : Pers.			20		20	
132	*Steccherinum* sp. creamy yellow crust (R.M. Robinson & J. Fielder FC1080)						2

Species number	Species name	Treatments 2012				2012	2006
		Ref	SW	SC	GR	Total	Total
94	*Steccherinum* sp. tiered white shelves (R.M. Robinson & R.H. Smith FC128)						25
62	*Stereum hirsutum* (Willd. : Fr.) Pers.	15	64	65	104	248	180
149	*Stereum illudens* Berk. - brown hymenium		5		25	30	45
773	*Stereum* sp. black with purple brown merulioid hymenium (R.M. Robinson, K. Syme FC1458)		62		1	63	
5	*Stereum* sp. grey brown, hirsute, white margin, purple hymenium (R.M. Robinson & R.H. Smith FC468)		1			1	
67	*Stropharia semiglobata* (Batsch : Fr.) Quél.		2	4	5	11	20
537	*Tephrocybe* sp. (R.M. Robinson & K. Syme WFM158)			11		11	
587	*Tephrocybe* sp. dark brown with grey brown gills (R.M. Robinson & J. Fielder FC1036)				3	3	30
513	*Tephrocybe* sp. dark grey brown convex (R.M. Robinson, R.H. Smith & K. Syme FC948)						2
301	*Tephrocybe* sp. dark grey with dimpled cap (R.M. Robinson & K. Pearce FC580)						1
512	*Tephrocybe* sp. small grey brown (R.M. Robinson, R.H. Smith & K. Syme FC945)						1
549	*Thelephora* sp. small rosette (R.M. Robinson & K. Syme WFM176)						1
266	*Thelephora* sp. white with orange margin (R.M. Robinson & R.H. Smith FC476)		10	10	13	33	51
586	Thelephore brown feathers (R.M. Robinson & J. Fielder FC1034)						1
63	*Trametes versicolor* (L. : Fr.) Lloyd		1	4		5	20
287	*Tremella globispora* D.A.Reid		8	30	15	53	105
685	*Tremella globispora* D.A.Reid - translucent white (R.M. Robinson FC1231)			10		10	
60	*Tremella mesenterica* Retz. : Fr.				1	1	
109	*Trichaptum byssogenum* (Jungh.) Ryvarden				10	10	1
54	*Tricholoma eucalypticum* A.Pearson	3	1	5		9	
594	*Tricholoma* sp. creamy brown (R.M. Robinson & J. Fielder FC1063)						1
733	*Tricholoma* sp. olive green (R.M. Robinson & R.S. Wittkuhn FC 1427)				1	1	
375	*Tricholoma* sp. orange cap with orange ring on stem (R.M. Robinson & R.H. Smith FC 753)						10
161	*Tricholoma virgatum* (Fr.) Gillet				1	1	2
910	Unknown thelephore. Plant snot (R.M. Robinson & P. Anderson WFM712)	8				8	
905	Unknown. Pink coral-like mycelium on marri nuts (R.M. Robinson FC1796)	53				53	
2	*Xerula mundroola* (Grgur.) R.H.Petersen		3		1	4	3
	Total species	87	104	128	134	242	250
	Total fruit bodies	1444	2092	2618	2882	9036	13578

CRYPTOGAMS

Ray Cranfield, Richard Robinson and Verna Tunsell

Introduction

Lichens, mosses and liverworts are collectively known as cryptogams. Some species of lichens are important indicators of ecosystem health, being sensitive to changes and disturbance in the environment in which they grow. Many colonise primary substrates such as rocks and decaying organic matter and are active in the initial breakdown of these materials. Mosses also play an important role in the stabilisation of bare soil. Lichens, mosses and liverworts are a major component of the biodiversity of forest ecosystems, and most species in Western Australia have poorly known distributions and many are yet to be named.

The object of this component of FORESTCHECK is to:

- record species richness and abundance in each FORESTCHECK grid and treatment
- record species habitat and substrate preference
- monitor the effect of disturbance on cryptogam communities
- record the presence of 35 monitoring (or indicator) species
- determine successional trends in communities and life-forms.

Additional information is collected to:

- monitor the availability and usage of suitable substrates and strata levels
- determine the relationship of cryptogam presence with litter cover

Monitoring

Eleven FORESTCHECK grids, including three external reference (FC38, FC39, FC40) two shelterwood (FC41, FC42), three gap release (FC46, FC47, FC48) and three selective cut (FC43, FC44 & FC45) grids, were established in the Blackwood Plateau jarrah forest ecosystem in the Blackwood District in 2005. All the grids were initially surveyed for cryptogams in spring 2005. They were surveyed again in spring 2011 and the results are presented in this report. Since the previous measurements (2005) the Butler selective cut (FC45) and Layman external reference (FC40) grids were burnt by prescribed fire in spring 2010.

Following a review of survey methods outlined in the FORESTCHECK Operating Plan, updated survey methods are described in the FORESTCHECK Report of Progress 2007–08 (available from www.dec.wa.gov.au). Briefly, the presence of 35 selected monitoring species, the total number of cryptogam species and life-forms present and the presence and use of substrates and strata are assessed in 20 1x1 m plots along a 200 m transect. To assess the impact of litter coverage on cryptogams, litter cover was also scored as either none, scarce (0-25% coverage), moderate (26-75% coverage) or dense (>75% coverage) in each 1x1m plot. The presence of all cryptogam species is also recorded in each 50 m section of a separate 400m transect (updated from 200 m used prior to 2010–11), which extends around the perimeter of the central 1 ha area of each monitoring grid (see grid layout on p. 5). An illustrated field guide featuring monitoring species was used to facilitate the recognition of species encountered.

Voucher Specimen Processing

Voucher collections were extensively gathered during the 2005 survey. In 2011, voucher specimens were restricted to a small number of samples needed to verify species identifications and to voucher new species records. All specimens collected in 2011 have been identified to species or given informal field names. Advances in identification, and re-examination of previously collected specimens has resulted in name changes for a number of species which required updating in the FORESTCHECK and Western Australian Herbarium databases. All new collections have been prepared for database entry and label generation prior to submitting these vouchers to the Western Australian Herbarium.

Results and Discussion

Previous surveys were conducted in September 2005. The 2011 Blackwood Plateau jarrah survey was conducted in the spring over the period 4 August to 1 September. Generally cryptogams grow in wetter months but their persistent nature allows their continued presence over extended periods throughout the year, independent of rain. Although fragile when desiccated, and easily damaged, they are still readily recognised. However when making comparisons between the 2005 and 2011 survey, it needs to be noted that methods were reviewed and modified in 2007 (see FORESTCHECK Report of Progress 2007–08).

Transect surveys

Species richness

A total of 71 species of cryptogams were recorded from transects in 2011; 55 lichens, 10 mosses and six liverworts. Lichens were the most common group on all grids. There were generally more lichens recorded on the external control grids and the longer unburnt grids in the harvested treatments (Fig. 1). The mosses *Campylopus bicolour* and *Campylopus introflexus* were recorded on all the grids and *Funaria hygrometrica*, the common fire moss, was recorded on all grids except the St John external reference (FC39), which had not been burnt for 19 years. The liverwort species, *Cephaloziella exiliflora and Chaetophyllopsis whiteleggei* were the most common liverworts, being recorded on most grids in all treatments in 2011.

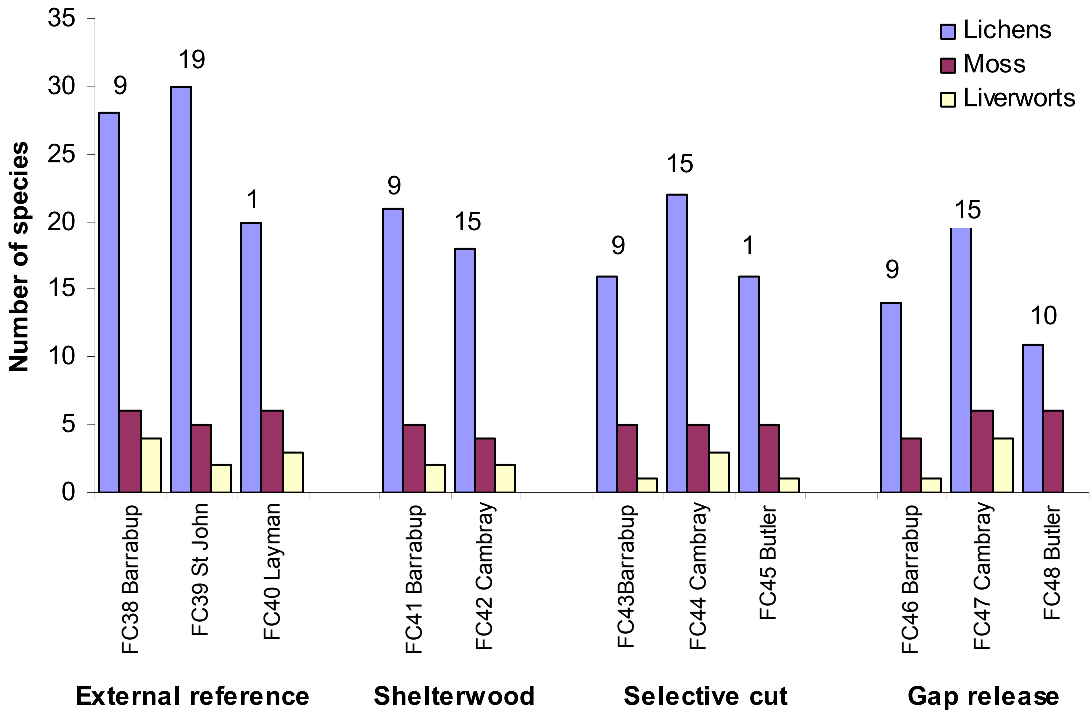

Figure 1. Total number of lichens, moss and liverwort species recorded from transects on each grid in each FORESTCHECK treatment in Blackwood Plateau in 2011 (numbers above bars indicates the time since fire).

The mean species richness per grid for lichens was higher in the external reference treatment compared to harvested treatments, but was similar in all treatments for mosses and liverworts (Fig. 2).

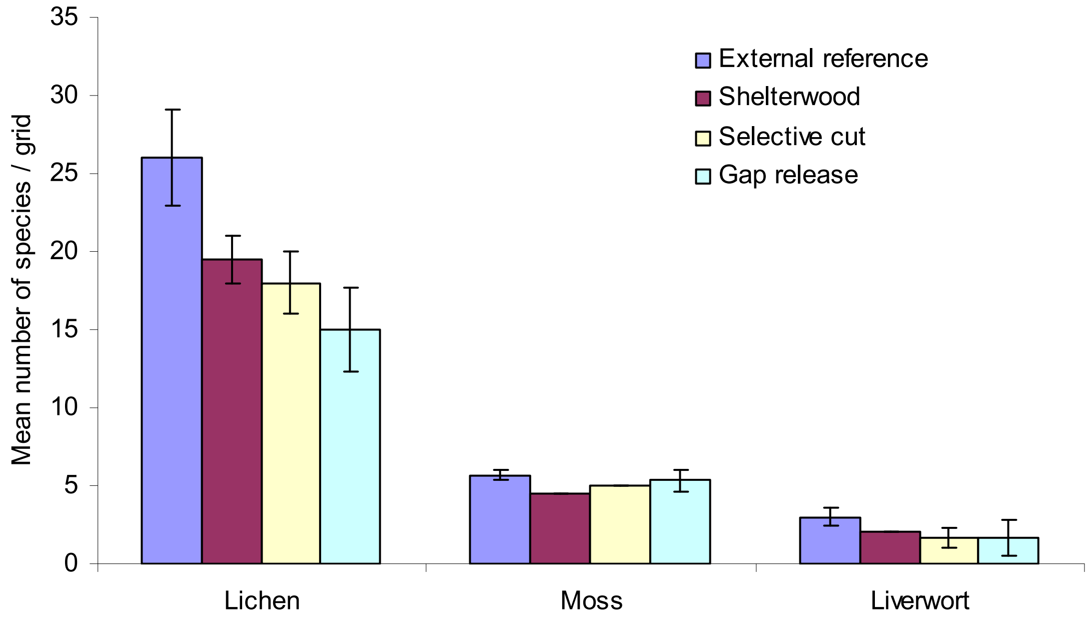

Figure 2. Mean number of lichen, moss and liverwort species per grid recorded from transects in each treatment in Blackwood Plateaut FORESTCHECK grids in 2011.

The total number of lichens recorded in 2011 was about two-thirds (68%) of that recorded in 2005. The majority of the difference occurred in the external reference treatment (Fig. 3), while the number of species recorded in the shelterwood treatment was higher in 2011 and similar in both years in the selective cut and gap release treatments. The reasons for the lower species richness recorded in the external reference treatment in 2011 are at present unclear.

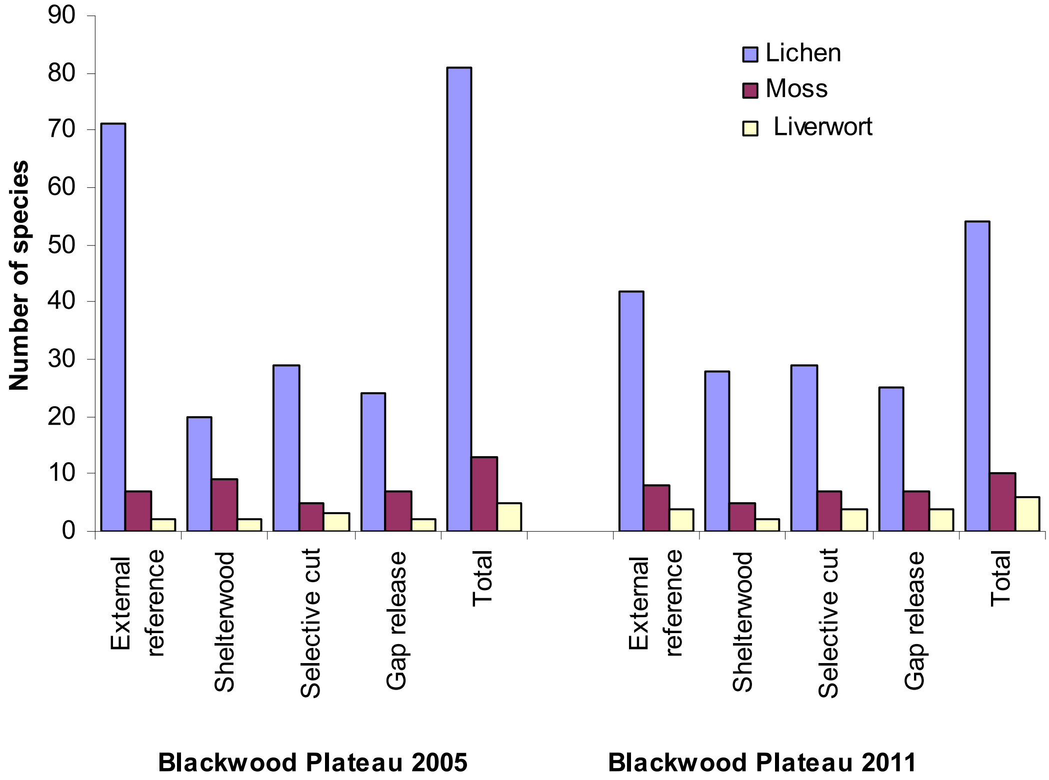

Figure 3. Total number of lichen, moss and liverwort species per grid recorded from transects in each treatment in Blackwood Plateau FORESTCHECK grids in 2006 and 2011.

Tephromela alectoronica (Fig. 4) was a species of lichen recorded in 2011 that is known to colonise tree crowns (and occasionally found on the solid but weathered wood surface of large logs). It was recorded on fallen branch material on three grids, the Cambray shelterwood (FC42) and the Barrabup (FC38) and Layman external references and is generally associated with mature trees. *Ochrolechia subpallescens* and *Hypogymnia subphysodes* are two other species of lichens recorded in 2011 that also occur in the tree layer, but they can also occur in the shrub layer. The number of moss and liverwort species recorded was similar in both 2005 and 2011 (Fig. 3). *Chaetophyllopsis whiteleggei* (Fig. 4) was not recorded in 2005 but was a common liverwort in 2011.

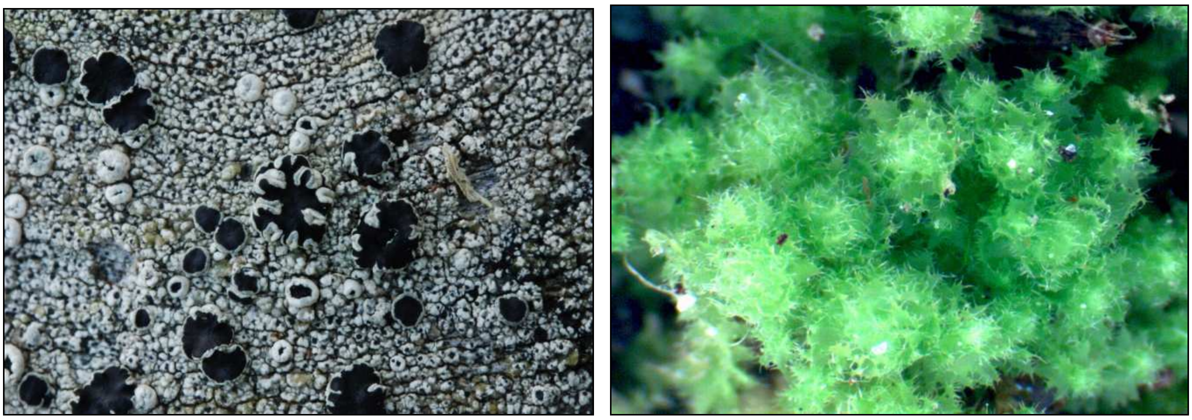

Figure 4. *Tephromela alectoronica* (left) was only recorded in external reference and shelterwood grids in 2011 and *Chaetophyllopsis whiteleggei* (right) was a new liverwort species recorded in 2011.

Plot surveys

Plot surveys were not conducted at Blackwood in 2005, having only been introduced to the FORESTCHECK protocol in 2007. The following results are therefore from 2011 data only.

Substrate availability and usage

Most substrates needed for the establishment and maintenance of cryptogams were available on the majority of grids; but not all substrates were consistently colonised (Fig. 5). Time since treatment has an influence on the condition of substrates and their consequent colonisation by cryptogams. On external reference grids, bark, organic material and stone were the most frequently colonised habitats. Similarly on shelterwood grids organic material and stone was well utilised and on gap release grids soil, charcoal and stone were the most utilised substrate.

Strata layers and cryptogam colonisation

The presence of cryptogams at different levels in the strata depends on the availability of suitable substrates at each level. Of the three strata layers investigated, the ground layer (0–30 cm) was the most utilised strata on every grid (Fig. 6). The shrub layer (31 cm–3 m) usage was relatively low on all grids and not colonised on two out of 20 plots on the Cambray gap release (FC47) and the Butler selective cut grids. The epiphytic tree layer (over 3 m) is difficult to examine and surveys depend on recording material which has fallen from tree crowns, and as such the results do not reflect the true extent of tree crown colonisation. However, lichens that colonise the tree layer (>3m) were recorded in one plot each on the Barrabup and St John external reference, Cambray selective cut (FC44) and in two plots in the Cambray shelterwood. None were recorded in plots in gap release treatment grids.

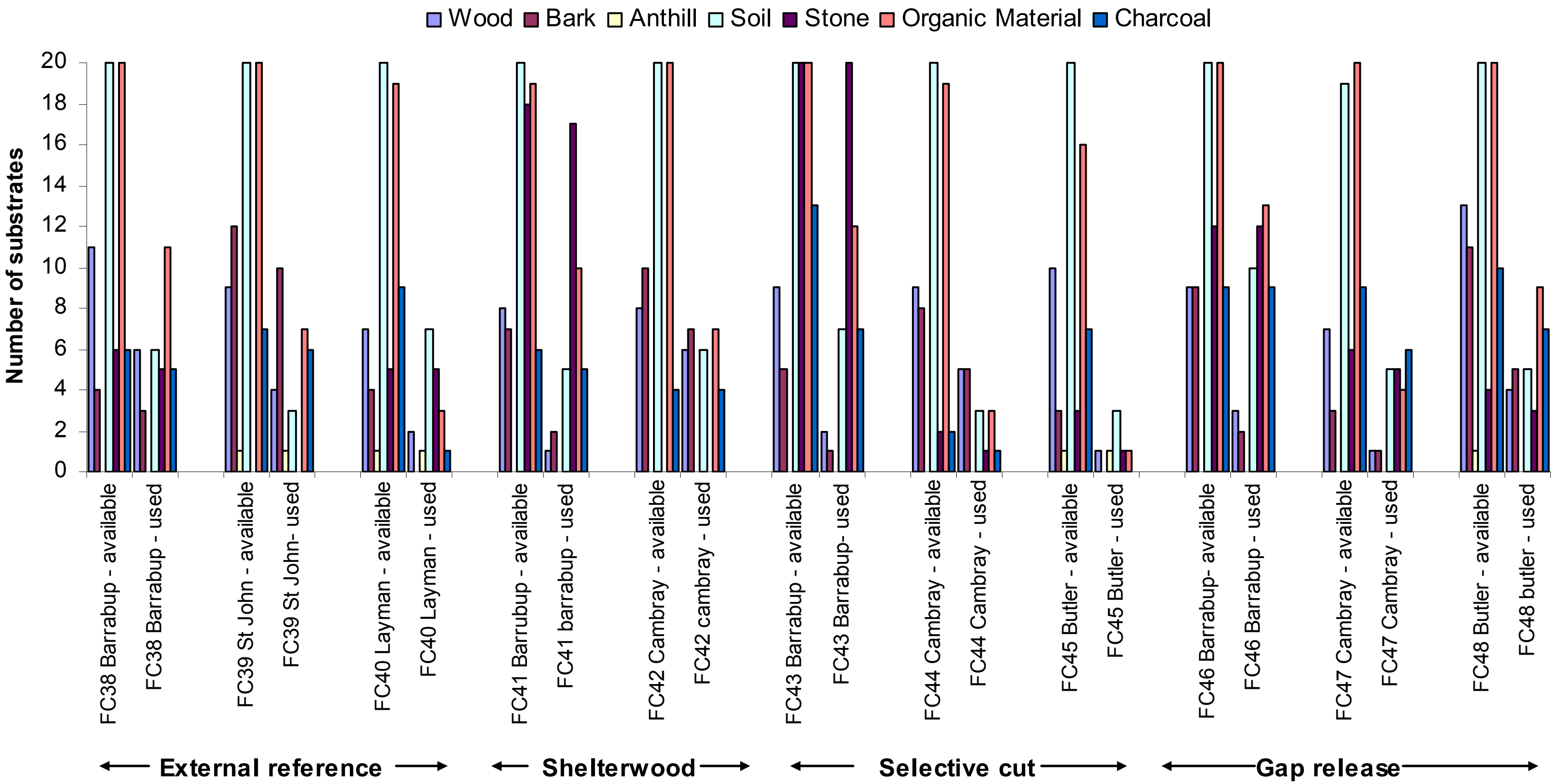

Figure 5. Number of plots with substrates available for colonisation and their utilisation by cryptogams on each Blackwood Plateau FORESTCHECK grid in 2011.

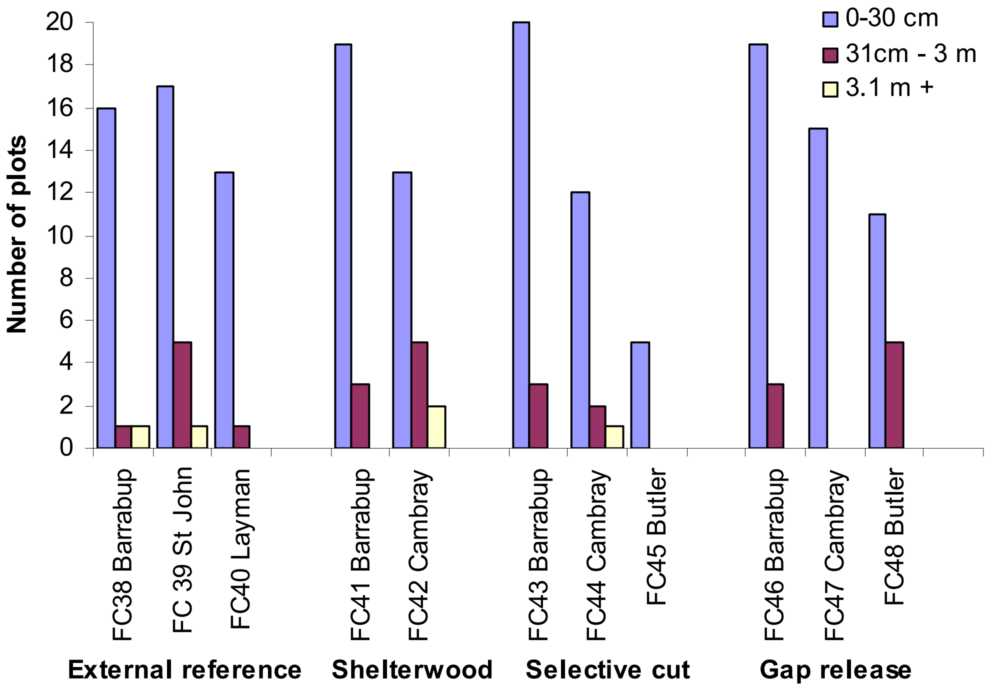

Figure 6. Number of 1x1 m plots with different strata levels occupied by cryptogams on each Blackwood Plateau FORESTCHECK grid in 2011 (NB. 20 plots per grid).

Life forms and population structure

Morphologically, cryptogams can be grouped into different life-form groups. Lichens are foliose, crustose or fruticose; mosses are creeping or tufted and liverworts are thallose or leafy. Species within each life-form group generally have similar life strategies. Crustose and fruticose lichens and tufted mosses were the most common types recorded in plots (Figs 7 and 8).

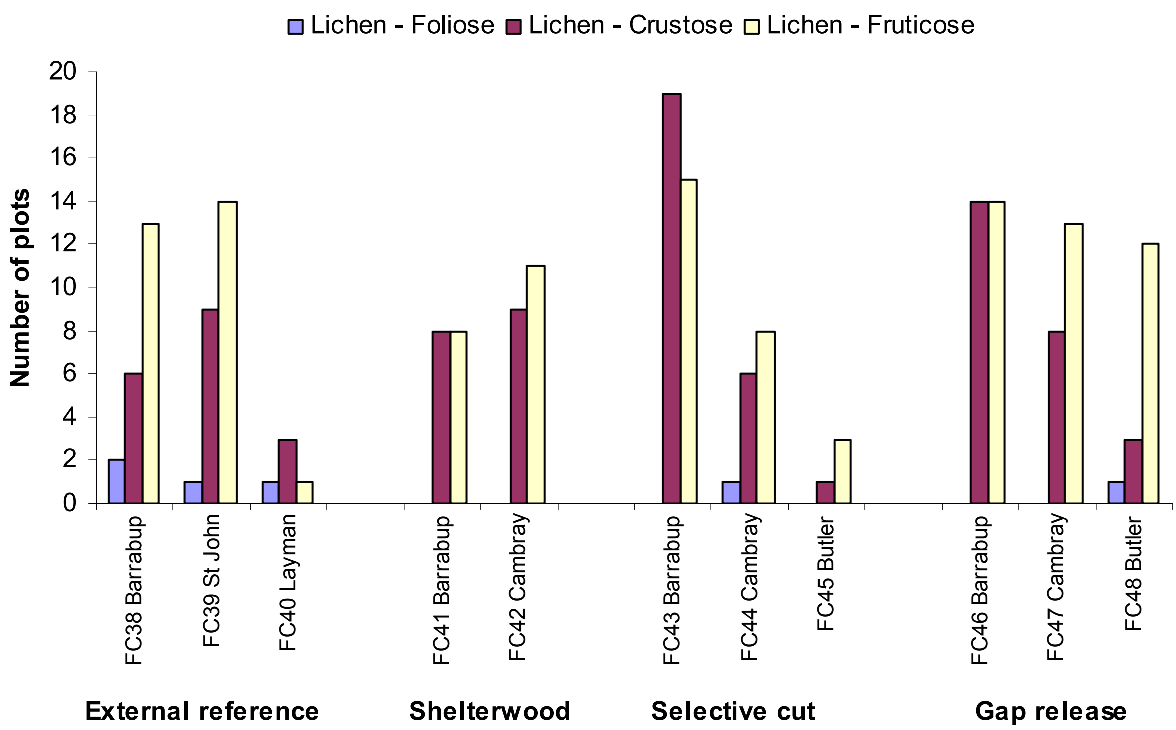

Figure 7. Number of 1x1 m plots in which each lichen life form was recorded on each Blackwood Plateau FORESTCHECK grid in 2011 (NB. 20 plots per grid).

Several tufted mosses, including *Campylopus bicolor* were recorded on all grids, while *Orthodontium lineare* was recorded on all external reference and gap release grids, but only on one grid, the Butler selective cut (FC45), within the shelterwood and selective cut treatments. Thallose liverworts were recorded on two grids, the Layman external reference and the Butler gap release. Leafy liverworts, including *Cephaloziella exiliflora* and *Chaetophyllopsis whiteleggei*, were recorded on all grids except the Butler gap release (Fig. 8).

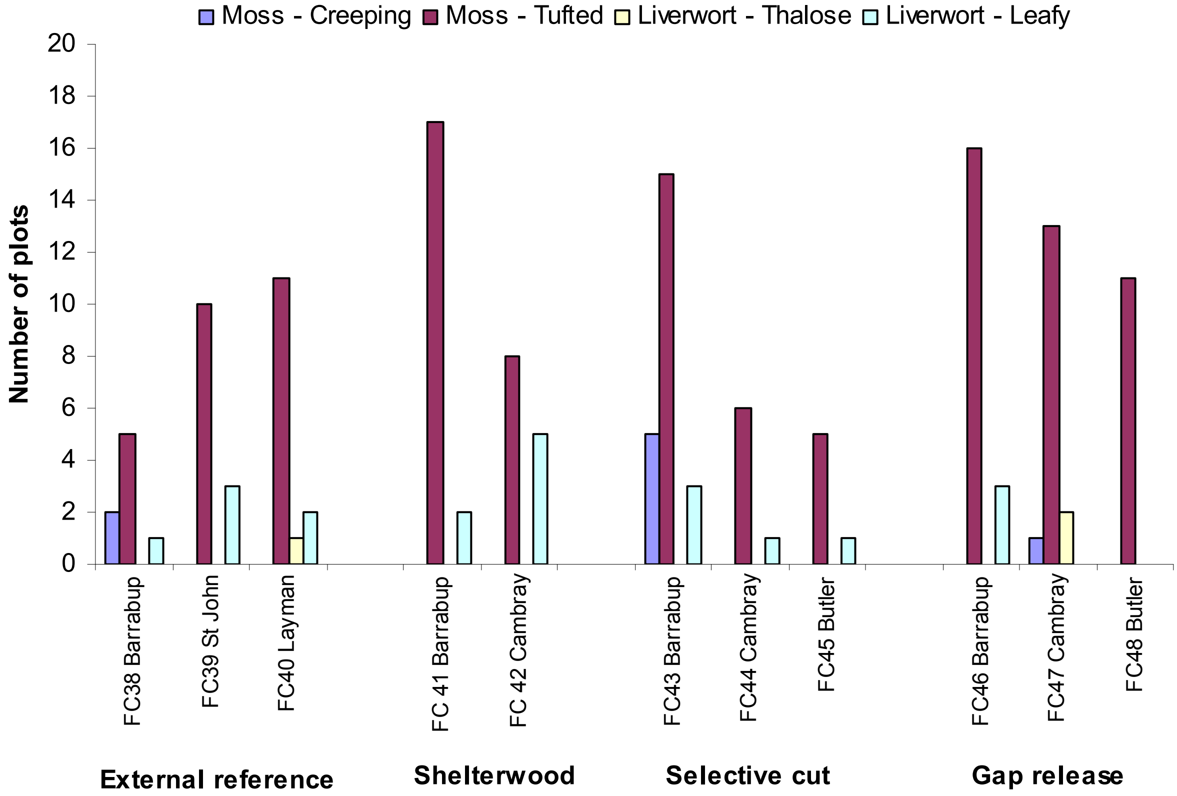

Figure 8. Number of 1x1 m plots in which each moss and liverwort life form was recorded on each Blackwood Plateau FORESTCHECK grid in 2011 (NB. 20 plots per grid).

Litter cover on individual 1x1 m plots

Heavy or constant litter cover has the potential to affect the presence and growth of a number of cryptogams. Lichens growing on soil or stones rapidly decline when covered by litter for extended periods. However, if the litter cover is temporary and able to be moved by wind and not become trapped, some species can withstand short periods of being covered without being totally excluded. At Blackwood Plateau in 2011, eight grids had a dense (< 75% cover) to moderate (26–75% cover) cover of litter in the majority of the plots (Fig. 9). Litter cover on the recently burnt (2010) Layman external reference and Butler selective cut grids, was generally sparse to moderate. Bare ground was recorded in a number of plots on the Layman external reference and Barrabup gap release (FC46) grids. Despite the generally dense litter cover, ground dwelling cryptogams were recorded in the majority of plots on all grids except the recently burnt Butler selective cut (see 0–30 cm strata class in Fig. 6).

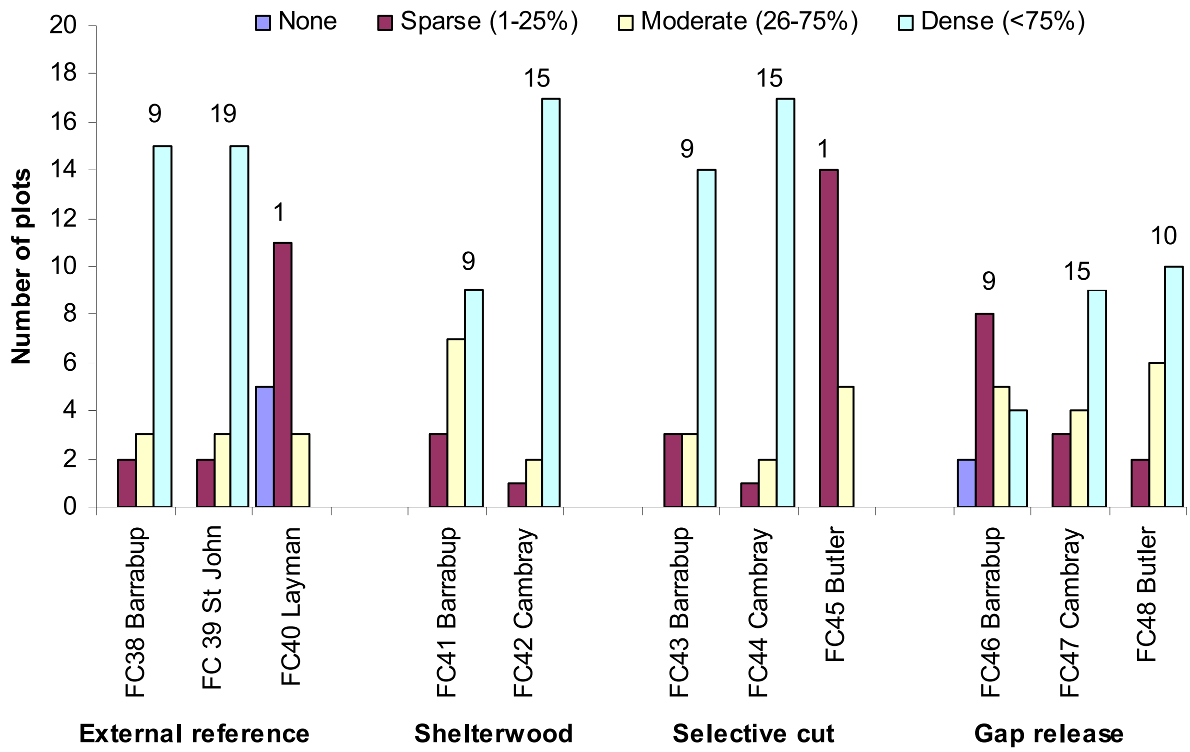

Figure 9. Number of 1x1 m plots with sparse, moderate and dense litter cover on each Blackwood Plateau FORESTCHECK grid in 2011 (NB. 20 plots per grid). Numbers above columns indicate years since fire on each grid.

Monitoring potential indicator species recorded in plots and on transect surveys
The 35 monitoring taxa (Table 1) were selected on the basis of the substrates and strata layers they occupied and on their perceived resilience and response to environment and physical changes.

A total of 20 monitoring species were recordrd in plots and 24 on transects. The lichens *Cladia aggregata, Cladia schizopora*, *Cladonia rigida, Cladonia sulcata* and *Thysanothecium scutellatatum* were recorded in most treatments using both survey methods (Table 1). *Thysanothecium hookerii*, a common termite mound specialist, was not recorded on either transects or in plots despite termite mounds being observed on most grids during transect surveys, and present in plots on four grids (see Fig. 5). However, the closely related *T. hookerii* subsp. *xanthonicum* was recorded on the Barrabup external reference grid. *Pannoparmelia wilsonii*, a common foliose lichen, was recorded in transects but not in plots.

Most species of the selected mosses were recorded in both plot and transect surveys. *Campylopus introflexus* and *Funaria hygrometrica* were the most common mosses recorded by both survey methods in all treatments (Table 1). *Cephaloziella exiliflora* was the only selected liverwort commonly recorded in both plot and transect surveys (Table 1).

To test the reliability of monitoring a short list of representative species to pick up trends or differences between treatments, the proportion of all lichen, moss and liverwort species in each treatment was determined and compared to that for the selected monitoring species recorded in both plots and transects (Fig. 10). The proportion of each group was similar in all treatments when either all cryptogams or just the monitoring species were recorded. However, when only the monitoring species were recorded from plots, mosses were present in larger proportions in harvested treatments.

Table 1. Frequency of selected monitoring species in plots and on transects for each treatment in the Blackwood Plateau FORESTCHECK grids in 2011 (ER = external reference, SW = shelterwood, SC = selective cut, GR = gap release).

Monitoring number	Species Name	Group[1]	Lifeform	Number of 1 x 1 m plots in which the species were recorded[2]				Number of 50 m sections of transect in which the species were recorded[3]			
				ER	SW	SC	GR	ER	SW	SC	GR
	Lichen										
1	*Cladia aggregata*	L	Fruticose	13	10	9	24	14	14	15	22
2	*Cladia schizopora*	L	Fruticose	7	2	4	2	18	8	11	13
3	*Cladonia cervicornis* var. *verticellata*	L	Fruticose					2			
4	*Cladonia krempelhuberi*	L	Fruticose	2	1		4	6	5		5
5	*Cladonia rigida*	L	Fruticose	5	2	1	7	20	7	10	8
6	*Cladonia sulcata*	L	Fruticose	1	4	6	7	3	5	7	9
7	*Calicium glaucellum*	L	Crustose					4			2
8	*Diploschistes sticticus*	L	Crustose								
9	*Flavoparmelia haysonii*	L	Foliose								
10	*Hypocenomyce foveata*	L	Crustose	1				4			
11	*Hypocenomyce scalaris*	L	Crustose	1		1		11		6	2
12	*Hypogymnia subphysodes* var. *subphysodes*	L	Foliose	1		1		2	2	2	
13	*Menegazzia platytrema*	L	Foliose								
14	*Glonium circumserpens*	L	Crustose								
15	*Ochrolechia* sp. (G. Kantavilis 306/92)	L	Crustose	2		3		12	6	9	4
16	*Pannoparmelia wilsonii*	L	Foliose	3				11	6	6	1
17	*Paraporpidia glauca*	L	Crustose			1	2	1	2	5	
18	*Parmotrema reticulatum*	L	Foliose								
19	*Ramboldia stuartii*	L	Crustose	4	1	2		12	6	6	
20	*Tephromela alectoronica*	L	Crustose					2	1		
21	*Thysanothecium hookeri*	L	Fruticose								
22	*Thysanothecium scutellatum*	L	Fruticose	18	17	10	23	18	15	18	23
23	*Usnea inermis*	L	Fruticose	4		3	1	6	8	8	10
24	*Usnea* sp. leuco (R.J. Cranfield 20195)	L	Fruticose								
25	*Xanthoparmelia isidiigera*	L	Foliose								
26	*Xanthoparmelia notata*	L	Foliose								

Monitoring number	Species Name	Group[1]	Lifeform	Number of 1 x 1 m plots in which the species were recorded[2]				Number of 50 m sections of transect in which the species were recorded[3]			
				ER	SW	SC	GR	ER	SW	SC	GR
	Liverwort										
27	*Cephaloziella exiliflora*	H	Leafy	2	5	3	1	11	13	8	10
28	*Chiloscyphus semiteres*	H	Leafy								1
29	*Fossombronia intestinalis*	H	Thallose								
30	*Frullania probosciphora*	H	Leafy								
	Moss										
31	*Barbula calycina*	B	Tufted	1		2	2	2			
32	*Campylopus introflexus*	B	Tufted	11	13	9	17	19	13	13	19
33	*Dicranoloma diaphanoneum*	B	Tufted		1	1					
34	*Funaria hygrometrica*	B	Tufted	2	14	16	23	5	13	12	18
35	*Sematophyllum subhumile* var. *contiguum*	B	Creeping		1	4		7	5	8	2
	Total number of species [4]			17	12	17	12	22	17	16	16
	Total lichen species			13	7	11	8	17	13	12	11
	Total moss species			3	4	5	3	4	3	3	3
	Total liverwort species			1	1	1	1	1	1	1	2

[1] L = lichen, B = bryophyte (moss) and H = heptophyte (liverwort).
[2] Max score = 60 for the external reference, gap release and selective cut (20 plots x 3 grids each) and 40 for the shelterwood (20 plots x 2 grids).
[3] Max score = 24 for external reference, gap release and selective cut (8 x 50 m sections x 3 grids each) and 16 for the shelterwood (8 x 50 m sections x 2 grids).
[4] There was a total of 30 monitoring species recorded in plots and 24 on transects.

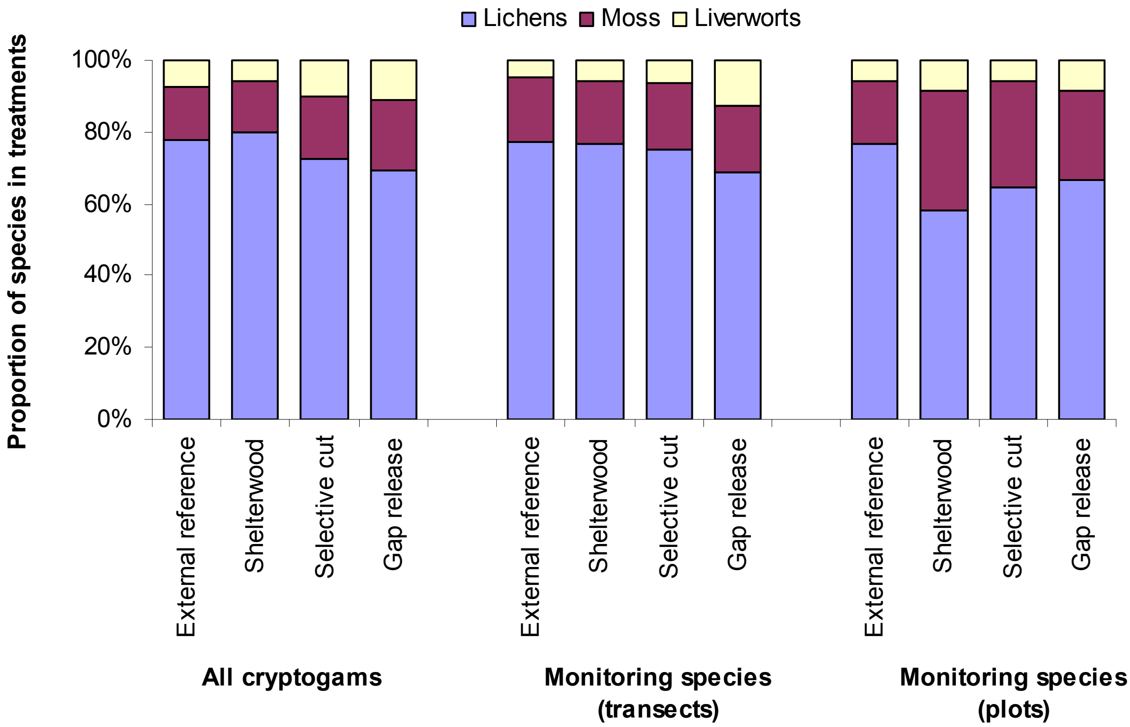

Figure 10. Proportion of lichen, moss and liverwort species in each treatment when considering all cryptogams (left) and only the selected list of potential indicator species recorded on transects (centre) and in plots (right) at the Blackwood Plateau FORESTCHECK grids in 2011.

When a similar comparison was done using mean species richness per grid, the trend was similar when all cryptogams were recorded or just the selected monitoring species on both transects and plots. The number of monitoring species recorded in both plots and on transects was similar in all treatments (Fig. 11). Overall, the number of cryptogam species recorded in the external reference treatment was higher than that in harvested grids. In harvested treatments the number of cryptogams tended to be lower as the intensity of harvest increased, but not significantly so.

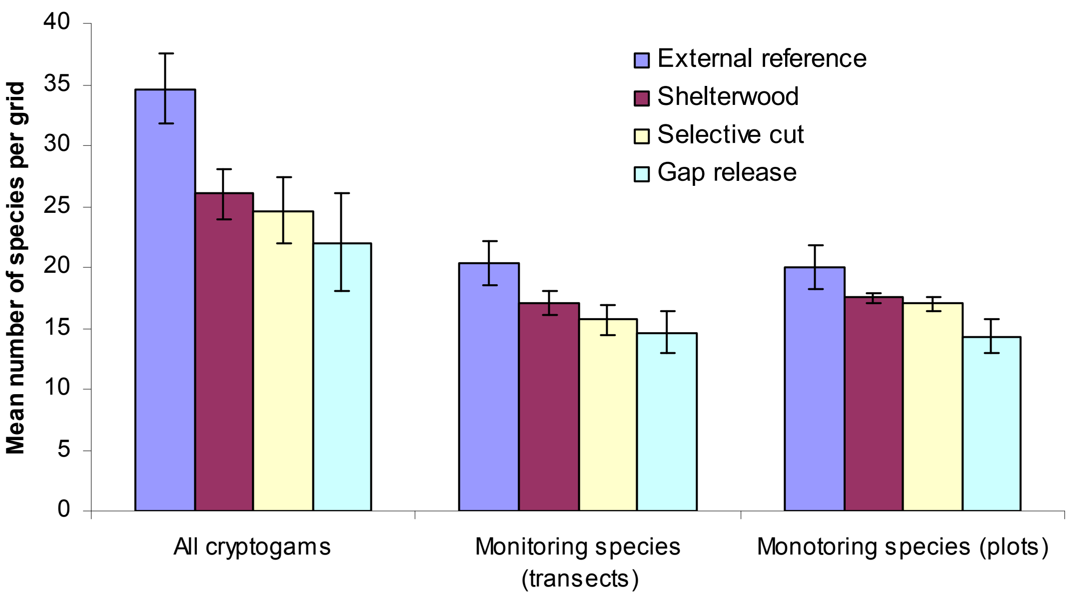

Figure 11. Mean species richness per grid for all cryptogams (left) and only the selected monitoring species (right) recorded in the Blackwood Plateau FORESTCHECK grid in 2011

Because the jarrah forest covers a large region encompassing a variety of ecosystem types and vegetation complexes (as represented by the five established FORESTCHECK locations; Donnelly, Wellington 1, Perth Hills, Wellington East and Blackwood Plateau) several monitoring species do not occur in all locations. The suitability of monitoring the current list of 35 species will be further tested when data from all five locations is analysed.

Conclusions

Some trends observed from monitoring the Blackwood Plateau FORESTCHECK grids in 2011 were:

- The number of lichens recorded in 2011 was markedly lower (32% less) than in 2005, and the difference occurred mainly in the external reference treatment.
- The external reference had more species of lichens than those in harvested grids.
- The vast majority of cryptogams were recorded in the 0–30 cm strata layer.
- The majority of cryptogams were crustose lichens and tufted mosses.
- Within each treatment, similar numbers of monitoring species were recorded on transects and in plots.

Other observations:

- The use of monitoring species may be a viable alternative for assessing the impacts of timber harvesting and silviculture on cryptogam communities, future monitoring will help to determine whether this is the case.

Acknowledgements

Thank you to Bruce Ward for assistance with surveys.

Appendix 1. Frequency of all cryptogam species recorded from transects at the Blackwood Plateau FORESTCHECK grids in 2011. Numbers in treatment columns indicate the number of 50 m sections (max. = 24 in external reference, and gap release treatments and selective cut and 16 in shelterwood) of transect within which each species was recorded.

Species Number	Monitor Species Number	Species	Group[1]	Treatment[2]				Total
				ER	SW	GR	SC	
382		*Arthonia ilicina*	L				1	1
241		*Austroparmelina conlabrosa*	L	4	2		2	8
4		*Buellia cranfieldii*	L		2	1		3
313		*Buellia substellulans*	L	2			1	3
279		*Buellia tetrapla*	L	1				1
174		*Buellia xanthonica*	L	3			1	4
5	7	*Calicium glaucellum*	L	4		2		6
7		*Calicium victorianum* subsp. *victorianum*	L			1	3	4
16	1	*Cladia aggregata*	L	14	14	22	15	65
314		*Cladia inflata*	L	3	1		2	6
17	2	*Cladia schizopora*	L	18	8	13	11	50
23	3	*Cladonia cervicornis* var. *verticellata*	L	2				2
34		*Cladonia fimbriata*	L	1				1
26	4	*Cladonia krempelhuberi*	L	6	5	5		16
154		*Cladonia merochlorphaea*	L		1	1		2
19		*Cladonia praetermissa*	L				2	2
30	5	*Cladonia rigida*	L	20	7	8	10	45
31		*Cladonia scabriuscula*	L	4				4
155		*Cladonia southlandica*	L		2	1		3
37	6	*Cladonia sulcata*	L	3	5	9	7	24
220		*Diploschistes scruposus*	L				1	1
222		*Ephebe lanata*	L	1				1
69		Genus sp. grey green (R.J. Cranfield 18054)	L				1	1
344	36	Genus sp. grey green slick	L	4	1	5	4	14
378		Genus sp. mustard	L	3	4	4	6	17
327		Genus sp. termite mound (R.J. Cranfield 21529)	L	1				1
96		*Hypocenomyce australis*	L	2				2
61	10	*Hypocenomyce foveata*	L	4				4
78	11	*Hypocenomyce scalaris*	L	11		2	6	19
330		*Hypogymnia subphysodes*	L	2	2			4
103	12	*Hypogymnia subphysodes* var. *subphysodes*	L	2	2		2	6
376		*Lecidea* sp.	L	1				1
115	15	*Ochrolechia* sp. (G.S. Kantvilis 306/92)	L	12	6	4	9	31
347		*Ochrolechia subpallescens*	L	8	3	1	3	15
111		*Ochrolechia subrhodotropa*	L	4	2	1		7
118	16	*Pannoparmelia wilsonii*	L	11	6	1	6	24
119	17	*Paraporpidia glauca*	L	1	2		5	8
346		*Peltigera dolichorriza*	L			1		1
277		*Pertusaria georgeana* var. *occidentalis*	L				1	1
113		*Pertusaria* sp. twiggy (R.J. Cranfield 17960)	L	1				1
290		*Ramboldia laeta*	L		1			1
199		*Ramboldia petraeoides*	L			1		1
52	19	*Ramboldia stuartii*	L	12	6		6	24
79	20	*Tephromela alectoronica*	L	2	1			3
381		*Thysanothecium hookeri* subsp. *xanthonicum*	L	2				2
132	22	*Thysanothecium scutellatum*	L	18	15	23	18	74
362		*Thysanothecium sorediatum*	L	2		1	1	4
204		*Toninia* sp. (R.J. Cranfield 18753)	L	1	1			2
178		*Trapelia crystallifera*	L	5	8	8	8	29

Species Number	Monitor Species Number	Species	Group[1]	Treatment[2]				Total
				ER	SW	GR	SC	
379		*Trapelia lilacea*	L	12	8	21	9	50
298		*Trapelia* sp. Bell (R.J. Cranfield 20850)	L	2				2
136	23	*Usnea inermis*	L	6	8	10	8	32
246		*Usnea nidulifera*	L	7				7
367		*Lichenomphalia chromacea*	LF	6	4	5	4	19
2	31	*Barbula calycina*	B	2				2
9	38	*Campylopus bicolor*	B	15	6	15	7	43
10	32	*Campylopus introflexus*	B	19	13	19	13	64
44		*Fissidens tenellus* var. *tenellus*	B				1	1
50	34	*Funaria hygrometrica*	B	5	13	18	12	48
383		Genus sp. (R.J. Cranfield 25713)	B	1				1
40	40	*Orthodontium lineare*	B	8		4	2	14
295		*Rosulabryum billarderi*	B			5		5
336	37	*Rosulabryum capillare*	B	4	5	3	5	17
128	35	*Sematophyllum subhumile* var. *contiguum*	B	7	5	2	8	22
12	27	*Cephaloziella exiliflora*	H	11	13	10	11	45
380		*Chaetophyllopsis whiteleggei*	H	4	3	2	3	12
15	28	*Chiloscyphus semiteres*	H			1		1
47	41	*Fossombronia altilamellosa*	H	1				1
319		*Fossombronia* sp. (R.J. Cranfield 21591)	H			2	1	3
332		*Lethocolea pansa*	H	2			1	3
		Total species		**54**	**35**	**36**	**40**	**70**
		Total Lichen species		42	28	25	29	54
		Total moss species		8	5	7	7	10
		Total Liverwort species		4	2	4	4	6
		Total monitoring species (Transects)		22	17	16	16	27
		Total lichen monitoring species		17	13	11	12	17
		Total moss monitoring species		4	3	3	3	4
		Total liverwort monitoring species		1	1	2	1	2

[1]L = lichen, B = bryophyte (moss) and H = heptophyte (liverwort), LF = lichenised fungus
[2]ER = external reference, SW = shelterwood, SC = selective cut, GR = gap release

VASCULAR PLANTS

Bruce Ward, Richard Robinson and Ray Cranfield

Introduction

Understorey plants are key organisms for monitoring impacts of commercial timber harvesting in jarrah (*Eucalyptus marginata*) forest. FORESTCHECK utilises data on species richness and abundance to determine impacts across silvicultural harvesting treatments. One of the strengths of this monitoring is that it is applied at an operational scale under standard industry conditions providing results that are representative of forest management practices.

Disturbance associated with timber harvesting includes soil mixing and compaction, and direct physical impact on trees and shrubs during felling and extraction operations. These effects may reduce the abundance of some plant species, but can also provide opportunities for regeneration by creating mineral earth seedbeds and stimulating rootstocks and germination of seed stored in the soil. When analysing species richness data from harvest treatment sites it is important to also consider time since fire as observed differences may be due to succession following fire rather than a direct impact of timber harvesting. Vegetation complexes of the jarrah forest are considered to be relatively stable and resilient to natural disturbances such as fire. In most circumstances, and in time, species that were present before disturbance are generally present after the event, although abundances may temporarily change.

The specific aim of monitoring vascular plants for the FORESTCHECK project is to:

- determine species richness and abundance in the various silvicultural treatments of managed jarrah forest (shelterwood, selective cut and gap release) and in uncut reference forest
- compare species richness, abundance and composition recorded within and between silvicultural treatment grids to those in uncut reference grids
- compare results from Blackwood Plateau in 2005 with those from 2011.

Monitoring

Eleven FORESTCHECK monitoring grids were established in Jarrah Blackwood Plateau in 2005. They included three external reference (FC38, FC39, FC40), two shelterwood (FC41, FC42), three selective cut (FC43, FC44, FC45) and three gap release treatment (FC46, FC47, FC48) grids. All are established within the Kingia vegetation complex, (Matiske and Havel 2000) located on lateritic uplands in perhumid and humid zones. The initial monitoring of vascular flora on the grids was conducted in spring (September) 2005, coinciding with the peak flowering time for most plants. This second round of monitoring was conducted in August 2011. In the time between the two monitoring events, the Layman external reference (FC40) and the Butler selective cut (FC45) grids were burnt by prescribed fire in spring 2010.

Species richness and understorey vegetation structure was determined, by recording each species, estimating its area of cover, frequency of occurrence and measuring its position in the understorey strata in six 1000 m^2 plots in each grid. Vegetation structure was determined from levy contact data at various height categories up to 2 m in the understorey (Levy and Madden 1933). Point samples were taken at 1m intervals on two internal sides of the 1000 m^2 plots (for 60 point samples per plot or 360 per grid) and numbers of contacts were used to describe the vertical profile of the vegetation. Canopy cover was also assessed at each point sample using a periscope with a vertical view set at eye level on the levy pole. Canopy was rated as present (Y) or not (N) with canopy cover calculated as a percentage of the total contacts that have a 'yes' (Y). Cover was divided into mid- and upper-storey ratings. The mid-storey was further split into eucalypt and other species so that the structure of the developing stand could be tracked as it progressed from saplings into poles and from poles to mature trees. Detailed descriptions of all monitoring methods including abundance, cover and frequency ratings is documented in the FORESTCHECK Operating Plan (available at www.dec.wa.gov.au). From 2001 to 2005, flora assessments were undertaken using four 1000 m^2 plots in each FORESTCHECK grid. Following a review of methods, this was increased to six for the second round of monitoring from 2007 to 2012.

The area around each grid was used to search and voucher flowering plant specimens to aid in or confirm their identification. During the original assessment, 174 vouchers were collected representing 60% of the species recorded in 2005. A further 15% were added to the collection in 2011. Other specimens will be gathered opportunistically during future survey.

Preliminary results
Species Richness
A total of 220 vascular plant species were recorded at Blackwood Plateau in 2011. This was 23 fewer species than that recorded in 2005 (Table 1) and may be due to plant senescence associated with age during the preceding six years. Despite a reduction in species numbers, the Blackwood Plateau location has the highest plant diversity (13–23% higher) of all the FORESTCHECK locations. The number of weed species increased from four in the 2005 assessment to five in 2011 (Table 1).

Total species richness in each grid was generally similar in 2005 and 2011, with noticeable increases on the Barrabup selective cut (FC43) and Barrabup gap release (FC46) grids and a slight decrease on the Layman external reference (Fig. 1). Mean species richness per treatment was similar across all treatments in 2011 (Fig. 2). Mean species richness of the shelterwood was lower than the external reference in 2005, but both were similar in 2011. Although species richness was similar in both 2005 and 2011, species recorded changed, reflecting the developing seral stages within the grids. Two grids, the Layman external reference and the Butler selective cut, were burnt by prescribed fire in spring 2010, but all other grids remained unburnt since the initial assessment and and ranged in time since fire from 9–19 years. Two priority species (both P3), *Conospermum paniculatum* and *Stylidium barleei*, were recorded during the 2011 assessment. C. *paniculatum* was recorded in the Butler selective cut grid while S. *barleei* was recorded in the Butler selective cut and Layman external reference grids.

Plant life forms and fire responses
In vegetation ecology, plants have been grouped into life form- or growth form categories on the basis of their similarity in structure and function; which also often displays an obvious relationship to environmental influences.

A high degree of species turn over was detected within life form categories between the 2005 and 2011 monitoring results (Table 2 and Fig. 3). The largest decline in species numbers in 2011 occurred within the shrub and dwarf shrub categories, and some gains occurred within the herb and geophyte categories (Fig. 3). Overall, 13 fewer shrub (>30cm) and six fewer dwarf shrub (<30cm) species were recorded in 2011 compared to 2005. They were a mix of soil stored obligate seeders and resprouting species that have a short to moderate life span (5–15 years). Also notable was the absence of *Xanthorrhoea preissii* from the shelterwood and gap release and *Kingia australis* from the shelterwood, selective cut and gap release treatments in 2005. In 2011 *X. preisii* was recorded in the shelterwood and *K. australis* in the selective cut treatments (see Fig. 3). One weed species from 2005, *Sonchus oleraceus*, was not recorded in 2011, but two additional weeds *Aira cupaniana* and *Conyza bonariensis*, were recorded in 2011.

Table 1 Comparison of total plants recorded for silvicultural treatments for the 2004 and 2010 sampling sessions (ER = external reference, SW = shelterwood, SC = selective cut, GR = gap release).

Number of species	Blackwood Plateau 2005					Blackwood Plateau 2011					Blackwood Plateau 2005+2011				
	ER	SW	SC	GR	Total	ER	SW	SC	GR	Total	ER	SW	SC	GR	Total
Total	184	112	143	140	243	158	107	152	146	220	223	140	194	181	294
Unique to treatment	46	6	18	21	91	27	2	14	23	66	50	4	18	27	99
Common to all treatments					73					78					107
Exclusive to each year					74					511					
Recorded in both years										109					
Weeds	0	2	2	3	4	1	3	3	2	5	1	3	3	4	6

Table 2. Number of plants in each life-form category recorded exclusively in each treatment for each sample session, 2005 and 2011, in the Blackwood Plateau FORESTCHECK grids.

Lifeform	External reference				Shelterwood				Selective cut				Gap release				Total for all treatments (2005 and 2011)			
	2005 only	2011 only	shared	Total	2005 only	2011 only	shared	Total	2005 only	2011 only	shared	Total	2005 only	2011 only	shared	Total	2005 only	2011 only	shared	Total
Tree	0	1	4	5	0	1	4	5	0	1	5	6	0	0	5	5	0	0	6	6
Shrub	35	13	53	101	15	9	32	56	20	19	43	82	15	18	42	75	32	19	73	124
Dwarf Shrub	15	8	27	50	19	4	18	31	10	11	23	44	9	7	26	42	17	11	39	67
Herb	1	6	1	8	3	1	2	6	3	4	3	10	3	4	3	10	6	8	6	20
Geophyte	9	8	16	33	3	8	11	22	7	10	12	29	5	9	12	26	11	11	23	45
Grass	0	0	1	1	0	2	0	2	0	3	0	3	1	1	1	3	0	1	2	3
Cycad	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Vine	2	1	1	4	1	0	2	3	0	0	2	2	0	1	1	2	2	0	2	4
Grass tree	0	0	3	3	0	0	1	1	0	1	2	3	0	1	1	2	0	0	3	3
Sedge	3	2	9	14	1	2	7	10	1	2	8	11	1	0	10	11	4	1	10	15
Fern	0	0	1	1	0	1	0	1	0	0	1	1	1	0	1	2	1	0	1	2
Rush	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
Parasite	0	0	2	2	1	0	0	1	1	0	1	2	0	0	2	2	1	0	2	3
Unknown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	66	40	119	**223**	44	29	79	**140**	43	52	101	**194**	36	42	105	**181**	75	52	169	**294**

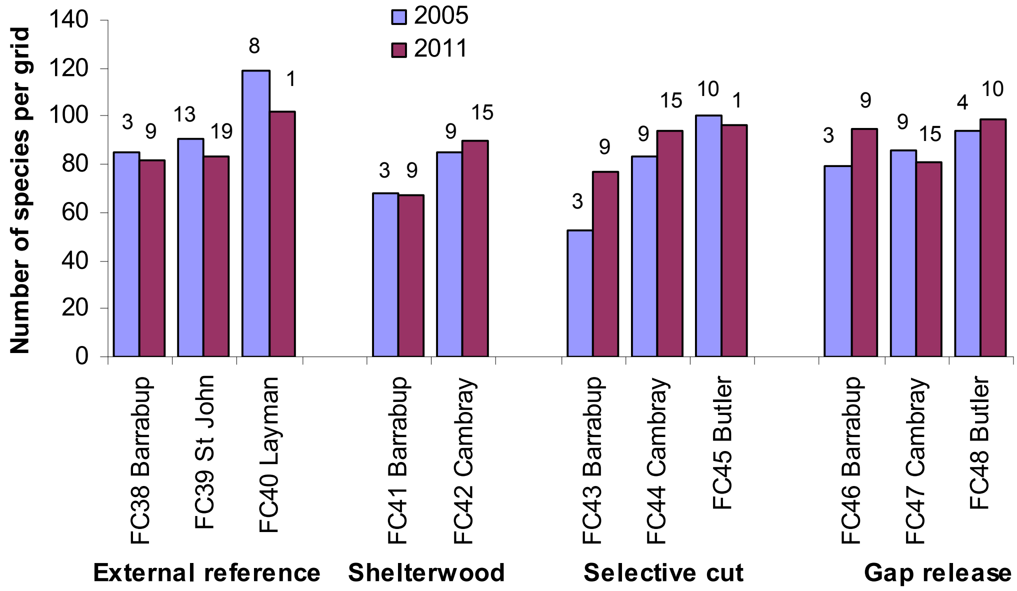

Figure 1. Number of plant species in each monitoring grid recorded at Blackwood Plateau FORESTCHECK grids in 2005 and 2011 (numbers above columns indicate the number of years since last fire).

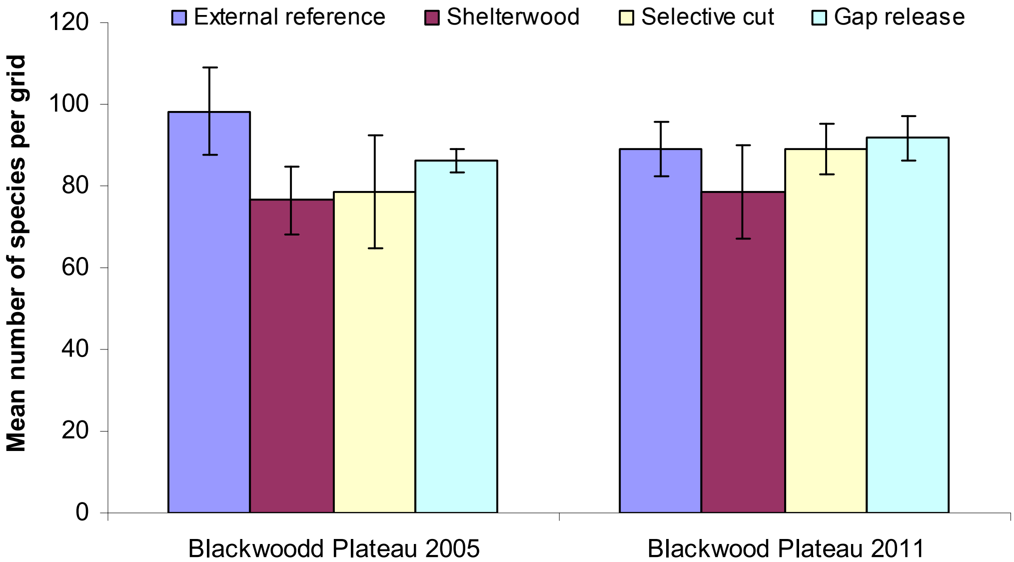

Figure 2. Mean species richness (±se) of plants per grid at Blackwood Plateau FORESTCHECK grids in 2005 and 2011.

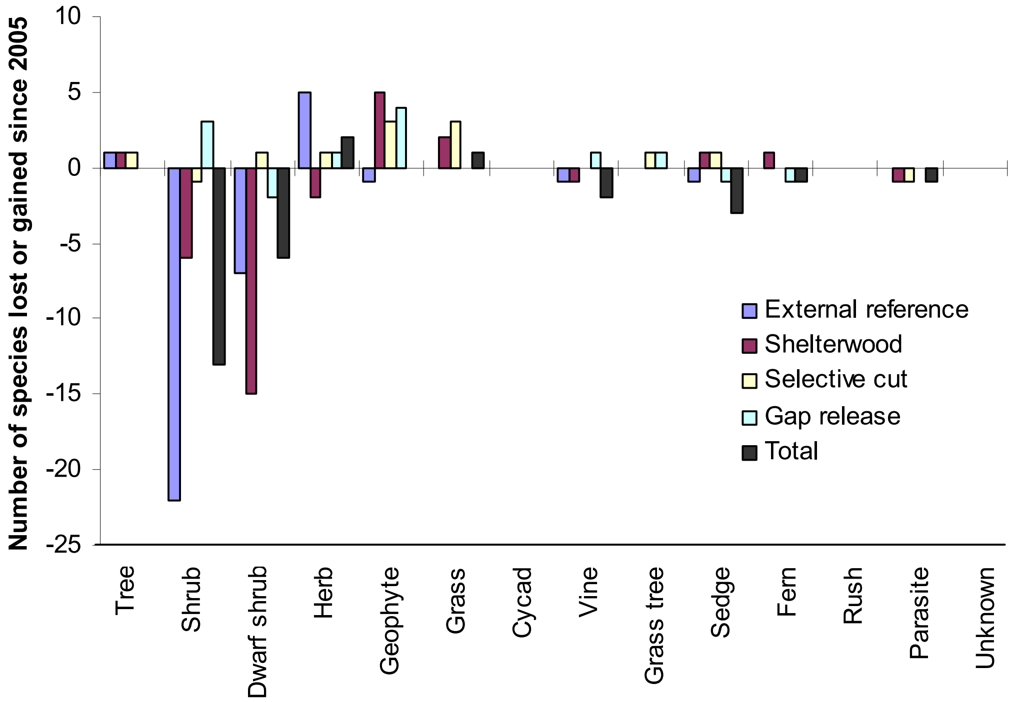

Figure 3. Gains and losses in species richness within each life form category at Blackwood Plateau FORESTCHECK grids following monitoring in spring 2005 and 2011.

About 60% of all species were recorded in both 2005 and 2011. The remaining 40% were either missed because of the timing of measurement or they were short-lived species having died between 2005 and 2011, or they were promoted by the recent prescribed fire on two grids in 2010.

The timing of surveys may influence the ability to detect some plants including annual herbs, grasses and geophytes, but our data indicate that most plant life form groups showed changes in species numbers and assemblages. Timing of assessments is a critical factor and August to October is generally targeted to capture the flowering and spring development of most species. Some changes may also be due to the two extra 1000 m^2 plots utilised in the 2011 survey.

Plant abundance

The total abundance of plants from all six plots on each grid was determined by summing the abundance class mid-point values for each species and then converted to plants m^{-2} for each grid.

Total plant abundance declined in all grids excepting the recently burnt Layman external reference grid. Abundance in the other recently burnt grid (Butler selective cut) was lower than in 2005, but not to the same degree as in other longer unburnt grids (Fig. 4).

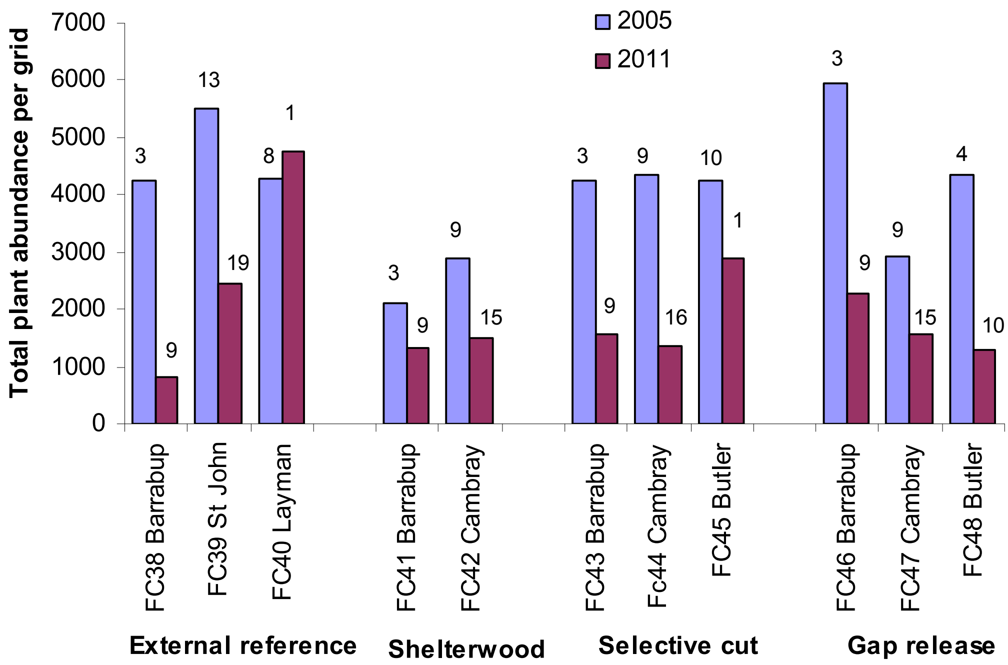

Figure 4 Total plant abundances for Blackwood Plateau FORESTCHECK grids in spring 2005 and 2011 (numbers above columns represent years since fire).

Mean plant abundances per treatment were significantly lower in all treatments in 2011 compared to 2005 (Fig. 5). Plant abundance in the shelterwood treatment was markedly lower than all other treatments in both 2005 and 2011. This decline in plant abundances is in line with the natural development of plant communities, which thin out over time due to competition for light, space and moisture. Plants with the best competitive advantage often become the dominant species.

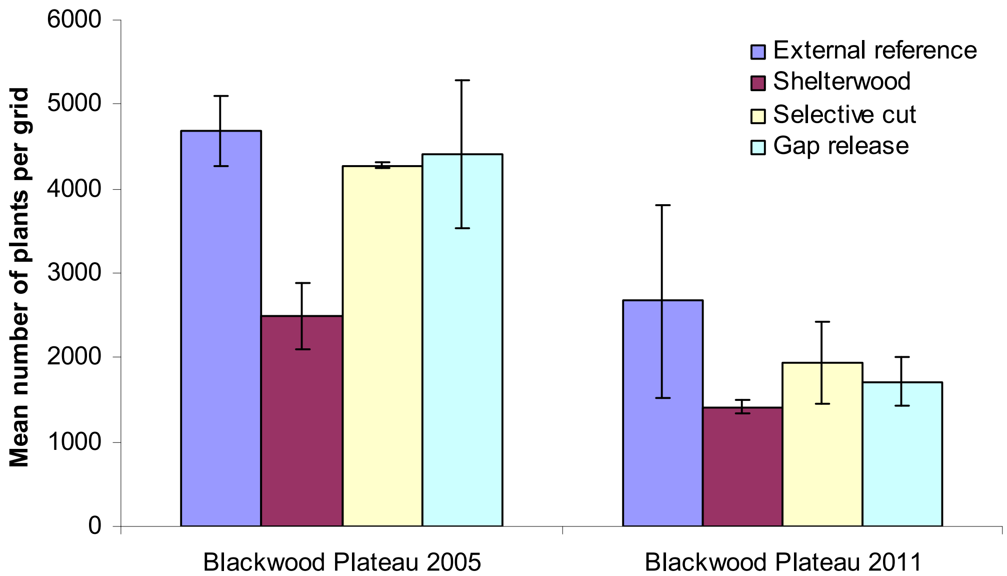

Figure 5. Mean number of plants (±se) per grid at Blackwood Plateau FORESTCHECK grids in 2005 and 2011.

Vegetation structure 2011

The mean understorey scrub height on each grid generally reflects time since fire, with height increasing over time (Fig. 6). The recently burnt Layman external reference and Butler selective cut had the lowest mean scrub height and the long-unburnt St John external reference grid (FC39) the tallest.

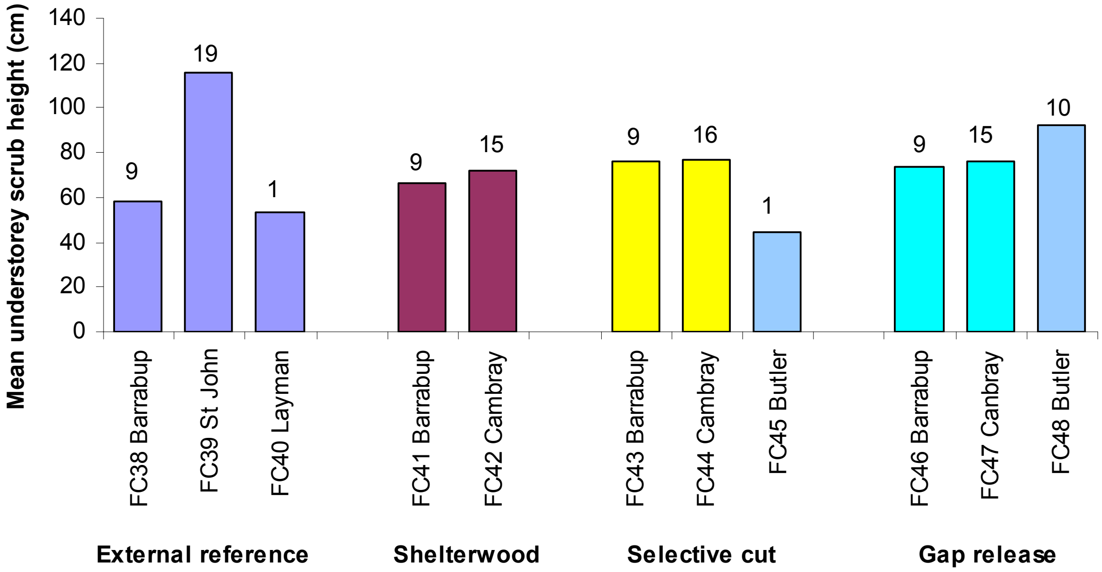

Figure 6. Mean understorey scrub height at Blackwood plateau FORESTCHECK grids in 2011 (numbers above columns indicate the number of years since fire).

The recently burnt grids also had a less complex understorey structure (Fig. 7), with 60% of the Layman external reference and 95% of the Butler selective cut grid understorey plants being under 20 cm tall. The long-unburnt St john external reference grid had the most and the recently burnt Layman external reference and Butler selective cut grids the least dead material in the understory—which reflects the stage of development and age of plants.

Conclusions

The main observations made following monitoring of vascular plants and measurement of plant structure at the Blackwood Plateau FORESTCHECK location were:

- Both species richness and abundance has declined on the Blackwood Plateau grids since 2005. It appears to be related to the senescence of short-lived plant species associated with development since disturbance and/or fire. Fewer shrub and dwarf shrub species were recorded in 2011.
- The structure of the understory vegetation is different in stands with longer times since fire (≥ 10 years) than those with more recent (< 10 years) times since fire.
- Flowering vouchers need to be collected to determine some species varieties.

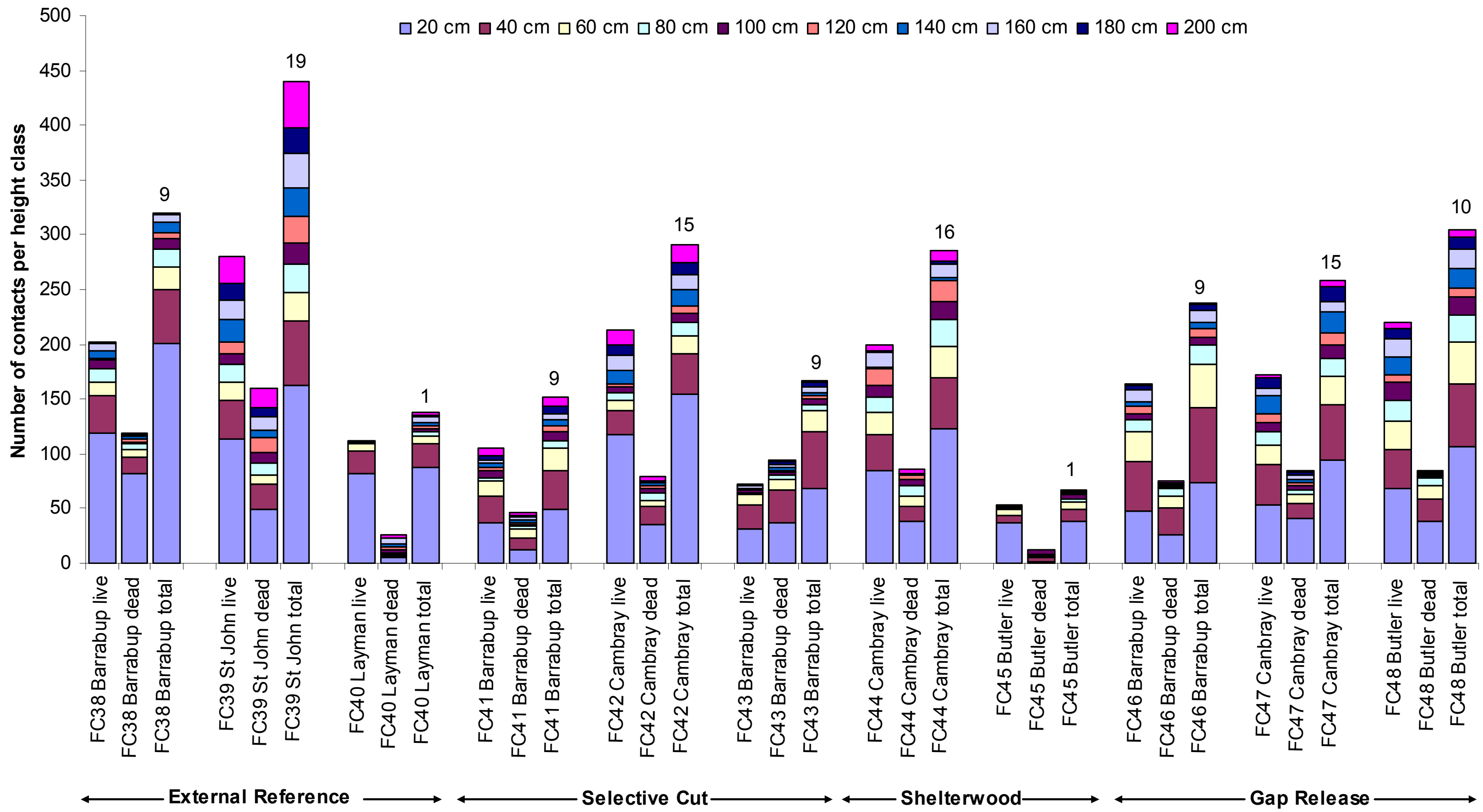

Figure 7. Numbers of live, dead and total vegetation contacts within 20cm height interval classes up to 2m at each Blackwood Plateau FORESTCHECK grid in 2011. Numbers above the 'total' bars indicate the time since last fire for that grid (legend displays the upper limits of each 20 cm class).

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Appendix 1. List of vascular plant species and their lifeforms recorded in each treatment at Blackwood Plateau Forestcheck grids in 2005 and 2011 (1 = present, blank cell indicates absence, numbers (1–4 or blank) in the 'Total' column indicate the number of treatments that species was recorded in)

Current Species Name	Life-form	Treatment 2005[1]					Treatment 2011[1]				
		ER	SW	SC	GR	Total	ER	SW	SC	GR	Total
Allocasuarina fraseriana	T	1	1	1	1	4	1	1	1	1	4
Banksia grandis	T	1	1	1	1	4	1	1	1	1	4
Corymbia calophylla	T	1	1	1	1	4	1	1	1	1	4
Eucalyptus marginata	T	1	1	1	1	4	1	1	1	1	4
Eucalyptus megacarpa	T			1		1			1		1
Persoonia elliptica	T				1	1	1	1	1	1	4
Acacia alata	S						1		1		2
Acacia applanata	S	1				1					
Acacia browniana	S						1		1		2
Acacia divergens	S			1		1	1				1
Acacia drummondii	S		1	1		2					
Acacia extensa	S	1	1	1	1	4	1	1	1	1	4
Acacia myrtifolia	S	1		1	1	3	1			1	2
Acacia nervosa	S				1	1					
Acacia obovata	S	1	1	1	1	4				1	1
Acacia pulchella	S	1				1	1		1	1	3
Acacia pulchella var. *pulchella*	S	1		1	1	3					
Acacia tayloriana	S	1	1		1	3					
Acacia varia	S	1		1	1	3	1		1		2
Acacia willdenowiana	S								1		1
Adenanthos barbiger	S	1	1	1	1	4	1	1	1	1	4
Adenanthos meisneri	S	1	1	1	1	4	1	1	1	1	4
Adenanthos obovatus	S	1		1	1	3	1	1	1		3
Andersonia latiflora	S	1	1			2	1		1		2
Andersonia spp.	S	1				1					
Baeckea sp.	S	1				1					
Banksia dallanneyi	S	1	1	1		3	1	1	1		3
Banksia dallanneyi var. *dallanneyi*	S	1		1		2					
Banksia meisneri subsp. *ascendens*	S	1				1					
Banksia sphaerocarpa	S						1				1
Boronia spathulata	S	1	1	1	1	4	1	1	1	1	4
Bossiaea linophylla	S		1		1	2		1		1	2
Bossiaea ornata	S	1	1	1	1	4	1	1	1	1	4
Callistachys lanceolata	S	1				1					
Calothamnus planifolius var. *planifolius*	S	1				1					
Comesperma confertum	S								1		1
Conospermum flexuosum	S	1				1					
Conostylis aculeata	S	1	1	1		3	1	1	1	1	4
Conostylis setigera	S	1		1	1	3	1	1	1	1	4
Conostylis setosa	S						1				1
Dasypogon bromeliifolius	S	1	1	1	1	4	1	1	1	1	4
Dasypogon hookeri	S	1				1	1				1
Daviesia incrassata	S									1	1
Daviesia inflata	S						1		1		2
Daviesia preissii	S	1		1	1	3	1	1	1	1	4

Current Species Name	Life-form	Treatment 2005[1]					Treatment 2011[1]				
		ER	SW	SC	GR	Total	ER	SW	SC	GR	Total
Dillwynia sp. Capel (P.A. Jurjevich 1771)	S								1	1	2
Glischrocaryon aureum	S	1				1			1		1
Gompholobium confertum	S	1	1	1	1	4	1	1	1	1	4
Gompholobium venustum	S	1				1					
Grevillea centristigma	S	1				1	1				1
Grevillea pulchella	S	1	1	1	1	4	1		1		2
Grevillea synapheae	S	1				1					
Grevillea trifida	S	1	1	1		3		1	1		2
Hakea amplexicaulis	S	1	1	1	1	4	1	1	1	1	4
Hakea cyclocarpa	S	1	1	1	1	4	1		1		2
Hakea lissocarpha	S	1				1	1				1
Hakea prostrata	S	1				1	1		1		2
Hakea ruscifolia	S	1	1	1	1	4		1	1	1	3
Hemigenia sericea	S				1	1					
Hibbertia acerosa	S	1	1	1	1	4				1	1
Hibbertia amplexicaulis	S	1	1	1	1	4	1	1	1	1	4
Hibbertia commutata	S	1	1	1	1	4	1	1	1	1	4
Hibbertia cuneiformis	S			1		1					
Hibbertia cunninghamii	S			1		1					
Hibbertia glomerata	S	1	1	1		3	1	1		1	3
Hibbertia hypericoides	S	1	1	1	1	4	1	1	1	1	4
Hibbertia quadricolor	S		1	1	1	3	1	1	1	1	4
Hibbertia spp.	S								1	1	2
Hibbertia vaginata	S									1	1
Hovea elliptica	S				1	1	1		1		2
Hovea trisperma	S	1			1	2	1	1	1	1	4
Hovea trisperma var*. trisperma*	S	1	1	1	1	4					
Hypocalymma angustifolium	S	1	1	1	1	4	1	1	1	1	4
Hypocalymma robustum	S				1	1				1	1
Isopogon sphaerocephalus	S	1		1	1	3	1		1	1	3
Labichea lanceolata	S						1				1
Lasiopetalum floribundum	S						1		1		2
Lechenaultia biloba	S	1		1	1	3	1	1	1	1	4
Leptomeria cunninghamii	S	1	1	1	1	4	1	1	1	1	4
Leucopogon australis	S	1	1	1	1	4	1	1	1	1	4
Leucopogon capitellatus	S	1	1	1	1	4	1	1	1	1	4
Leucopogon compactus	S									1	1
Leucopogon glabellus	S	1		1	1	3	1			1	2
Leucopogon pendulus	S						1		1		2
Leucopogon propinquus	S	1		1	1	3		1	1	1	3
Leucopogon revolutus	S	1	1		1	3					
Leucopogon spp.	S									1	1
Leucopogon unilateralis	S			1		1					
Leucopogon verticillatus	S	1	1	1	1	4	1	1	1	1	4
Melaleuca preissiana	S				1	1					
Melaleuca thymoides	S	1	1	1	1	4	1	1	1	1	4
Mirbelia dilatata	S	1				1					
Opercularia hispidula	S	1	1	1	1	4	1	1	1	1	4
Pentapeltis silvatica	S			1		1			1		1

Current Species Name	Life-form	Treatment 2005[1]					Treatment 2011[1]				
		ER	SW	SC	GR	Total	ER	SW	SC	GR	Total
Pericalymma ellipticum var. *ellipticum*	S	1		1		2					
Pericalymma spongiocaule	S		1			1			1		1
Persoonia graminea	S	1				1					
Persoonia longifolia	S	1	1	1	1	4	1	1	1	1	4
Persoonia saccata	S	1	1	1		3	1			1	2
Petrophile diversifolia	S	1				1					
Petrophile linearis	S	1	1	1	1	4	1	1	1	1	4
Philotheca spicata	S	1				1	1	1		1	3
Pimelea ciliata	S									1	1
Pimelea rosea	S	1			1	2			1	1	2
Pimelea spectabilis	S	1				1				1	1
Pimelea suaveolens	S	1		1		2	1		1	1	3
Platysace compressa	S	1				1					
Platysace filiformis	S	1			1	2					
Platytheca galioides	S	1			1	2	1	1			2
Podocarpus drouynianus	S	1	1	1	1	4	1	1	1	1	4
Pultenaea brachytropis	S	1			1	2				1	1
Pultenaea radiata	S	1				1					
Pultenaea reticulata	S						1				1
Sphaerolobium fornicatum	S	1	1	1	1	4				1	1
Sphaerolobium medium	S	1			1	2				1	1
Stackhousia monogyna	S	1				1	1		1		2
Strangea stenocarpoides	S	1		1		2					
Styphelia tenuiflora	S	1	1	1		3	1	1	1	1	4
Synaphea floribunda	S						1	1	1	1	4
Synaphea hians	S		1			1					
Synaphea petiolaris	S	1		1		2	1			1	2
Synaphea whicherensis	S	1				1					
Taxandria parviceps	S	1	1	1	1	4	1	1	1	1	4
Tetratheca affinis	S			1		1					
Tetratheca hirsuta	S	1	1	1	1	4	1		1		2
Tetratheca setigera	S	1	1	1	1	4	1	1	1	1	4
Thomasia foliosa	S	1				1	1				1
Trymalium ledifolium	S	1	1	1		3			1		1
Xanthosia atkinsoniana	S			1		1				1	1
Xylomelum occidentale	S	1	1	1	1	4	1	1	1	1	4
Actinotus omnifertilis	DS	1				1					
Amperea ericoides	DS								1	1	2
Amphipogon amphipogonoides	DS	1	1	1	1	4	1	1	1	1	4
Andersonia caerulea	DS	1	1			2	1		1		2
Andersonia involucrata	DS			1		1	1				1
Asterolasia pallida	DS	1		1		2					
Astroloma drummondii	DS						1				1
Astroloma pallidum	DS	1	1			2	1		1	1	3
Banksia bipinnatifida	DS	1				1	1				1
Banksia bipinnatifida subsp. *bipinnatifida*	DS	1				1					
Comesperma calymega	DS		1		1	2				1	1
Conospermum capitatum	DS	1	1	1	1	4	1	1		1	3
Dampiera linearis	DS	1		1	1	3	1	1	1	1	4

Current Species Name	Life-form	Treatment 2005[1]					Treatment 2011[1]				
		ER	SW	SC	GR	Total	ER	SW	SC	GR	Total
Dampiera sacculata	DS	1				1					
Darwinia sp. Whicher Range (M. Spencer 149)	DS						1		1		2
Gompholobium capitatum	DS				1	1					
Gompholobium knightianum	DS	1	1	1	1	4	1	1	1	1	4
Gompholobium marginatum	DS				1	1					
Gompholobium ovatum	DS	1				1	1		1		2
Gompholobium polymorphum	DS						1				1
Gompholobium preissii	DS	1	1	1	1	4			1	1	2
Gompholobium tomentosum	DS	1			1	2				1	1
Goodenia eatoniana	DS						1		1		2
Goodenia spp.	DS	1				1					
Hovea chorizemifolia	DS	1	1	1	1	4	1		1	1	3
Hybanthus debilissimus	DS									1	1
Labichea punctata	DS				1	1	1	1	1		3
Logania serpyllifolia	DS	1	1	1	1	4	1	1	1	1	4
Logania serpyllifolia subsp. *serpyllifolia*	DS	1	1	1	1	4					
Lomandra caespitosa	DS	1	1	1	1	4	1	1	1	1	4
Lomandra drummondii	DS	1	1		1	3		1	1	1	3
Lomandra hermaphrodita	DS	1	1	1	1	4	1	1	1	1	4
Lomandra integra	DS	1	1	1	1	4	1	1	1	1	4
Lomandra nigricans	DS	1		1	1	3		1	1	1	3
Lomandra pauciflora	DS	1				1					
Lomandra purpurea	DS				1	1					
Lomandra sericea	DS	1	1	1	1	4	1	1	1	1	4
Lomandra sonderi	DS	1	1	1	1	4	1	1	1	1	4
Monotaxis grandiflora	DS		1	1	1	3			1		1
Monotaxis occidentalis	DS								1	1	2
Patersonia juncea	DS	1				1	1		1		2
Patersonia occidentalis	DS	1	1	1		3	1	1	1		3
Patersonia pygmaea	DS	1		1		2					
Patersonia umbrosa	DS						1				1
Patersonia umbrosa var. *umbrosa*	DS	1				1					
Patersonia umbrosa var. *xanthina*	DS	1		1	1	3	1		1	1	3
Pentapeltis peltigera	DS	1	1	1	1	4	1		1	1	3
Phlebocarya ciliata	DS		1		1	2		1			1
Platysace tenuissima	DS	1	1	1	1	4	1	1	1	1	4
Poranthera huegelii	DS				1	1				1	1
Scaevola glandulifera	DS			1		1					
Scaevola lanceolata	DS	1				1					
Scaevola striata	DS	1	1	1	1	4	1	1	1	1	4
Scaevola striata var. *striata*	DS				1	1					
Senecio hispidulus	DS		1	1	1	3		1	1	1	3
Sphenotoma capitata	DS	1				1					
Stylidium amoenum	DS	1	1	1	1	4	1	1		1	3
Stylidium calcaratum	DS									1	1
Stylidium ciliatum	DS	1		1	1	3	1				1
Stylidium rhynchocarpum	DS			1		1					
Stylidium scandens	DS	1	1	1	1	4	1	1	1	1	4

Current Species Name	Life-form	Treatment 2005[1]					Treatment 2011[1]				
		ER	SW	SC	GR	Total	ER	SW	SC	GR	Total
Stylidium schoenoides	DS							1	1	1	3
Stylidium spp.	DS			1		1	1				1
Velleia trinervis	DS	1	1	1	1	4	1		1	1	3
Xanthosia candida	DS	1		1		2	1		1		2
Xanthosia huegelii	DS	1	1	1	1	4	1	1	1	1	4
Xanthosia spp.	DS									1	1
Centaurium erythraea	H			1	1	2			1		1
Conyza bonariensis	H						1				1
Haemodorum paniculatum	H	1	1	1		3	1		1		2
Haemodorum spicatum	H		1			1	1				1
Helichrysum luteoalbum	H				1	1					
Homalosciadium homalocarpum	H			1		1					
Hyalosperma demissum	H									1	1
Hydrocotyle alata	H						1				1
Hydrocotyle diantha	H	1		1		2					
Hypochaeris glabra	H		1	1	1	3		1	1	1	3
Isotoma hypocrateriformis	H						1				1
Isotropis cuneifolia	H						1			1	2
Levenhookia pusilla	H		1		1	2	1	1	1	1	4
Lobelia rarifolia	H								1		1
Millotia tenuifolia	H				1	1				1	1
Millotia tenuifolia var. *tenuifolia*	H		1			1					
Rhodanthe citrina	H							1	1	1	3
Sonchus oleraceus	H				1	1					
Trachymene pilosa	H								1	1	2
Tricoryne elatior	H			1		1					
Agrostocrinum scabrum	GP									1	1
Burchardia congesta	GP	1		1	1	3	1	1	1	1	4
Caesia micrantha	GP							1		1	2
Caladenia discoidea	GP			1		1					
Caladenia flava	GP		1	1	1	3	1	1	1	1	4
Caladenia reptans	GP	1				1			1		1
Caladenia reptans subsp. *reptans*	GP	1	1			2					
Chamaescilla corymbosa	GP	1				1	1	1	1	1	4
Chamaescilla corymbosa var. *corymbosa*	GP	1	1	1	1	4					
Craspedia variabilis	GP	1				1	1				1
Cryptostylis ovata	GP				1	1					
Cyanicula sericea	GP						1				1
Cyrtostylis huegelii	GP	1			1	2			1	1	2
Dianella revoluta	GP	1				1	1				1
Drakaea glyptodon	GP				1	1					
Drakaea livida	GP								1	1	2
Drosera bulbosa	GP						1				1
Drosera erythrorhiza	GP	1	1	1	1	4	1	1	1	1	4
Drosera glanduligera	GP						1				1
Drosera huegelii	GP		1			1					
Drosera menziesii	GP	1	1			2	1	1	1	1	4
Drosera pallida	GP	1	1	1	1	4	1	1	1	1	4
Drosera pygmaea	GP	1				1					

Current Species Name	Life-form	Treatment 2005[1]					Treatment 2011[1]				
		ER	SW	SC	GR	Total	ER	SW	SC	GR	Total
Drosera spp.	GP	1				1					
Drosera stolonifera	GP	1	1	1	1	4	1	1	1	1	4
Elythranthera brunonis	GP						1	1	1		3
Eriochilus dilatatus	GP							1	1		2
Haemodorum simplex	GP	1			1	2	1	1	1		3
Johnsonia lupulina	GP	1	1	1	1	4	1	1		1	3
Lagenophora huegelii	GP	1		1		2	1	1			2
Paracaleana disjuncta	GP						1				1
Patersonia babianoides	GP	1			1	2	1			1	2
Pterostylis barbata	GP									1	1
Pterostylis pyramidalis	GP	1	1	1	1	4	1	1	1	1	4
Pterostylis recurva	GP		1	1		2	1	1	1	1	4
Pterostylis vittata	GP	1		1	1	3			1		1
Pyrorchis nigricans	GP	1	1	1	1	4	1	1	1	1	4
Stylidium bulbiferum	GP								1		1
Thelymitra crinita	GP	1		1		2	1	1	1	1	4
Thelymitra macrophylla	GP	1		1		2					
Thelymitra spp.	GP			1		1					
Thysanotus dichotomus	GP			1		1					
Thysanotus multiflorus	GP	1	1	1	1	4		1	1	1	3
Thysanotus tenellus	GP		1		1	2	1	1	1	1	4
Trichocline spathulata	GP	1		1		2	1		1	1	3
****Aira cupaniana***	GR							1	1	1	3
Rytidosperma caespitosum	GR				1	1			1		1
Tetrarrhena laevis	GR	1			1	2	1	1	1	1	4
Macrozamia riedlei	CY	1	1	1	1	4	1	1	1	1	4
Billardiera variifolia	V	1	1	1		3	1	1	1	1	4
Hardenbergia comptoniana	V	1	1			2					
Kennedia coccinea	V		1	1	1	3	1	1	1	1	4
Kennedia microphylla	V	1				1					
Kingia australis	X	1				1	1		1		2
Xanthorrhoea gracilis	X	1	1	1	1	4	1	1	1	1	4
Xanthorrhoea preissii	X	1		1		2	1		1	1	3
Anarthria prolifera	Z	1	1		1	3	1	1	1	1	4
Anarthria scabra	Z	1		1	1	3	1	1	1	1	4
Cyathochaeta avenacea	Z	1	1	1	1	4	1		1	1	3
Desmocladus fasciculatus	Z	1	1	1	1	4	1	1	1	1	4
Desmocladus flexuosus	Z	1	1	1	1	4	1	1	1	1	4
Hypolaena exsulca	Z	1	1	1	1	4	1	1	1	1	4
Lepidosperma leptostachyum	Z				1	1	1	1	1	1	4
Lepidosperma longitudinale	Z	1				1					
Lepidosperma squamatum	Z	1	1	1	1	4	1	1	1	1	4
Loxocarya cinerea	Z				1	1					
Mesomelaena tetragona	Z	1				1					
Schoenus subbarbatus	Z						1				1
Schoenus subbulbosus	Z	1		1		2					
Tetraria capillaris	Z	1	1	1	1	4	1	1	1	1	4
Tetraria octandra	Z	1	1	1	1	4	1	1	1	1	4
Lindsaea linearis	F	1		1	1	3	1	1	1	1	4

Current Species Name	Life-form	Treatment 2005[1]					Treatment 2011[1]				
		ER	SW	SC	GR	Total	ER	SW	SC	GR	Total
Pteridium esculentum	F				1	1					
Isolepis marginata	R		1			1		1			1
Cassytha racemosa	P	1	1	1	1	4	1		1	1	3
Cassytha racemosa forma *racemosa*	P			1		1					
Nuytsia floribunda	P	1			1	2	1			1	2
TOTALS		184	112	143	140	243	158	107	152	146	220

[1] ER = external reference, SW = shelterwood, SC = selective cut, GR = gap release
[2] T = tree, S = shrub (>30 cm), DS = dwarf shrub (<30 cm), H = herb, GP = geophyte, GR = grass, CY = cycad, V = vine, X = grass tree, Z = sedge, F = fern, R = rush, P = parasite
[*] indicates weed species

INVERTEBRATES

Janet Farr, Allan Wills, and Paul Van Heurck

Introduction

Invertebrates, including class Insecta, comprise over 95% of the planet's biodiversity and therefore represent a crucial component in any ecosystem. Invertebrates play a major role in decomposition, nutrient recycling, plant pollination, and provide an important food source for vertebrates. In addition a wide range of species are already known to be exclusive to the southwest forests of Western Australia, and some of these are Gondwanan relics. Despite this, current knowledge of the invertebrate taxa present in the jarrah forest is limited.

The objectives of this component of FORESTCHECK monitoring are to:

- monitor and record the species of invertebrates in the various treatments of managed jarrah and uncut forest
- analyse trends in species composition, richness and abundance
- monitor the presence of Gondwanan relic and affinity invertebrate species with respect to the above treatments
- monitor the presence of known insect pest species.

Field survey and laboratory procedure

Sampling at all 11 Blackwood Plateau FORESTCHECK grids was carried out in November (spring) 2011 and March (autumn) 2012 using protocols outlined in the FORESTCHECK Operating Plan (available at www.dec.wa.gov.au). Briefly, active capture samples (hand sampling), involving sweeping, beating, and habitat searches of coarse woody debris (CWD) and litter were conducted once at each site for a total time of one person hour per capture/habitat method. Light traps were run for three nights, simultaneously at each site achieving one trap night per week for three weeks (no light trap failures) for each season, mean minimum overnight temperatures were 11 (± 1) and 8 (± 0.5) °C for spring and autumn respectively, suggesting autumn captures may be low; pitfall traps were opened for 10 days simultaneously at each site. Captures were bagged and labelled according to site and other capture details in the field and then transported in an insulated container back to a base camp were they were stored in a portable freezer. At the conclusion of a sampling period, specimens were then transported to the laboratory in Manjimup where they were sorted and compared to the extensive collection of voucher specimens held there. Morphospecies were assigned and vouchers for each morphospecies were erected as necessary and labelled according to site, date of capture and capture method and preserved as either pinned or alcohol specimens as a reference collection. To constrain sample processing times only macro-invertebrates are recorded, that is, invertebrates with a body length 10 mm or greater and Lepidoptera with a wing length of 12 mm or greater. Highly distinctive or relictual morphospecies, smaller than these sizes, were also recorded. Samples waiting to be processed were stored either frozen or in 80% ethanol.

Sorting, specimen identification and cataloguing have been completed for the spring light trap, hand and most of the pitfall samples. However, half of the light trap samples and all hand, and pitfall samples are yet to be sorted for the autumn monitoring period (Table 1). This report therefore summarises sampling results for 2011 and also includes a brief comparison with the initial Blackwood Plateau results for spring 2005. Note however, this is a preliminary report and results are from data as it exists for November 2012. Morphospecies assignment may change following data refinement from progressive taxonomic evaluation and will continue to be influenced by minor adjustments in the future as morphospecies assignment is further refined.

Site	Location	Sample method					
		Light trap		Pit fall trap		Active capture	
		Sp	Au	Sp	Au	Sp	Au
FC38	Barrabup	✓	1/3	X	X	✓	X
FC39	St John	✓	1/3	✓	X	✓	X
FC40	Layman	✓	1/3	✓	X	✓	X
FC41	Barrabup	✓	1/3	✓	X	✓	X
FC42	Cambray	✓	2/3	✓	X	✓	X
FC43	Barrabup	✓	2/3	✓	X	✓	X
FC44	Cambray	✓	2/3	✓	X	✓	X
FC45	Butler	✓	1/3	✓	X	✓	X
FC46	Barrabup	✓	1/3	X	X	✓	X
FC47	Cambray	✓	2/3	X	X	✓	X
FC48	Butler	✓	2/3	✓	X	✓	X

Table 1 Sample sorting summary for Blackwood Plateau FORESTCHECK grids in 2011–12 grouped by sample method and season (Sp = spring, Au = autumn). A tick indicates sorting and morphospecies allocation completed, a cross indicates sorting and morphospecies allocation is ongoing, 1/3 or 2/3 indicates proportion of sample sorted.

Preliminary results

Morphospecies richness and accumulation

Following the 2011–12 monitoring (given that sorting is still yet to be completed) the number of morphospecies recorded for FORESTCHECK increased to 2,133 (Fig. 1) and includes a total of 90,076 individual specimens. To date, the number of individual specimens captured at Blackwood Plateau in 2011 is 6,942, comprising 484 morphospecies. Comparing spring samples (pitfall captures excluded) for Blackwood Plateau in 2005 and 2011, 395 (3913 specimens) and 391 (6938 specimens) morphospecies were captured respectively (Table 2). Therefore species diversity is comparable between the two sample dates, although abundances differ. To date there are 44 new morphospecies recorded from Blackwood Plateau that were not previously captured in any of the FORESTCHECK locations (this figure will change following completion of sorting and morphospecies revision where synonymy is examined). Figure 1 shows the current cumulative captures for the successive sampling locations. The slope of the graph is now decreasing between successive sampling periods and shows a current trend of reduction indicating that there is a slight drop in species acquisition since the 2007–08 monitoring event. However this trend is tentative at this point. A species list for this current sample is shown in Appendix I.

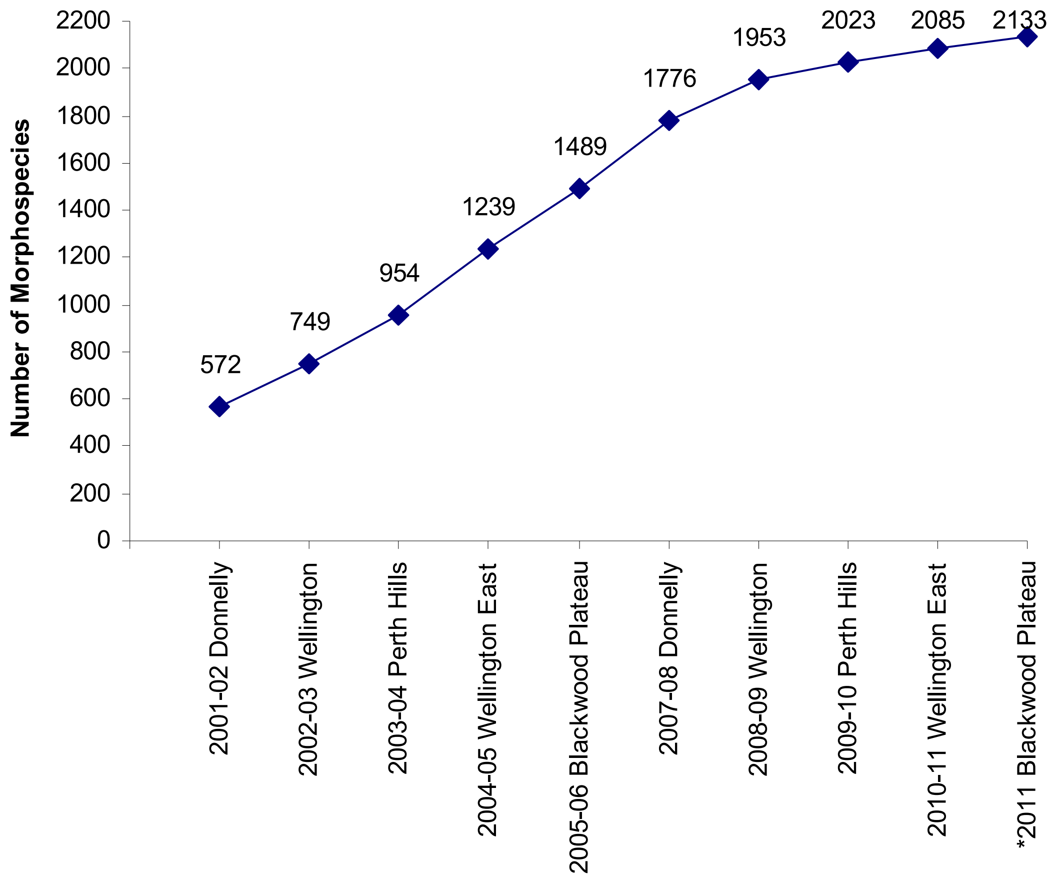

Figure 1. Cumulative morphospecies for 2001 (Donnelly) to spring 2011 (Blackwood Plateau, *figure excludes autumn 2012 captures and pitfall captures for 2011–12).

Morphospecies captures for other FORESTCHECK locations and sampling periods are shown in Table 2. Donnelly still appears the most diverse site followed by Blackwood Plateau and Wellington East 2004-5. Diversity for Blackwood Plateau is comparable for both sample periods, but abundance is much higher in 2011–12.

Table 2. Morphospecies comparisons between sample regions. Number of morphospecies and abundances for spring only, excluding pitfall captures, is shown in parentheses.

District	Sample period	Number of Morphospecies		Number of individuals	
Donnelly	2001–02	572		NA	
Wellington 1	2002–03	373		3080	
Perth Hills	2003–04	428		4883	
Wellington East	2004–05	617		28625	
Blackwood Plateau	2005–06	728	(395)	6959	(3913)
Donnelly	2007–08	787		13581	
Wellington 1	2008–09	592		5590	
Perth Hills	2009–10	529		6439	
Wellington East	2010–11	524		8040	
Blackwood Plateau	2011–12		(391)		(6938)

Figure 2 shows the numbers of morphospecies for invertebrate orders, where 10 or more morphospecies have been assigned, for spring 2005 and spring 2011 at Blackwood Plateau. Diversity was similar or slightly less for most orders in 2011, except for the Coleoptera group which was noticeably more diverse in 2011. No Onychophora were found in either sample period.

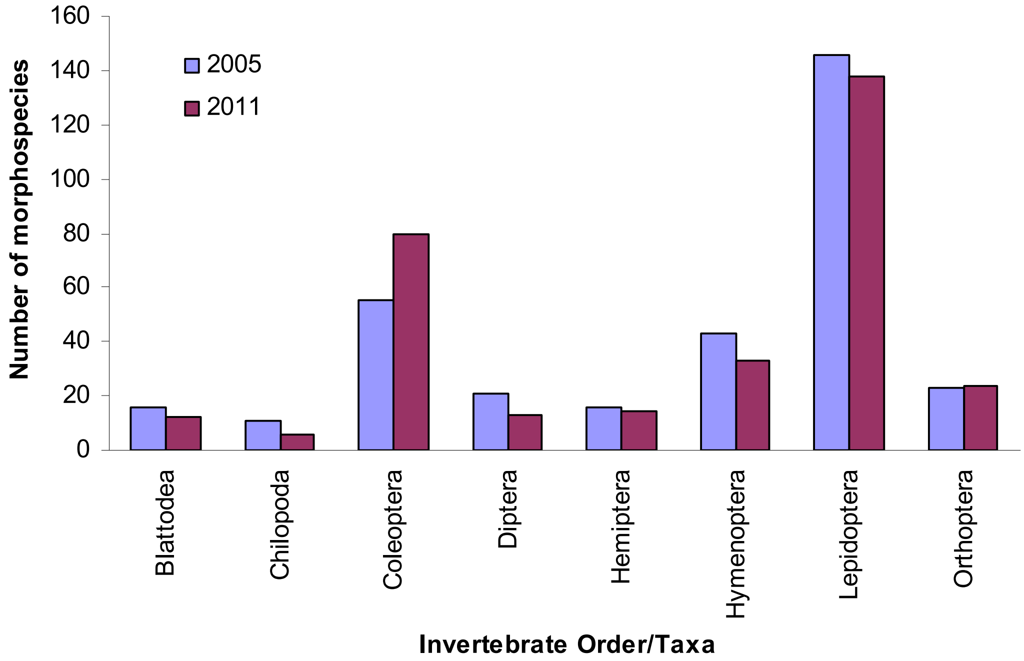

Figure 2. Numbers of morphospecies for invertebrate orders where ten or more morphospecies have been assigned for spring sampling (excluding pit fall samples) at Blackwood Plateau FORESTCHECK location in 2005 and 2011.

Comparing sample grids and silvicultural treatments
Comparison of sample grids and silvicultural treatments has not been reported in detail in this report since sorting to morpohospecies has not been completed. However a comparison of means for each sample period has been included (Fig. 3) since any trends should still be evident. At this stage of analysis, external reference grids seem consistently lower in diversity compared to other treatments. Shelterwood treatments appear to have the most diverse fauna, although these differences are not significant.

Species differences between localities
Species difference between localities has not been reported in this report since sorting to morpohospecies has not been completed.

Pest presence
Gumleaf skeletoniser (GLS) and Bullseye borer (BEB) were present in all but one grid and all grids respectively, but jarrah leafminer (JLM) was observed in only one grid in 2011–12 (Table 4). In the previous 2005–06 sample GLS was not observed in any grid; whereas BEB was observed in all but two grids (FC43 and FC46) and JLM were absent from five grids. The frequency of GLS occurrence reflects a significant outbreak of this species that began in the southern jarrah forest in 2009.

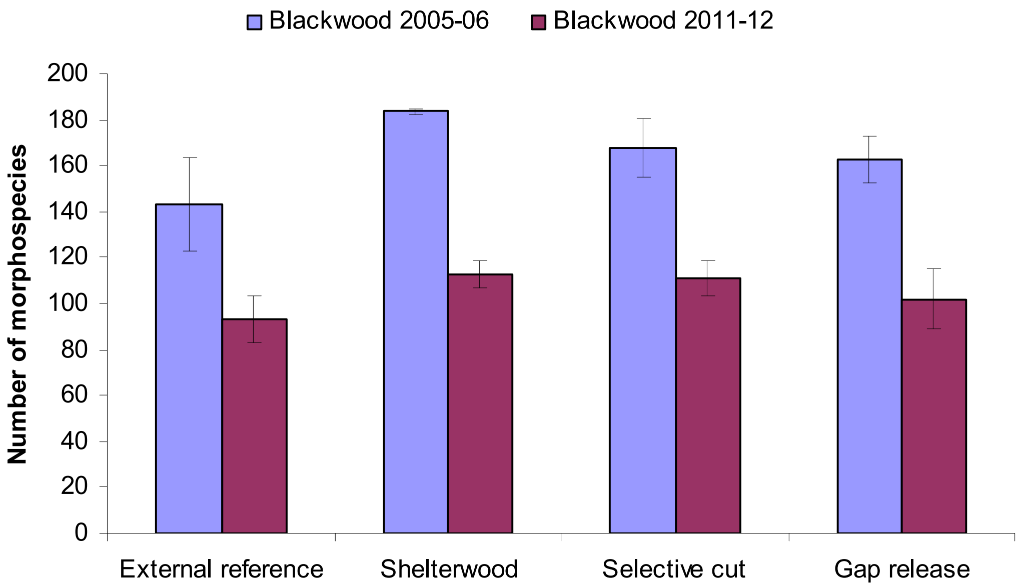

Figure 3 Mean (± se) number of morphospecies in each treatment at Blackwood Plateau FORESTCHECK grids in 2005–06 and 2011–12 (note sorting of 2011–12 sample is incomplete).

Table 4. Pest presence and abundance assessment at each Blackwood plateau FORESTCHECK grid (JLM = jarrah leaf miner; GLS = gumleaf skeletonizer; BEB = bullseye borer; 0 = absent, 1 = present, 2 = abundant).

Treatment	Site No	Location	JLM	GLS	BEB
External reference	FC38	Barrabup	1	1	1
External reference	FC39	St John	0	1	1
External reference	FC40	Layman	0	2	1
Shelterwood	FC41	Barrabup	0	1	1
Shelterwood	FC42	Cambray	0	1	1
Selective cut	FC43	Barrabup	0	1	1
Selective cut	FC44	Cambray	0	1	1
Selective cut	FC45	Butler	0	1	1
Gap release	FC46	Barrabup	0	1	1
Gap release	FC47	Cambray	0	1	1
Gap release	FC48	Butler	0	0	1

Assignment of taxa

Morphospecies consolidation in 2012 has enabled the taxonomic reference collection of Lepidoptera (moths and butterflies) to be refined. Identifying Lepidopteran taxa to family and further is difficult, even for expert taxonomists, since many of the characters are hidden and often requires destructive sampling to examine features such as genetalia and wing venation. This problem was also compounded by the predominant means of capture, namely light trapping, which results in many specimens being battered, often to a degree which prevents identification to even family level. As a consequence the collective morphospecies number of unidentifiable Lepidoptera is large, 1172. Sorting methods were also reviewed and are now more rapid, and don't include the standard setting procedure of pinned specimens. This procedure is time consuming and would eventually have made our assessment of invertebrate species diversity impossible to achieve with the time frame available. For many invertebrate taxa the problem of determining identity from improperly set specimens can be overcome to some degree, but for Lepidoptera it can be a problem for the less obvious taxa. Recently, however, we were fortunate enough to have three visiting Lepidopteran experts (from Victoria and South Australia, see Acknowlegements below) who helped sort and identify much of our moth collection. Their expertise provided the FORESTCHECK team with concepts that enable classification of most specimens to family, many even further.

Comparing sample periods for Blackwood Plateau, 146 and 138 morphospecies of Lepidoptera were determined for spring 2005 and 2011 respectively (see Fig. 2). Over all the FORESTCHECK grids from 2001 to 2012 there are 633 Lepidopteran morphospecies (Table 3) compared with 341 Coleopteran (beetles) and 243 Hymenopteran (wasps and ants) species. Although this suggests that Lepidoptera are the most predominant invertebrate group present in FORESTCHECK grids, it must be remembered that light trapping favours moth captures. Currently 31 Lepidopteran families have been collected and 42 morphospecies have no family assignment. Of the morphospecies determined to family level (although only 230 (36.3%) have been assigned genera), our application of parataxonomy to Lepidoptera now compares favourably with the other two large insect orders, Coleoptera (99.7 % identified to family) and Hymenoptera (99.6% identified to family). This will enable a more comprehensive comparison of taxa and functional groups across treatments in the future. Geometrids are the most common Lepidopteran family captured. These moths are predominantly plant feeders on forest over- and understorey. The most diverse beetle group, Curculionids (weevils) are also predominantly plant feeders. Weevils are recognised as the most diverse taxa on Earth, their food includes foliage, roots, wood, and seeds. Tiphiidae is the most diverse wasp family. They are well known flower pollinators — adults feed on nectar and many parasitize scarab larvae. Many females of this group are wingless and rely on males for dispersal. Males locate females using pheromones and some orchid species are known to mimic Tiphiid pheromones to attract male Tiphiidae pollinators. This group is therefore important in maintaining plant diversity. Some species are also used in biological control against scarab beetle pests.

Table 3. Comparison of taxa assignment between the three predominant insect orders for species collected from all FORESTCHECK grids.

Taxa	**Lepidoptera**		**Coleoptera**		**Hymenoptera**	
		%		%		%
Morphospecies	633		391		243	
Families collected	31		28		19	
Morphospecies with family assignment	591	93.4	390	99.7	242	99.6
Morphospecies assigned genera	230	36.3	294	75.2	48	19.8
Most diverse family	Geometridae		Curculionidae		Tiphiidae	
(number of species in family)	(263)		(87)		(48)	

Conclusions

In 2011–12 the Blackwood Plateau FORESTCHECK grids were re-sampled using the same sampling methods as for previous years. Autumn samples from all capture methods and all pitfall captures are yet to be sorted and morphospecies assigned. Consolidation of morphospecies assignment for all FORESTCHECK captures will enable a more comprehensive analysis of functional groups and taxa in respect to treatments. Pest observations reflected the current increase in GLS levels throughout the southern jarrah forest.

Acknowledgements
We would like to thank Patricia Dumitro and Julie Bickle for their assistance both in the field and laboratory. We are also grateful to David (Andy) Young (South Australia), Prof Doug Hilton (University Melbourne) and Dr Mike Halsey (LaTrobe University) for their assistance with Lepidoptera identification.

Appendix I. Species list and abundance of invertebrates recorded at Blackwood Plateau FORESTCHECK grids in 2011–12.

Species ID number	Order	Family	Superfamily, subfamily or tribe	Genus	Species	Abund-ance
2507	Araneomorphae					1
3600	Araneomorphae					1
1726	Araneomorphae	Araneidae		*Arachnura*	*higginsii*	1
938	Araneomorphae	Gnaphosidae		*Rebilus*	*sp*	1
3587	Araneomorphae	Gnaphosidae?				1
788	Araneomorphae	Theridiidae ?				1
3169	Blattodea					1
3595	Blattodea					3
3602	Blattodea					1
3649	Blattodea					2
27	Blattodea	Blaberidae	Epilamprinae	*Laxta*	*sp*	15
2017	Blattodea	Blattelidae				1
3151	Blattodea	Blattidae				5
122	Blattodea	Blattidae	Polyzosteriinae	*Platyzosteria*	*sp*	3
483	Blattodea	Blattidae	Polyzosteriinae	*Platyzosteria*	*sp*	1
899	Blattodea	Blattidae	Polyzosteriinae	*Platyzosteria*	*sp*	5
1474	Blattodea	Blattidae	Polyzosteriinae	*Platyzosteria*	*sp*	1
1888	Blattodea	Blattidae	Polyzosteriinae	*Platyzosteria*	*sp*	1
1897	Blattodea	Blattidae	Polyzosteriinae	*Platyzosteria*	*sp*	1
2003	Blattodea	Blattidae	Polyzosteriinae	*Polyzosteria*	*sp*	2
2224	Chilopoda					3
2981	Chilopoda					1
228	Chilopoda	Lithobiidae				3
1882	Chilopoda	Scolopendridae				3
1883	Chilopoda	Scolopendridae				1
223	Chilopoda	Scolopendridae	Otostigminae	*Ethmostigmus ?*		10
224	Chilopoda	Scolopendridae	Otostigminae	*Ethmostigmus ?*		6
1583	Chilopoda	Scolopendridae ?				1
3594	Coleoptera	Buprestidae	Buprestinae	*Castiarina*	*versicolor*	1
566	Coleoptera	Carabidae		*Notonomus*	*mediosulcatus ?*	7
1979	Coleoptera	Carabidae		*Promecoderus*	*sp*	13
3636	Coleoptera	Carabidae		*Sarcaphites*	*sp*	0
280	Coleoptera	Carabidae	Carabinae	*Carenum ?*		3
1059	Coleoptera	Carabidae	Lebiinae	*Agonocheila*	*sp*	1
2081	Coleoptera	Carabidae	Scaritinae	*Scaraphites ?*		2
1283	Coleoptera	Cerambycidae	Cerambycinae			1
654	Coleoptera	Cerambycidae	Cerambycinae	*Coptocercus*	*rubripes*	3
762	Coleoptera	Cerambycidae	Cerambycinae	*Phoracantha*	*semipuncta*	1
1041	Coleoptera	Cerambycidae	Cerambycinae	*Scolecobrotus*	*sp*	2
1040	Coleoptera	Cerambycidae	Cerambycinae	*Scolecobrotus*	*westwoodi*	1
351	Coleoptera	Cerambycidae	Cerambycinae	*Uracanthus*	*perthensis*	4
3583	Coleoptera	Cerambycidae	Lamiinae			1
1082	Coleoptera	Cerambycidae	Prioninae	*Sceleocantha*	*pilosicollis*	2
665	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsisterna*	*sp*	1
786	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsisterna*	*sp*	1
3597	Coleoptera	Cleridae		*Eleale*	*sp*	1
1103	Coleoptera	Cleridae	Clerinae	*Eunatalis*	*spinicornis*	1
244	Coleoptera	Curculionidae				2
1523	Coleoptera	Curculionidae	Amycterinae	*Acantholophus*	*sp*	2
1571	Coleoptera	Curculionidae	Amycterinae	*Cucullothorax*	*horridus*	2
1747	Coleoptera	Curculionidae	Amycterinae	*Euomus*	*sp nova*	1
3612	Coleoptera	Curculionidae	Amycterinae	*Euomus ?*		1
817	Coleoptera	Curculionidae	Amycterinae	*Talaurinus*	*sp*	2
1182	Coleoptera	Curculionidae	Aterpinae	*Pelororhinus*	*sp*	2
1238	Coleoptera	Curculionidae	Aterpinae	*Pelororhinus*	*sp*	1
349	Coleoptera	Curculionidae	Aterpinae	*Pelororhinus*	*stellio*	2
209	Coleoptera	Curculionidae	Aterpinae	*Rhinaria ?*		14
210	Coleoptera	Curculionidae	Entiminae	*Aesolithna*	*sp*	1
2088	Coleoptera	Curculionidae	Entiminae	*Mandalotus ?*		1
113	Coleoptera	Curculionidae	Entiminae	*Polyphrades*	*aesalon ?*	5
3598	Coleoptera	Curculionidae	Erihininae	*Aonychus ?*		1
161	Coleoptera	Curculionidae	Gonipterinae	*Oxyops*	*fasciata*	3
98	Coleoptera	Curculionidae	Gonipterinae	*Oxyops*	*pictipennis*	2
157	Coleoptera	Curculionidae	Rhadinosominae	*Rhadinosomus*	*lacordaire*	2

Species ID number	Order	Family	Superfamily, subfamily or tribe	Genus	Species	Abund-ance
13	Coleoptera	Dytiscidae	Colymbetinae	*Rhantus*	*suturalis*	5
2143	Coleoptera	Dytiscidae	Colymbetinae	*Rhantus*	*suturalis*	2
651	Coleoptera	Dytiscidae	Lancetinae	*Lancetes*	*lanceolatus*	160
1083	Coleoptera	Elateridae				38
1817	Coleoptera	Elateridae				9
26	Coleoptera	Elateridae	Agrypninae	*Conoderus*	*sp*	2
135	Coleoptera	Elateridae	Agrypninae	*Conoderus*	*sp*	1
444	Coleoptera	Elateridae	Agrypninae	*Conoderus*	*sp*	13
636	Coleoptera	Elateridae	Agrypninae	*Conoderus*	*sp*	1
909	Coleoptera	Elateridae	Agrypninae	*Conoderus*	*sp*	1
1062	Coleoptera	Elateridae	Agrypninae	*Conoderus*	*sp*	2
1109	Coleoptera	Elateridae	Agrypninae	*Conoderus*	*sp*	4
1818	Coleoptera	Elateridae	Agrypninae	*Conoderus*	*sp*	7
2443	Coleoptera	Elateridae	Agrypninae	*Conoderus*	*sp*	1
3325	Coleoptera	Elateridae	Agrypninae	*Conoderus*	*sp*	4
1120	Coleoptera	Elateridae	Agrypninae	*Drasterius ?*		1
14	Coleoptera	Hydrophilidae				394
1994	Coleoptera	Lycidae				2
99	Coleoptera	Lycidae	Metriorrhynchinae	*Metriorrhynchus*	*sp*	16
208	Coleoptera	Lycidae	Metriorrhynchinae	*Metriorrhynchus*	*sp*	9
802	Coleoptera	Lycidae	Metriorrhynchinae	*Metriorrhynchus*	*sp*	1
2000	Coleoptera	Lycidae	Metriorrhynchinae	*Metriorrhynchus*	*sp*	1
2852	Coleoptera	Scarabaeidae				1
189	Coleoptera	Scarabaeidae	Dynastinae	*Cryptodus*	*sp*	2
1838	Coleoptera	Scarabaeidae	Dynastinae	*Trissodon*	*sp*	1
2084	Coleoptera	Scarabaeidae	Dynastinae	*Trissodon*	*sp*	1
2625	Coleoptera	Scarabaeidae	Geotrupiinae	*Bolborhachium*	*dacoderum?*	3
1836	Coleoptera	Scarabaeidae	Geotrupinae	*Bolborhachium*	*hollowayi*	2
1847	Coleoptera	Scarabaeidae	Melolonthinae			30
1853	Coleoptera	Scarabaeidae	Melolonthinae			30
1926	Coleoptera	Scarabaeidae	Melolonthinae			40
2652	Coleoptera	Scarabaeidae	Melolonthinae			1
1138	Coleoptera	Scarabaeidae	Melolonthinae	*Colpochila*	*andersoni*	14
846	Coleoptera	Scarabaeidae	Melolonthinae	*Colpochila*	*antennalis*	4
1063	Coleoptera	Scarabaeidae	Melolonthinae	*Colpochila*	*bogaria ?*	11
353	Coleoptera	Scarabaeidae	Melolonthinae	*Colpochila*	*major*	8
845	Coleoptera	Scarabaeidae	Melolonthinae	*Colpochila*	*major*	4
3171	Coleoptera	Scarabaeidae	Melolonthinae	*Diphucephala*	*sp*	1
94	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	*sp*	63
347	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	*sp*	17
363	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	*sp*	9
951	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	*sp*	1
1566	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	*sp*	5
1660	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	*sp*	7
1856	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	*sp*	10
1843	Coleoptera	Scarabaeidae	Melolonthinae	*Maechidus*	*sp*	12
668	Coleoptera	Scarabaeidae	Melolonthinae	*Phyllotocus*	*ustulatus*	17
1813	Coleoptera	Scarabaeidae	Melolonthinae	*Scitalini*	*sp*	1
1846	Coleoptera	Scarabaeidae	Rutelinae	*Clilopocha*	*sp*	1
1187	Coleoptera	Tenebrionidae				1
2153	Coleoptera	Tenebrionidae	Alleculinae	*Homotrysis*	*sp*	2
340	Coleoptera	Tenebrionidae	Alleculinae	*Metistete*	*sp*	5
839	Coleoptera	Tenebrionidae	Alleculinae	*Metistete*	*sp*	1
192	Coleoptera	Tenebrionidae	Lagriinae	*Metriolagria*	*sp*	12
1061	Coleoptera	Trogidae				1
825	Coleoptera	Trogidae		*Omorgus*	*sp*	1
848	Coleoptera	Trogidae		*Omorgus*	*sp*	1
1538	Dermaptera					3
1790	Dermaptera					1
3550	Dermaptera					1
491	Dermaptera					2
492	Dermaptera					3
1433	Dermaptera	Anisolabididae				2
123	Dermaptera	Anisolabididae				1
258	Dermaptera	Anisolabididae				1
257	Dermaptera	Anisolabididae	Anisolabidinae			1
484	Dermaptera	Anisolabididae	Anisolabidinae			3
3609	Diplopoda					1

Species ID number	Order	Family	Superfamily, subfamily or tribe	Genus	Species	Abund-ance
3610	Diplopoda					3
3611	Diplopoda					1
259	Diplopoda	Julida				2
1478	Diptera	Asilidae				1
2648	Diptera	Asilidae				1
2709	Diptera	Asilidae				1
564	Diptera	Asilidae				1
204	Diptera	Asilidae				2
217	Diptera	Asilidae				1
312	Diptera	Asilidae				1
313	Diptera	Asilidae				6
1419	Diptera	Calliphoridae ?	poor specimen			1
3486	Diptera	Lonchaeidae ?				1
1850	Diptera	Pyrgotidae				1
54	Diptera	Syrphidae				2
206	Diptera	Syrphidae				2
2922	Diptera	Tabanidae				1
1151	Diptera	Tachinidae				1
2075	Diptera	Tachinidae				1
3590	Diptera	Tachinidae				1
498	Diptera	Tachinidae				1
532	Diptera	Therevidae				1
16	Diptera	Tipulidae				52
3604	Gastropoda					20
2021	Hemiptera	Alydidae		*Riptortus*	*sp*	1
200	Hemiptera	Cicadellidae				1
1851	Hemiptera	Cicadidae				2
1873	Hemiptera	Cicadidae				1
3023	Hemiptera	Cicadidae				1
3599	Hemiptera	Cicadidae				1
49	Hemiptera	Cicadidae	Tibicininae	*Cicadetta*	*sp*	1
700	Hemiptera	Coreidae	Coreinae	*Amorbus*	*bispinus*	4
2142	Hemiptera	Fulgoridae				1
764	Hemiptera	Fulgoridae				1
886	Hemiptera	Reduviidae				7
163	Hemiptera	Reduviidae				7
284	Hemiptera	Reduviidae				1
311	Hemiptera	Reduviidae				1
714	Hemiptera	Reduviidae				4
863	Hemiptera	Reduviidae	Harpactorinae			1
203	Hymenoptera	Anthophoridae				4
52	Hymenoptera	Apidae		*Apis*	*mellifera*	5
1093	Hymenoptera	Braconidae				1
3651	Hymenoptera	Braconidae				1
1553	Hymenoptera	Evaniidae				1
3382	Hymenoptera	Formicidae	Formicinae	*Camponotus*	*sp*	1
423	Hymenoptera	Formicidae				30
222	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*analis*	9
487	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*clarki*	1
3584	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*infima*	1
2046	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*michaelseni*	1
1880	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*swalei*	1
712	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*vindex*	4
697	Hymenoptera	Gasteruptiidae				1
1055	Hymenoptera	Ichneumonidae	Ophioninae	*Enicospilus*	*sp*	2
1079	Hymenoptera	Ichneumonidae	Ophioninae	*Enicospilus*	*sp*	2
1637	Hymenoptera	Ichneumonidae	Ophioninae	*Enicospilus*	*sp*	2
2885	Hymenoptera	Ichneumonidae	Ophioninae	*Enicospilus*	*sp*	1
1146	Hymenoptera	Ichneumonidae	Ophioninae	*Leptophion*	*sp*	1
1153	Hymenoptera	Ichneumonidae	Ophioninae	*Leptophion*	*sp*	1
1105	Hymenoptera	Ichneumonidae	Ophioninae	*Riekophion*	*bolus*	1
87	Hymenoptera	Ichneumonidae	Tryphoninae			1
1037	Hymenoptera	Ichneumonidae	Tryphoninae			4
1165	Hymenoptera	Ichneumonidae	Tryphoninae			10
2910	Hymenoptera	Ichneumonidae	Tryphoninae			1
6307	Hymenoptera	Mutilidae				1
2232	Hymenoptera	Pergidae		*Pergagrapta*	*sp*	1
2712	Hymenoptera	Pergidae		*Xyloperga*	*semipurpurata*	1

Species ID number	Order	Family	Superfamily, subfamily or tribe	Genus	Species	Abund-ance
3588	Hymenoptera	Pompilidae				1
3591	Hymenoptera	Pompilidae	Epipompilinae	*Epipomilus*	*sp*	1
1859	Hymenoptera	Scoliidae	Scoliinae			2
1894	Hymenoptera	Tiphiidae				1
3601	Hymenoptera	Tiphiidae				1
2228	Hymenoptera	Tiphiidae	Thyninnae			1
2668	Hymenoptera	Tiphiidae	Thyninnae			1
3592	Hymenoptera	Tiphiidae	Thyninnae			1
3593	Hymenoptera	Tiphiidae	Thyninnae			2
699	Hymenoptera	Tiphiidae	Thyninnae	*Eirone*	*sp*	1
2025	Hymenoptera	Tiphiidae	Thyninnae	*Eirone*	*sp*	1
544	Isopoda					21
1586	Isopoda					1
539	Isopoda					1
671	Isopoda					1
600	Lepidoptera					1
1870	Lepidoptera					1
1967	Lepidoptera					1
3647	Lepidoptera					1
3654	Lepidoptera					1
3656	Lepidoptera					5
3659	Lepidoptera					1
430	Lepidoptera					2
1627	Lepidoptera	Anthelidae				6
755	Lepidoptera	Anthelidae				3
457	Lepidoptera	Anthelidae	Anthelinae	*Anthela*	*ferruginosa?*	15
6	Lepidoptera	Arctiidae				22
1091	Lepidoptera	Arctiidae	Arctiinae	*Nyctemera*	*amica*	1
376	Lepidoptera	Arctiidae	Lithosiinae	*Castulo*	*doubledayi*	61
366	Lepidoptera	Arctiidae	Lithosiinae	*Scoliacma*	*sp*	31
1519	Lepidoptera	Arctiidae	Lithosiinae	*Threnosia*	*sp*	9
3426	Lepidoptera	Arctiidae	Lithosiinae	*Threnosia ?*		2
1	Lepidoptera	Carthaeidae		*Carthaea*	*saturnioides*	15
2957	Lepidoptera	Cossidae	Cossinae	*Culama*	*australis*	2
3579	Lepidoptera	Cossidae ?				1
324	Lepidoptera	Depressariidae				30
141	Lepidoptera	Depressariidae		*Thalamarchella*	*alveola*	9
1222	Lepidoptera	Gelechiidae		*Miscera ?*		17
658	Lepidoptera	Gelechiidae ?				8
954	Lepidoptera	Geometridae				3
1034	Lepidoptera	Geometridae				3
1127	Lepidoptera	Geometridae				3
1514	Lepidoptera	Geometridae				1
1964	Lepidoptera	Geometridae				1
2634	Lepidoptera	Geometridae				5
2637	Lepidoptera	Geometridae				1
3494	Lepidoptera	Geometridae				1
3650	Lepidoptera	Geometridae				1
3652	Lepidoptera	Geometridae				1
24	Lepidoptera	Geometridae				2
369	Lepidoptera	Geometridae				4
382	Lepidoptera	Geometridae				4
407	Lepidoptera	Geometridae				4
422	Lepidoptera	Geometridae				23
434	Lepidoptera	Geometridae				1
441	Lepidoptera	Geometridae				4
758	Lepidoptera	Geometridae				2
760	Lepidoptera	Geometridae				2
66	Lepidoptera	Geometridae	Ennominae			6
3577	Lepidoptera	Geometridae	Ennominae			1
47	Lepidoptera	Geometridae	Ennominae			2
326	Lepidoptera	Geometridae	Ennominae			2
383	Lepidoptera	Geometridae	Ennominae			7
655	Lepidoptera	Geometridae	Ennominae			2
436	Lepidoptera	Geometridae	Ennominae	*Casbia ?*		3
50	Lepidoptera	Geometridae	Ennominae	*Euphronarcha ?*		2
77	Lepidoptera	Geometridae	Ennominae	*Gastrinodes*	*sp*	5
459	Lepidoptera	Geometridae	Ennominae	*Gastrinodes*	*sp*	1

Species ID number	Order	Family	Superfamily, subfamily or tribe	Genus	Species	Abund-ance
424	Lepidoptera	Geometridae	Ennominae	*Melanodes*	*sp*	3
757	Lepidoptera	Geometridae	Ennominae	*Melanodes*	*sp*	1
758	Lepidoptera	Geometridae	Ennominae	*Melanodes*	*sp*	47
3113	Lepidoptera	Geometridae	Ennominae	*Melanodes*	*sp*	4
384	Lepidoptera	Geometridae	Ennominae	*Pholodes*	*sp*	7
858	Lepidoptera	Geometridae	Ennominae	*Stibaroma*	*melanotoxa*	1
920	Lepidoptera	Geometridae	Ennominae	*Stibaroma*	*melanotoxa*	1
19	Lepidoptera	Geometridae	Geometrinae	*Chlorocoma*	*dicloraria*	12
22	Lepidoptera	Geometridae	Geometrinae	*Chlorocoma*	*sp*	25
330	Lepidoptera	Geometridae	Geometrinae	*Crypsiphona*	*ocultaria*	4
1179	Lepidoptera	Geometridae	Geometrinae	*Euloxia*	*sp*	1
835	Lepidoptera	Geometridae	Geometrinae	*Hypobapta*	*barnardi*	1
41	Lepidoptera	Geometridae	Larentiinae			1
95	Lepidoptera	Geometridae	Larentiinae			1
652	Lepidoptera	Geometridae	Larentiinae			2
2630	Lepidoptera	Geometridae	Larentiinae	*Poecilasthena*	*sp*	2
42	Lepidoptera	Geometridae	Larentiinae	*Xanthorhoe*	*sp*	5
417	Lepidoptera	Geometridae	Larentiinae	*Xanthorhoe*	*sp*	2
455	Lepidoptera	Geometridae	Larentiinae	*Xanthorhoe*	*sp*	1
957	Lepidoptera	Geometridae	Oenochrominae			5
1875	Lepidoptera	Geometridae	Oenochrominae			1
3453	Lepidoptera	Geometridae	Oenochrominae			4
3456	Lepidoptera	Geometridae	Oenochrominae			3
411	Lepidoptera	Geometridae	Oenochrominae			4
631	Lepidoptera	Geometridae	Oenochrominae	*Arcina*	*fulgorigera*	4
2	Lepidoptera	Geometridae	Oenochrominae	*Arhodia*	*lasiocamparia*	10
389	Lepidoptera	Geometridae	Oenochrominae	*Cernia*	*sp*	2
31	Lepidoptera	Geometridae	Oenochrominae	*Circopetes*	*sp*	9
900	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*astrosignata ?*	1
1834	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*consignata ?*	17
321	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*personalis*	3
48	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*sp*	84
67	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*sp*	209
855	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*sp*	1
1155	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*sp*	2
2639	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*sp*	4
2905	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*sp*	1
3618	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*sp*	1
425	Lepidoptera	Geometridae	Oenochrominae	*Epidesmia ?*		1
861	Lepidoptera	Geometridae	Oenochrominae	*Nearcha ?*		2
59	Lepidoptera	Geometridae	Oenochrominae	*Oenochroma*	*cerasiplaga*	1
2140	Lepidoptera	Geometridae	Oenochrominae	*Oenochroma*	*ochripennata*	1
72	Lepidoptera	Geometridae	Oenochrominae	*Oenochroma*	*sp*	3
320	Lepidoptera	Geometridae	Oenochrominae	*Oenochroma ?*		3
1828	Lepidoptera	Geometridae	Oenochrominae	*Oenochroma ?*		63
377	Lepidoptera	Geometridae	Oenochrominae	*Phallaria*	*ophiusaria*	2
3648	Lepidoptera	Hepialidae				1
372	Lepidoptera	Hepialidae		*Abantiades*	*hydrographis*	3
373	Lepidoptera	Hepialidae		*Abantiades*	*ocellatus*	1
761	Lepidoptera	Hepialidae		*Abantiades*	*sp*	1
1832	Lepidoptera	Lasiocampidae				5
3658	Lepidoptera	Lasiocampidae				1
380	Lepidoptera	Lasiocampidae				4
91	Lepidoptera	Lasiocampidae	Lasiocampinae	*Entometa*	*fervens*	1
426	Lepidoptera	Lasiocampidae	Lasiocampinae	*Entometa*	*sp*	5
1625	Lepidoptera	Limacodidae		*Doratifera*	*sp*	23
1830	Lepidoptera	Limacodidae		*Doratifera*	*sp*	9
81	Lepidoptera	Limacodidae		*Doratifera*	*sp*	3
332	Lepidoptera	Limacodidae		*Doratifera*	*sp*	6
398	Lepidoptera	Limacodidae		*Doratifera*	*sp*	2
60	Lepidoptera	Lymantriidae				5
80	Lepidoptera	Lymantriidae				7
657	Lepidoptera	Lymantriidae				4
1501	Lepidoptera	Noctuidae				2
3578	Lepidoptera	Noctuidae				1
3580	Lepidoptera	Noctuidae				2
3589	Lepidoptera	Noctuidae				1
3646	Lepidoptera	Noctuidae				2

Species ID number	Order	Family	Superfamily, subfamily or tribe	Genus	Species	Abund-ance
33	Lepidoptera	Noctuidae				1
38	Lepidoptera	Noctuidae				1
140	Lepidoptera	Noctuidae				1
770	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*melanographa ?*	2
39	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*pissonephra*	98
388	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*poliocrossa*	1
1139	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*sp*	2
1502	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*sp*	54
1858	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*sp*	2
1899	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*sp*	2
2627	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*sp*	1
2752	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa ?*		3
30	Lepidoptera	Noctuidae	Catocalinae	*Dasypodia*	*selenophora*	1
5	Lepidoptera	Noctuidae	Catocalinae	*Pantydia*	*sp*	20
2882	Lepidoptera	Noctuidae	Catocalinae	*Pantydia*	*sp*	1
329	Lepidoptera	Noctuidae	Catocalinae	*Pantydia*	*sparsa*	1
391	Lepidoptera	Noctuidae	Hadeninae			3
40	Lepidoptera	Noctuidae	Hadeninae	*Persectania*	*ewingii*	3
336	Lepidoptera	Noctuidae	Heliothinae	*Helicoverpa*	*sp*	1
43	Lepidoptera	Noctuidae	Hypeninae	*Sandava*	*scitisigna*	12
419	Lepidoptera	Noctuidae	Noctuinae			1
18	Lepidoptera	Noctuidae	Noctuinae	*Agrotis*	*infusa*	3256
686	Lepidoptera	Noctuidae	Nolinae	*Uraba*	*lugens*	16
656	Lepidoptera	Notodontidae		*Antimima*	*sp*	6
4	Lepidoptera	Notodontidae		*Destolmia*	*sp*	16
76	Lepidoptera	Notodontidae		*Gallaba*	*sp*	7
2893	Lepidoptera	Notodontidae		*Gallaba*	*sp*	3
57	Lepidoptera	Notodontidae		*Danima*	*banksiae*	5
58	Lepidoptera	Notodontidae		*Sorama*	*bicolor*	2
370	Lepidoptera	Notodontidae		*Sorama*	*bicolor*	9
1068	Lepidoptera	Notodontidae	Thaumetopoeinae			2
32	Lepidoptera	Notodontidae	Thaumetopoeinae	*Epicoma*	*sp*	12
3	Lepidoptera	Notodontidae	Thaumetopoeinae	*Epicoma*	*spp*	28
4	Lepidoptera	Notodontidae	Thaumetopoeinae	*Ochrogaster*	*sp*	7
7	Lepidoptera	Notodontidae	Thaumetopoeinae	*Ochrogaster*	*sp*	63
8	Lepidoptera	Notodontidae	Thaumetopoeinae	*Ochrogaster*	*sp*	2
10	Lepidoptera	Notodontidae	Thaumetopoeinae	*Ochrogaster*	*sp*	30
1626	Lepidoptera	Oecophoridae				1
1840	Lepidoptera	Oecophoridae				18
1903	Lepidoptera	Oecophoridae				2
3586	Lepidoptera	Oecophoridae				2
62	Lepidoptera	Oecophoridae				5
64	Lepidoptera	Oecophoridae				8
65	Lepidoptera	Oecophoridae				81
104	Lepidoptera	Oecophoridae				59
396	Lepidoptera	Oecophoridae				9
111	Lepidoptera	Oecophoridae	Oecophorinae	*Philobota*	*xanthastis*	1
236	Lepidoptera	Oecophoridae ?				1
3582	Lepidoptera	Oenosandridae				1
404	Lepidoptera	Oenosandridae		*Oenosandra*	*boisduvalii*	1
374	Lepidoptera	Oenosandridae				90
864	Lepidoptera	Psychidae?				15
63	Lepidoptera	Pyralidae				43
333	Lepidoptera	Pyralidae				17
948	Lepidoptera	Pyralidae				2
1051	Lepidoptera	Pyralidae				18
1134	Lepidoptera	Pyralidae				3
1491	Lepidoptera	Pyralidae				1
1864	Lepidoptera	Pyralidae				4
2631	Lepidoptera	Pyralidae				1
2888	Lepidoptera	Pyralidae				1
2890	Lepidoptera	Pyralidae				3
2901	Lepidoptera	Pyralidae				2
3483	Lepidoptera	Pyralidae				1
3653	Lepidoptera	Pyralidae				1
3655	Lepidoptera	Pyralidae				1
342	Lepidoptera	Pyralidae				6
397	Lepidoptera	Pyralidae				1

Species ID number	Order	Family	Superfamily, subfamily or tribe	Genus	Species	Abund-ance
401	Lepidoptera	Pyralidae				1
922	Lepidoptera	Pyralidae	Crambinae	*Hednota*	*recurvella*	4
2884	Lepidoptera	Pyralidae	Crambinae	*Hednota*	*sp*	1
460	Lepidoptera	Pyralidae	Epipaschiinae			4
1126	Lepidoptera	Pyralidae	Epipaschiinae			4
73	Lepidoptera	Pyralidae	Epipaschiinae ?			4
322	Lepidoptera	Pyralidae	Nymphulinae	*Nymphula*	*nitens*	24
84	Lepidoptera	Pyralidae	Pyraustinae	*Uresiphita*	*ornithopteralis*	5
947	Lepidoptera	Pyralidae ?				2
1490	Lepidoptera	Pyralidae ?				5
2441	Lepidoptera	Pyralidae ?				1
2892	Lepidoptera	Pyralidae ?				1
3221	Lepidoptera	Pyralidae ?				1
3415	Lepidoptera	Pyralidae ?				1
3581	Lepidoptera	Pyralidae ?				1
328	Lepidoptera	Saturniidae		*Opodiphthera*	*helena*	2
319	Lepidoptera	Tineidae		*Moerarchis*	*clathrella*	13
92	Lepidoptera	Tortricidae				8
950	Lepidoptera	Tortricidae ?				3
1172	Lepidoptera	UNIDENTIFIABLE		*unidentifiable*	*unidentifiable*	109
1833	Lepidoptera	Xyloryctidae				7
1895	Lepidoptera	Xyloryctidae				6
316	Lepidoptera	Xyloryctidae ?				9
45	Lepidoptera	Zygaenidae		*Pollanisus*	*cupreus*	5
78	Lepidoptera	Zygaenidae		*Pollanisus*	*sp*	9
132	Mantodea	Amorphoscelidae	Paraoxypilinae			3
784	Mantodea	Mantidae				2
89	Mecoptera	Meropeidae		*Austromerope*	*poultoni*	1
3596	Mygalomorphae	Nemesiidae				1
721	Mygalomorphae	Nemesiidae		*Chenistonia*	*sp*	3
3658	Neuroptera					1
2710	Neuroptera	Chrysopidae				2
3464	Neuroptera	Chrysopidae				6
822	Neuroptera	Chrysopidae		*Chrysopa*	*sp*	2
3463	Neuroptera	Hemerobiidae				19
131	Neuroptera	Hemerobiidae				1
1938	Neuroptera	Osmylidae				1
3402	Neuroptera	Osmylidae				4
3645	Neuroptera	Osmylidae				12
1758	Odonata	Lestidae	Lestoidea	*Austrolestes*	*io*	1
3605	Oligochaeta					9
3606	Oligochaeta					1
890	Orthoptera	Acrididae				2
174	Orthoptera	Acrididae				3
234	Orthoptera	Acrididae				1
738	Orthoptera	Acrididae				2
868	Orthoptera	Acrididae	Catantopinae	*Adreppus*	*sp*	2
690	Orthoptera	Acrididae	Catantopinae	*Cedarinia*	*sp*	2
890	Orthoptera	Acrididae	Catantopinae	*Cedarinia*	*sp*	4
892	Orthoptera	Acrididae	Catantopinae	*Cedarinia*	*sp*	1
231	Orthoptera	Acrididae	Catantopinae	*Coryphistes*	*sp*	2
233	Orthoptera	Acrididae	Catantopinae	*Goniaea*	*sp*	1
235	Orthoptera	Acrididae	Catantopinae	*Goniaea*	*sp*	2
256	Orthoptera	Acrididae	Catantopinae	*Goniaea*	*sp*	3
872	Orthoptera	Acrididae	Catantopinae	*Goniaea*	*sp*	1
1441	Orthoptera	Acrididae	Catantopinae	*Goniaea*	*sp*	1
1470	Orthoptera	Acrididae	Catantopinae	*Goniaea*	*sp*	1
1984	Orthoptera	Acrididae	Catantopinae	*Goniaea*	*sp*	4
232	Orthoptera	Acrididae	Catantopinae	*Goniaea*	*vocans?*	1
255	Orthoptera	Acrididae	Catantopinae	*Goniaea*	*vocans?*	3
1261	Orthoptera	Acrididae	Catantopinae	*Goniaoidea*	*sp*	1
857	Orthoptera	Gryllidae				1
3585	Orthoptera	Gryllidae				1
1916	Orthoptera	Gryllidae		*Teleogryllus*	*commodus*	2
180	Orthoptera	Gryllidae				6
609	Orthoptera	Gryllidae				1
526	Orthoptera	Stenopelmatidae	Henicinae	*Onosandrus*	*sp*	18
3189	Orthoptera	Tettigoniidae				1

Species ID number	Order	Family	Superfamily, subfamily or tribe	Genus	Species	Abund-ance
3190	Orthoptera	Tettigoniidae				1
167	Orthoptera	Tettigoniidae				1
218	Orthoptera	Tettigoniidae				1
314	Orthoptera	Tettigoniidae				8
715	Orthoptera	Tettigoniidae				1
1052	Orthoptera	Tettigoniidae	Phasmodinae			1
521	Platyhelminthes	Tricladida				5
880	Scorpionida					5
2693	Scorpionida					1
469	Scorpionida					2
1852	Trichoptera	Hydropsychidae				13
144	Trichoptera	Hydropsychidae				20

DIURNAL and NOCTURNAL BIRDS

Graeme Liddelow, Richard Robinson and Verna Tunsell

Introduction

Studies on the response of birds to disturbance in eucalypt forests and woodlands have demonstrated that deforestation (permanent removal of forest) has the largest impact on bird species (Catterall *et al.* 1998). The object of recording birds in FORESTCHECK is to monitor the impacts of logging and associated burning on bird species composition and abundance. This is achieved by:

- recording species richness and abundance within each treatment (external reference, shelterwood , selective cut and gap release)
- comparing species richness and abundance between each treatment
- analysing trends within species between treatments.

Monitoring

There are 11 FORESTCHECK monitoring grids in the Blackwood Plateau. Three external reference, two shelterwood, three selective cut and three gap release grids. Sight and sound are both used to identify birds and the census techniques are detailed in the FORESTCHECK Operating Plan (available at www.dec.wa.gov.au). Briefly, for diurnal birds each grid was monitored five times during the spring of 2011, with at least 7 days between each census. Monitoring commenced at sunrise and continued for four hours after sunrise in fine still weather. The central 1 ha area at each grid was monitored for 20 mins before moving on to the next grid. Monitoring of diurnal birds was undertaken in spring 2011.

Nocturnal bird monitoring is normally carried out at a point central to a set of grids (a set consists of one of each external reference, shelterwood, selective cut and gap release grid). Each census includes periods of listening (15 mins), playback (5 mins per species) and spotlighting (10 mins). However, formal monitoring for nocturnal birds was not conducted in 2011–12.

Preliminary results and discussion

Diurnal birds

2011 survey

A total of 36 species of birds comprising 640 individuals were recorded in 2011, with 18 species having 10 or more individuals (Fig. 1 and Table 1). Twenty six species and 177 individuals were recorded in the external reference treatment and 24 species and 106 individuals in the shelterwood, 27 species and 173 individuals in the gap release and 27 species and 184 individuals in the selective cut treatments. Numbers of species and individuals in the shelterwood treatment was lower than the other three treatments as there were only two monitoring grids in this treatment compared to three in each of the external reference, gap release and selective cut treatments.

Six species of birds were recorded in only one treatment (either external reference, shelterwood, selective cut or gap release — see Table 1). However, none of these would be expected to be restricted to that particular treatment.

The most common bird recorded was the broad-tailed thornbill (*Acanthiza apicalis*) with a count of 112. Only six other birds were recorded 30 times or more; they were the striated pardalote (*Pardalotus striatus*) 55, western spinebill *(Acanthorhynchus superciliosus)* 53, western gerygone (*Gerygone fusca*) 42, western thornbill *(Acanthiza inornata)* 35, scarlet robin *(Petroica multicolor)* 34, and golden whistler (*Pachycephala pectoralis*) with 32. These seven species accounted for well over one-half (57%) of the total records for 2011 (i.e. 363 of 640) (Table 1).

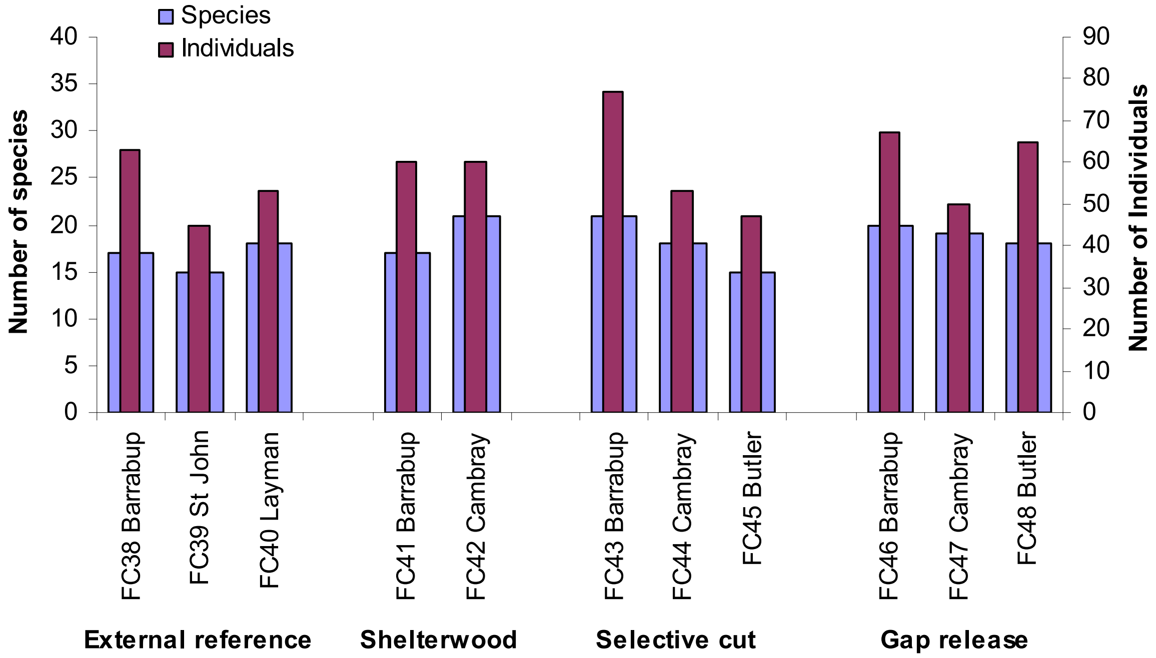

Figure 1. Number of bird species and individuals recorded in each Blackwood Plateau FORESTCHECK grid in 2011.

The average density of birds within the treatments in 2011 was 11.6. This is almost identical to the long-term Kingston Study (see Abbott *et al*. 2003, 2009) in the southern jarrah forest region, where the yearly average density is 10.4 birds ha^{-1} (Liddelow, unpublished). The densities in each treatment at Blackwood Plateau were 11.8 birds ha^{-1} in the external reference, 11.7 in both the shelterwood and gap release and 11.5 in the selective cut.

Two small scrub bird species, the red-winged fairy-wren (*Malurus elegans*) and white-browed scrubwren (*Sericornis frontalis*) were relatively common with 28 and 23 individuals respectively. However, the white-browed scrubwren was not recorded in any external reference grids. This stage of development on harvested grids provides ideal habitat for both species, while the more open understorey in external reference grids is less suitable.

Comparing 2005 and 2011 surveys

A total of 38 species has been recorded at Blackwood Plateau over the two sample years (2005 and 2011) (Table 1). There were 36 species recorded in 2011 and 28 species in 2005. Two species recorded 2005 were not recorded in 2011; Baudin's cockatoo (*Calyptorhynchus baudinii*) and the splendid fairy-wren (*Malurus splendens*). There were 10 species recorded in 2011 that were not recorded in 2005; the pallid cuckoo *(Cuculus pallidus*), fan-tailed cuckoo (*Cacomantis flabelliformis*), tree martin (*Hirundo nigricans*), restless flycatcher (*Myiagra inquita*), red-capped robin (*Petroica goodenovii*), white-breasted robin (*Eopsaltria georgiana*), New Holland honeyeater (*Phylidonyris novaehollandiae*), red wattlebird (*Anthochaera carunculata)*, grey butcherbird (*Cracticuc toruatus*) and the Australian raven (*Corvus coronoides*).

Table 1 Species list and the number of birds recorded in each treatment at Blackwood in 2011.

RAOU No.[1]	Scientific name	Common Name	Treatment 2005				Total 2005	Treatment 2011				Total 2011
			External reference	Shelter-wood	Selective cut	Gap release		External reference	Shelter-wood	Selective cut	Gap release	
930	*Corvus coronoides*	Australian raven						1			1	**2**
294	*Platycerus zonarius*	Australian ringneck	6	2			**8**			8	3	**11**
266	*Calyptorhynchus baudinii*	Baudins cockatoo			2		**2**					
424	*Coracina novaehollandiae*	Black-faced cuckoo-shrike	1	2	1	1	**5**	3		5	1	**9**
476	*Acanthiza apicalis*	Broad-tailed (Inland) thornbill	22	23	32	41	**118**	31	18	30	33	**112**
338	*Cacomantis flabelliformis*	Fan-tailed cuckoo						1		2		**3**
264	*Calyptorhynchus banksii naso*	Forest red-tailed black cockatoo		2			**2**			4		**4**
398	*Pachycephala pectoralis*	Golden whistler	8	4	17	12	**41**	8	5	10	9	**32**
702	Cracticus torguatus	Grey butcherbird								1		**1**
697	*Sterpera versicolor*	Grey currawong		1			**1**	5	3		2	**10**
361	*Rhipidura fuliginosa*	Grey fantail		1		1	**2**	5	1	9	2	**17**
408	*Colluricincla harmonica*	Grey shrike-thrush	5	1	2	2	**10**	3	2	2	1	**8**
574	*Zosterops lateralis*	Grey-breasted white-eye (Silvereye)			3	3	**6**		4			**4**
342	*Chrysococcyx basalis*	Horsefield's bronze-cuckoo			1		**1**	1	3	1	2	**7**
322	*Dacelo novaeguineae*	Laughing kookaburra		2			**2**	1		1	1	**3**
631	*Phylidonyris novaehollandiae*	New Holland honeyeater							2			**2**
337	*Cuculus pallidus*	Pallid cuckoo						2		1		**3**
638	*Anthochaera carunculata*	Red wattlebird								1	3	**4**
290	*Platycerus spurius*	Red-capped parrot	6			3	**9**	6	2		6	**14**
381	*Petroica goodenovii*	Red-capped robin									1	**1**
538	*Malurus elegans*	Red-winged fairy-wren	2	3	4	2	**11**	5	4	11	8	**28**
369	Myiagra inquieta	Restless flycatcher						1				**1**
556	*Climacteris rufa*	Rufous treecreeper	2	1	1		**4**	5	1	2		**8**
380	*Petroica multicolor*	Scarlet robin	4	8	5	2	**19**	12	4	10	8	**34**
344	*Chrysococcyx lucidus*	Shining bronze-cuckoo			1	2	**3**	1		1	3	**5**
532	*Malurus splendens*	Spendid fairy-wren			4		**4**					
565	*Pardalotus puntatus*	Spotted pardalote	8	9	26	16	**59**	2	2	5	6	**15**
976	*Pardolotus striatus*	Striated pardalote	15	16	11	20	**62**	14	9	17	15	**55**
359	*Hirundo nigricans*	Tree martin						13	3	2	6	**24**
549	*Daphoenositta chrysoptera*	Varied sitella	1			4	**5**	5	2			**7**

Table 1.

RAOU No.[1]	Scientific name	Common Name	Treatment 2005				Total 2005	Treatment 2011				Total 2011
			External reference	**Shelter-wood**	**Selective cut**	**Gap release**		**External reference**	**Shelter-wood**	**Selective cut**	**Gap release**	
463	*Gerygone fusca*	Western gerygone	9	8	10	9	**36**	15	7	13	7	**42**
289	*Platycercus icterotis*	Western rosella	2	2	1	1	**6**		3	12	6	**21**
592	*Acanthorhynchus superciliosus*	Western spinebill	10	3	13	18	**44**	15	10	12	16	**53**
472	*Acanthiza inornata*	Western thornbill	3	2	5		**10**	9	5	10	11	**35**
578	*Melithreptus chloropsis*	Western white-naped honeyeater			2		**2**	4	4	5	9	**22**
394	*Eopsaltria australis griseogularis*	Western yellow robin	1			2	**3**	9	2	4	2	**17**
387	*Eopsaltria georgiana*	White-breasted robin							2		1	**3**
488	*Sericornis frontalis*	White-browed scrubwren	6	1	5	4	**16**		8	5	10	**23**
		Total Species	**18**	**19**	**20**	**18**	**28**	**26**	**24**	**27**	**27**	**36**
		Total Individuals	**111**	**91**	**146**	**143**	**491**	**177**	**106**	**184**	**173**	**640**

[1] RAOU = Royal Australian Ornithology Union number

None of the species recorded would be restricted to any particular successional stage following harvesting and all could be expected to have been recorded in each of the monitoring years.

The number of species and the number of individual birds recorded increased in all treatments in 2011 (Fig. 2 and 3). The overall bird density and numbers increased from 8.9 birds ha^{-1} with 491 individuals in 2005 to 11.6 birds ha^{-1} with 640 individuals in 2011 (Fig. 4).

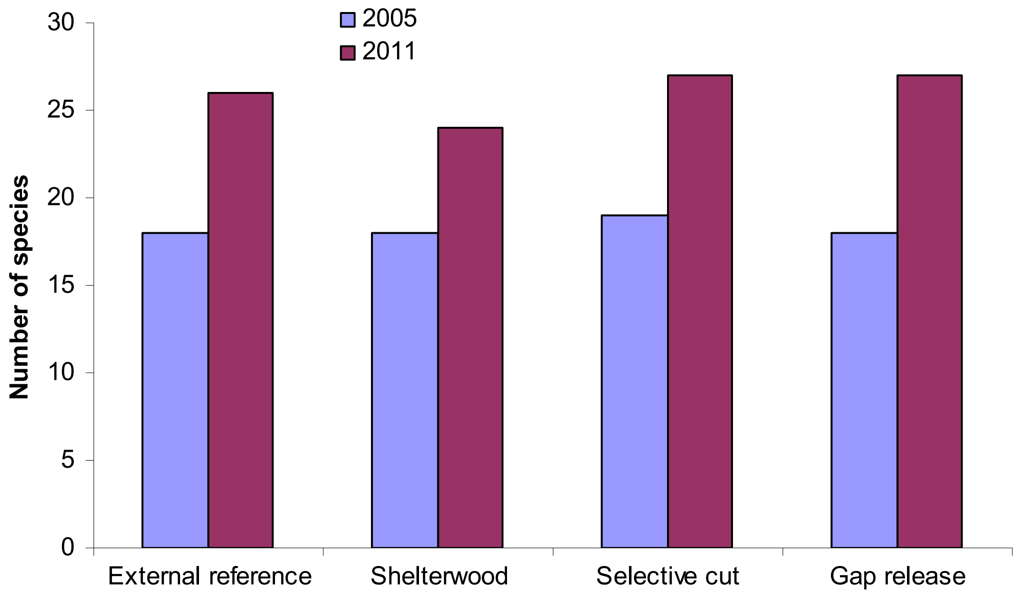

Figure 2. Total number of bird species recorded in each treatment at Blackwood Plateau in 2005 and 2011.

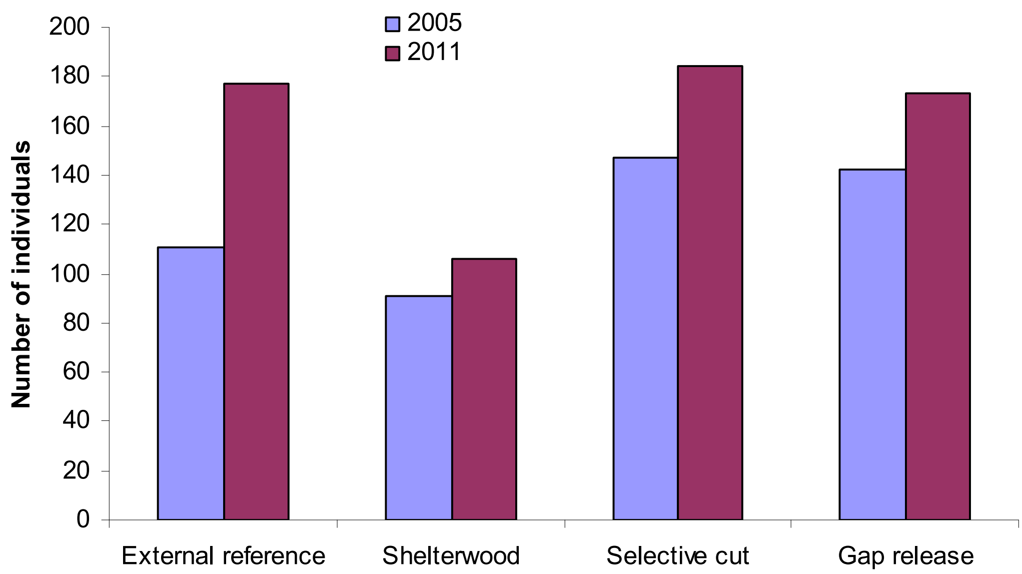

Figure 3. Total number of individual birds recorded in each treatment at Blackwood Plateau in 2005 and 2011.

In 2005 the selective cut treatment had the highest density with 9.7 birds ha^{-1} followed by gap release with 9.5 ha^{-1}, shelterwood with 9.1 and external reference with 7.4. In 2011 the selective cut treatment recorded 12.3 birds ha^{-1}, external reference 11.8, gap release 11.7 and shelterwood 10.6 (Fig. 2).

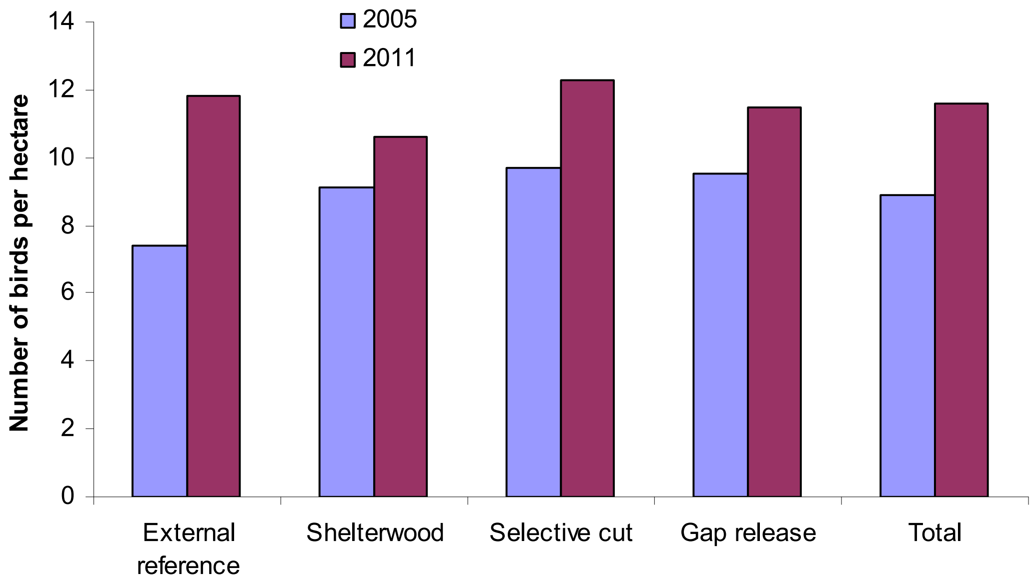

Figure 4. Bird density comparison between sample years and treatments at Blackwood Plateau FORESTCHECK grids in 2005 and 2011.

Seven different leaf gleaning and trunk and branch feeding birds were recorded in the Blackwood Plateau study area during the two sample years; the western gerygone, western thornbill, broad-tailed thornbill, varied sitella (*Daphoenositta chrysoptera*), rufous treecreeper (*Climacteris rufa*), spotted pardelote (*Pardalotus punctatus*)and striated pardalote . The overall abundance of these birds has not changed markedly, with 294 individuals recorded in 2005 and 275 in 2011; although there have been some changes within individual species. For example, western thornbill records increased from 10 in 2005 to 35 in 2011 and spotted pardalote declined from 59 in 2005 to 15 in 2011. Generally this group of birds remained constant, but their overall proportion of the total individuals recorded decreased from 60% in 2005 to 43% in 2011. This can be attributed to the increase in numbers of other species, including parrots (3 species) (Fig. 5), tree martins, grey fantails (*Rhipidura fuliginosa*), scarlet robins (Fig. 5), western yellow robins (*Eopsaltria australis griseogularis*), white-browed scrubwrens, red-winged fairy-wrens, western white-naped honeyeaters (*Melithreptus chloropsis*) and grey currawongs (*Sterpera versicolor*).

Potentially, about 90 bird species could inhabit jarrah forest within the range of the 48 FORESTCHECK grids (estimated from species featured in Abbott 1999 and Simpson and Day 1993). Since FORESTCHECK surveys began in 2001 a total of 62 bird species have been recorded. This includes 41 at Donnelly, 42 at Wellington 1, 45 at Perth Hills, 33 at Wellington East and 38 at Blackwood Plateau.

There are potentially 12 species of birds of prey in jarrah forest, but none have been recorded in Blackwood Plateau FORESTCHECK bird surveys. Similarly nine parrots/cockatoos, and nine honeyeaters also occur in jarrah forest of which five of each have been recorded at the Blackwood Plateau location. Some of the potential species are vagrants or migrants that are rarely seen in the true forest and are more commonly seen on forest edges, farmland and around town sites. Others are associated with the denser vegetation along gullies and creeks, and FORESTCHECK grids do not include these habitats as they are not harvested. However, the total FORESTCHECK grid area is only 48ha and recording 62 species represents over two-thirds of the potential species from a much larger forest area.

Figure 5. The western rosella (left) and scarlet robin (right) increased in numbers in 2011 compared to 2005.

Nocturnal Birds

No systematic survey for nocturnal birds was undertaken in 2011–12. However, opportunistic records were kept when possible (e.g. during spotlight surveys for mammals in autumn 2012).

Southern boobook owls (*Ninox novaeseelandiae*) were heard and Australian owlet-nightjars (*Aegotheles cristatus*) and tawny frogmouths (*Podargus strigoides*) were seen at night when travelling roads between grid locations during mammal spotlight surveys. A masked owl (*Tyto novaehollandiae*) was heard in Layman Brook gully east of the reference grid (FC40) on Crouch Road and another was heard in Rosa Brook gully on Crouch Road west of the same grid. A barn owl (*Tyto alba*) was seen on two occasions; east of Nannup on the Brockman Highway adjacent private farm land which is a preferred hunting zone for this nocturnal bird of prey. However, most nocturnal birds familiar to jarrah forest should be encountered within the Blackwood Plateau FORESTCHECK location (Liddelow et al. 2002).

Conclusions

Bird species composition and abundances change continuously as the understory density and fuel ages vary. These changes occur in harvested areas as the vegetation structure changes over time and through crown separation in regrowth trees and understory shrubs, and in uncut forest as structural and successional changes occur in the understory with time since fire. Changes in population also occur with variation in flowering cycles in plant species. Observations in 2011 related to these changes are:

- Honeyeaters increased from 46 individuals in 2005 to 81 in 2011. The western white-naped honeyeater accounted for most of the increase (two in 2005, 22 in 2011).
- Numbers of scarlet and western yellow robins increased in external reference grids in 2011, as expected since scrub density generally decreases with time since last prescribed fire.
- White-browed scrubwrens and the red-winged fairy-wrens increased in number, especially in the harvested treatments where regeneration of tree and scrub species provide an ideal habitat for these two scrub birds.
- Numbers within the group of leaf gleaning birds remained constant over both census years, but their proportion of the total number of birds recorded decreased in 2011.

- Although no systematic survey was carried out for nocturnal birds, opportunistic records confirmed the presence of five species that are known to be common to the study area.

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MAMMALS AND HERPETOFAUNA

Graeme Liddelow, Richard Robinson and Verna Tunsell

Introduction

The object of recording mammals and herpetofauna in FORESTCHECK is to monitor the impacts of logging and associated burning on species status and abundance. This is achieved by:

- trapping and recording the suite of medium and small sized mammals, reptiles and amphibians on each FORESTCHECK grid
- comparing species richness, abundance, sex ratios and trap percentages between grids and treatments at each location and between FORESTCHECK locations
- recording the presence of the larger mammals along set transects that cover all treatments of the FORESTCHECK location on a landscape basis
- recording the presence of nocturnal mammals by spotlighting along set transects that cover all the treatments of the FORESTCHECK location.

Monitoring

There are 11 FORESTCHECK monitoring grids located at Blackwood Plateau. They include three unlogged external reference (FC38, FC39, FC40), two shelterwood (FC41, FC42), three selective cut (FC43, FC44, FC45) and three gap release grids (FC46, FC47, FC48). Trapping was conducted over eight consecutive nights in both autumn and spring; using protocols outlined in the FORESTCHECK Operating Plan (available at www.dec.wa.gov.au). Briefly on each 2 ha grid, 15 wire cage traps (20 cm x 20 cm x 45 cm) are set-up in a 50 x 50 m grid pattern and 15 20-litre pit fall traps (25 cm diam. x 40 cm deep) are installed in a 25 x 20 m grid pattern. Trapping is conducted over eight consecutive nights. Trapping is normally carried out on FORESTCHECK grids for two weeks in spring then again in autumn the following year (i.e. over a financial year). However, due to other commitments, trapping at Blackwood Plateau in 2012 was undertaken in autumn and spring of the same calendar year.

In 2012 trapping sessions were conducted from 30 April to 9 May in autumn and 17–26 September in spring. Trapping had to be postponed for one night in spring (22 September) due to inclement weather. The spring trapping session also had to be modified due to new (reviewed) protocols introduced by the Animal Ethics Committee which required traps to be checked twice daily.

In addition to trapping, spotlighting surveys and road transect surveys are normally conducted to record macro vertebrates in the vicinity of each monitoring grid. The increased work load for spring trapping meant that spotlighting and road surveys were only conducted in the autumn and those results will not be reported here.

Voucher Specimens

No specimens were lodged with the Western Australian Museum from this trapping session.

Preliminary Results

Trapping

Overall captures

The 2012 trapping sessions consisted of a total of 5280 trap nights. This included 2640 trap nights for pit traps and 2640 trap nights for wire cages. The overall capture rate was 19 animals per night (cpn); 22.4 in spring and 15.4 in autumn (Fig. 1).

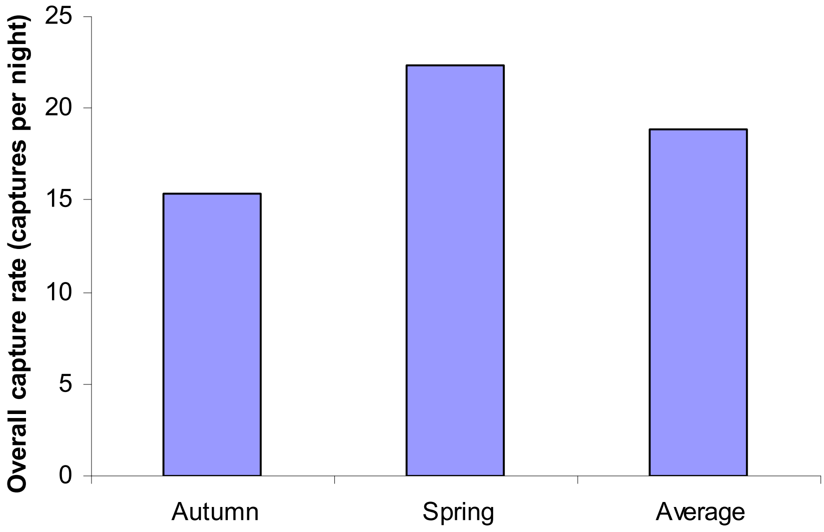


Figure 1. Mean number of animals captured per night (cpn) on Blackwood Plateau FORESTCHECK grids in 2012.

A total of 305 captures were recorded over the two sessions (Table 1, Figs 2 and 3); 182 in spring and 123 in autumn. Six species of mammals were recorded with a total of 210 captures, 13 species of reptiles with 47 captures and five species of amphibians with 48 captures over both seasons.

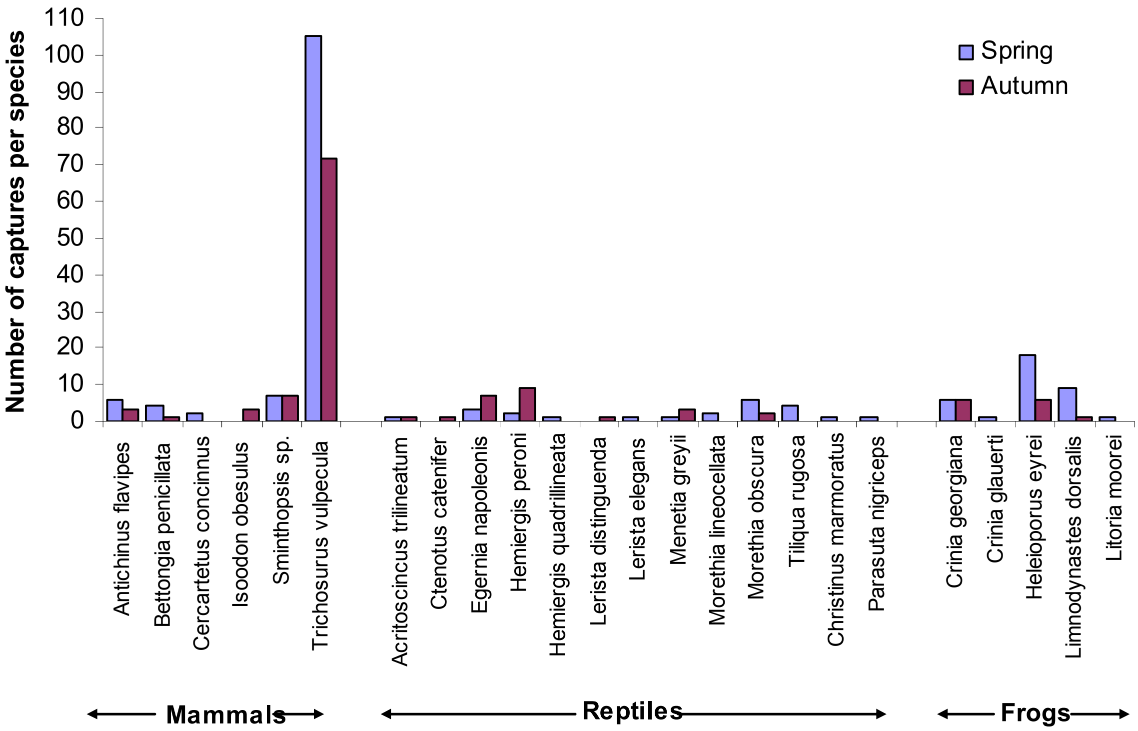


Figure 2. Total number of animals captured at Blackwood Plateau FORESTCHECK grids in 2012.

Table 1. Total number of animals captured at Blackwood Plateau FORESTCHECK grids in 2012.

Species	Common Name	External reference				Shelterwood				Selective cut				Gap release				Total captures		
		Autumn		Spring		Autumn		Spring		Autumn		Spring		Autumn		Spring		Au	Sp	Total
		P	W	P	W	P	W	P	W	P	W	P	W	P	W	P	W			
MAMMALS																				
Antichinus flavipes	Mardo				1		1				2						5	3	6	9
Bettongia penicillata	Woylie						1		1								3	1	4	5
Cercartetus concinnus	Mundarda															2		0	2	2
Isoodon obesulus	Quenda										1				2			3	0	3
Sminthopsis sp.	Dunnart			5		1				2		1		4		1		7	7	14
Trichosurus vulpecula	Common brushtail possum		22		41		20		21		8		15		22		28	72	105	177
REPTILES																				0
Acritoscincus trilineatum	South western cool skink									1		1						1	1	2
Christinus marmoratus	Marbled Gecko			1														0	1	1
Ctenotus catenifer	Chain-striped southwest skink									1								1	0	1
Egernia napoleonis	Smith's skink	2								4		2		1		1		7	3	10
Hemiergis peroni	Peron's earless skink	3				4		2		2								9	2	11
Hemiergis quadrilineata	Two-toed earless skink																	0	0	0
Lerista distinguenda	Southwest orange-tailed slider													1				1	0	1
Lerista elegans	Elegant slider											1						0	1	1
Menetia greyii	Common dwarf skink									1				2		1		3	1	4
Morethia lineocellata	Western pale-flecked Morethia															2		0	2	2
Morethia obscura	Shrubland morethia			2				1		1		3		1		1		2	7	9
Parasuta nigriceps	Black-backed snake							1										0	1	1
Tiliqua rugosa	Bobtail / shingle back								1				1				2	0	4	4
AMPHIBIANS																				0
Crinia georgiana	Quacking frog	3		5						1		1		2				6	6	12
Crinia glauerti	Clicking frog			1														0	1	1
Heleioporus eyrei	Moaning frog					1				5		15				3		6	18	24
Limnodynastes dorsalis	Western banjo frog											3		1		6		1	9	10
Litoria moorei	Motorbike frog							1										0	1	1
TOTAL		8	22	14	42	6	22	5	23	18	11	27	16	12	24	17	38	123	182	**305**

(a) Autumn—overall

(b) Spring—overall

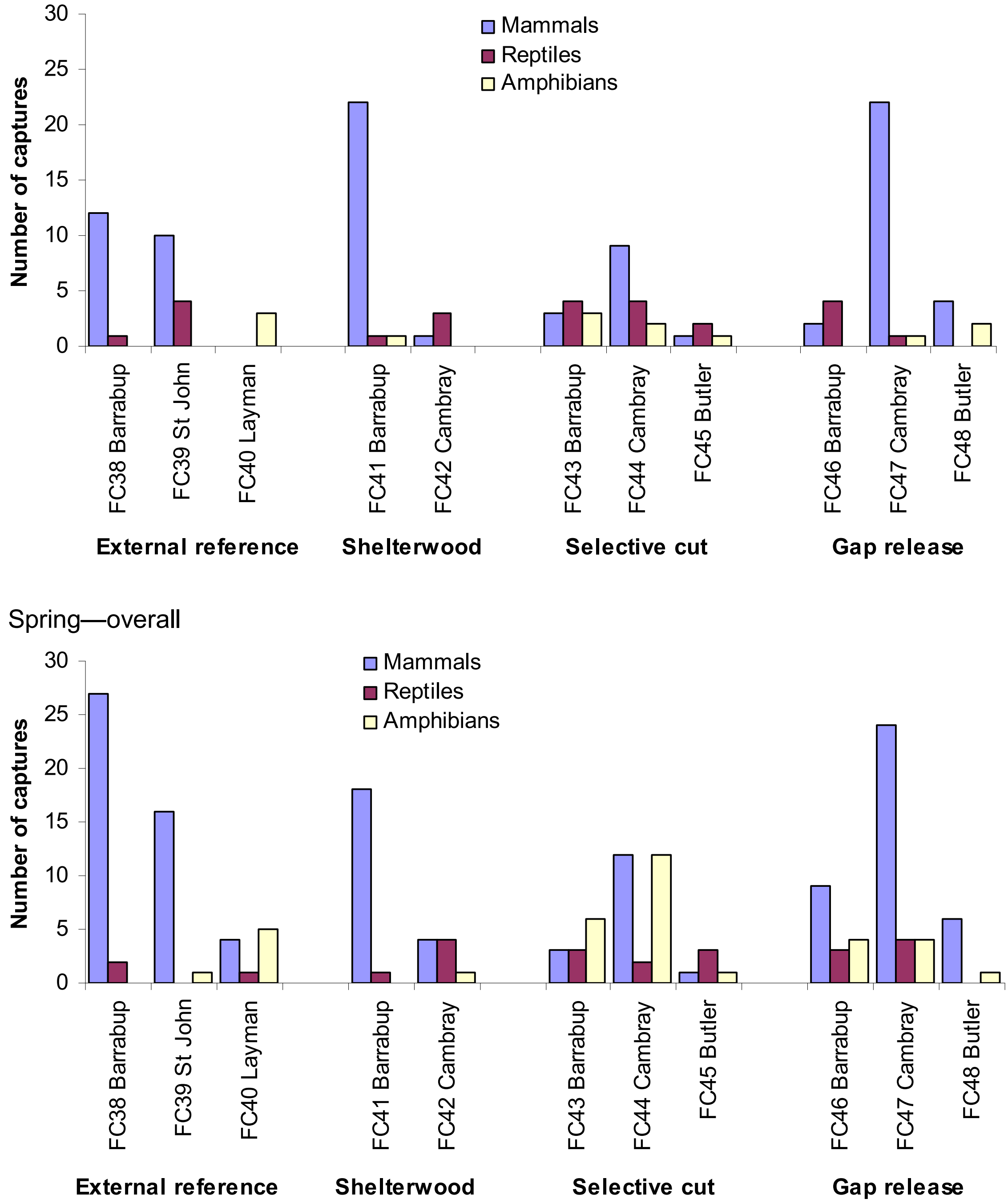


Figure 3. Total number of mammals, reptiles and amphibians captured in traps in (a) autumn and (b) spring at Blackwood Plateau FORESTCHECK grids in 2012.

The most common mammals captured were the brushtail possum (*Trichosurus vulpecula)* with 33 individuals and177 total captures. One hundred and five captures occurred in spring (26 individuals) and 72 in autumn (21 individuals). Next were dunnarts *(Sminthopsis* spp.*)* with 14 captures (7 in each season) and then the mardo (*Antechinus flavipes)* with nine captures (six in spring and three in autumn) (Table 1, Fig. 2).

Sixty three possum captures were recorded in external reference grids (13 individuals) and 114 in silviculture treatment areas including 50 in gap release (7 individuals), 41 in shelterwood (8 individuals) and 23 in selective cut grids (5 individuals). Of the14 dunnart captures, five occurred in external reference and nine in silviculture treatment areas including five in gap release grids. One mardo was trapped in an external reference grid, five in gap release, two in selective cut and one in shelterwood grids. Five woylie *(Bettongia penicillata ogilbyi)* captures (2 individuals) were recorded on Keene Road in Barrabup block. One individual was captured twice on the Barrabup shelterwood grid (FC41), and another three times on the Barrabup gap release grid (FC46).

Trapping reptiles is usually most successful in spring. This year, however, due to inclement weather spring and autumn captures were almost identical with 23 in spring and 24 in autumn (Table 1). Peron's earless skink (*Hemiergis peroni*) was the most common reptile recorded with 11 captures; two in spring and nine in autumn. Smith's skink (*Egernia napoleonis*) had 10 captures; three in spring and seven in autumn, and the shrubland morethia (*Morethia obscura*) had eight captures; six in spring and two in autumn.

Five species of amphibians were caught over the two trapping sessions. The total number of captures was 48 with 35 occurring in spring. The moaning frog (*Heleioporus eyrei*) recorded 24 individual captures; 18 in spring and six in autumn. The banjo frog (*Limnodynastes dorsalis*) recorded 10 captures, of which 9 were in spring. There were also 10 captures of quacking frog (*Crinia georgiana*) recorded; four in spring and six in autumn.

Wire cage captures

Total captures recorded from wire cages over the two sessions was 198 (12.4 cpn) including 119 captures in spring (14.8 cpn) and 79 in autumn (9.9 cpn) (Figs 4 and 5).

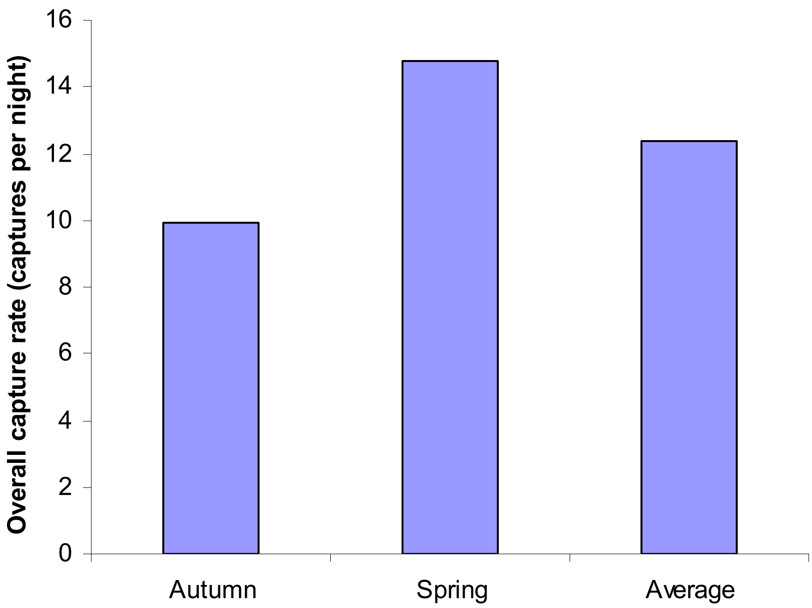
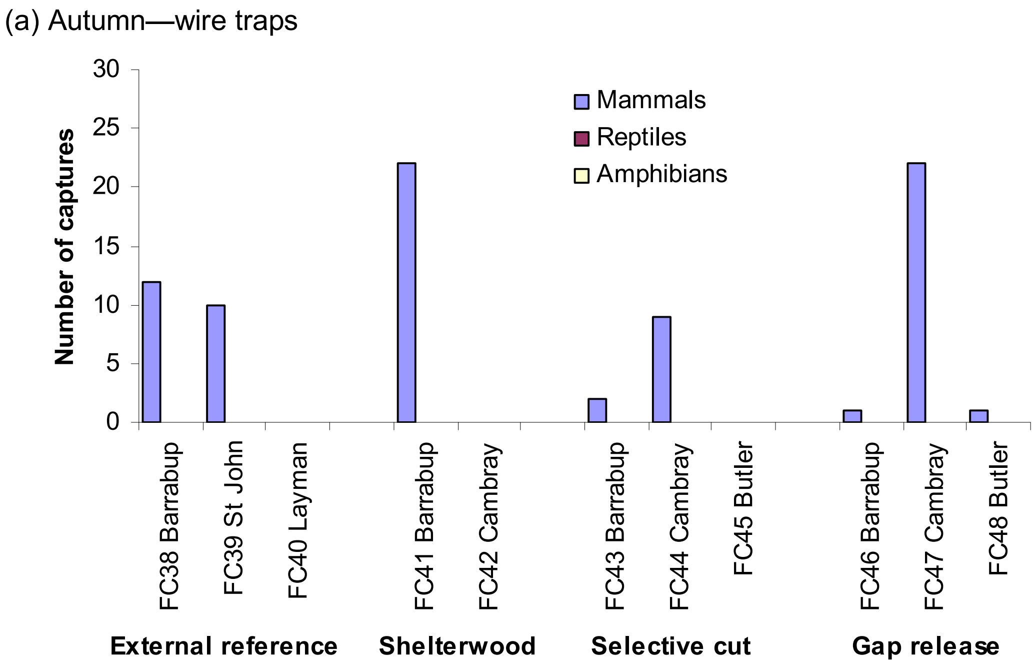


Figure 4. Mean number of animal captures per night in wire cage traps at Blackwood Plateau FORESTCHECK grids in 2012.

Mammals were the most common group of vertebrates captured in wire traps. One hundred and fifteen of the 119 spring captures and all of the 79 autumn captures were mammals. The remaining four spring captures were bobtail skinks (*Tiliqua rugosa*). The most common animal caught in wire traps was the brush-tailed possum, with 105 captures in spring and 72 in autumn.



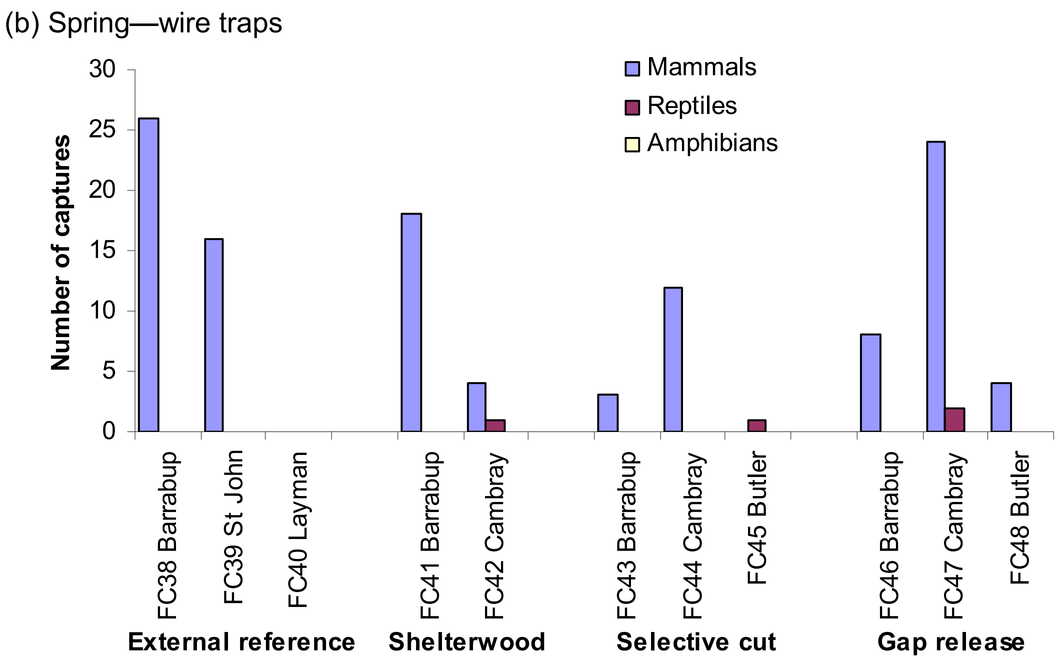


Figure 5. Total captures of mammals, reptiles and amphibians recorded in wire traps in (a) autumn and (b) spring at Blackwood Plateau FORESTCHECK grids in 2012.

Pit fall trap captures

One hundred and seven (6.7 cpn) of the 305 total captures were recorded from pit falls. Sixty three in spring (7.8 cpn) and 44 were in autumn (5.5 cpn) (Fig. 6). Even though the spring trapping session was cool and wet, captures were about twice that recorded in autumn.

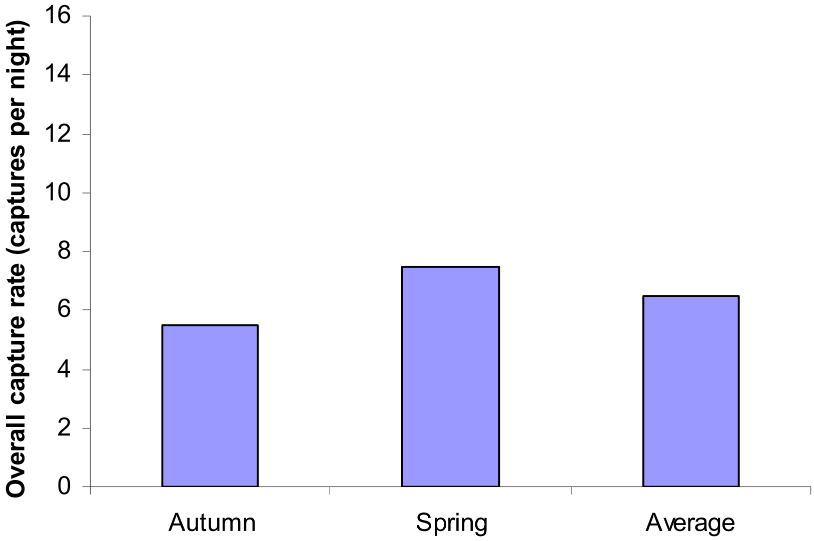


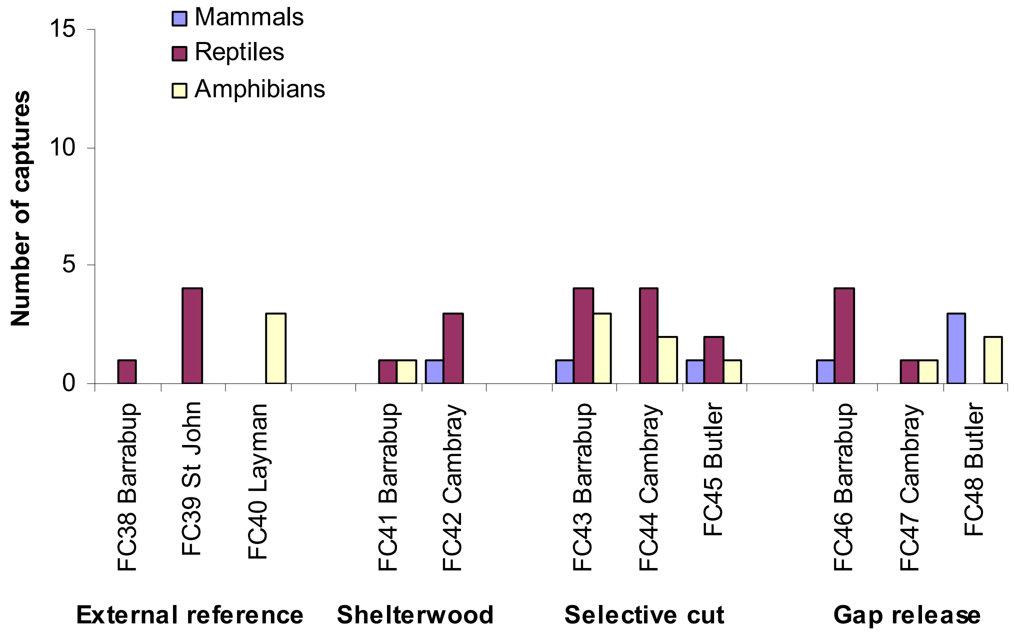
Figure 6. Mean number of animal captures per night in pit traps at Blackwood FORESTCHECK grids.

Of the 107 captures in pit fall traps, only 16 were mammals; comprising 14 dunnarts and two pygmy possums (*Cercartetus concinnus*). Five out of the 14 dunnarts were recorded in external reference grids, one in the shelterwood, three in the selective cut and five in the gap release treatments. Both pygmy possum captures were recorded in the gap release treatment (Table 2).

Forty three of the 47 reptiles caught were recorded in pit falls and included 24 captures in autumn and 19 in spring (Fig. 7). Spring is generally the best season to trap reptiles, but cool and wet weather conditions in spring reduced the captures. Seventeen captures were recorded in the selective cut treatment (seven in spring and 10 in autumn), 10 in the gap release (five in both autumn and spring) and eight in the shelterwood treatment (four in each season). The external reference recorded eight captures (three in spring and five in autumn). The only snake recorded was a black-backed snake (*Parasuta nigriceps*) which was trapped in the Cambray shelterwood (FC42) in spring.

A Total of 48 amphibians were caught in pit traps over the two trapping sessions. Twenty five captures were recorded in the selective cut (19 in spring and six in autumn), 12 in the gap release (nine spring and three autumn), nine in the external reference (six spring and three autumn) and only two captures in the shelterwood treatment (one in each season). All the amphibians recorded were frogs, of which there were five species. The most common was the moaning frog, with 6 captures recorded in autumn and 18 in spring (see cover photo).

(a) Autumn—pitfall traps



(b) Spring—pitfall traps

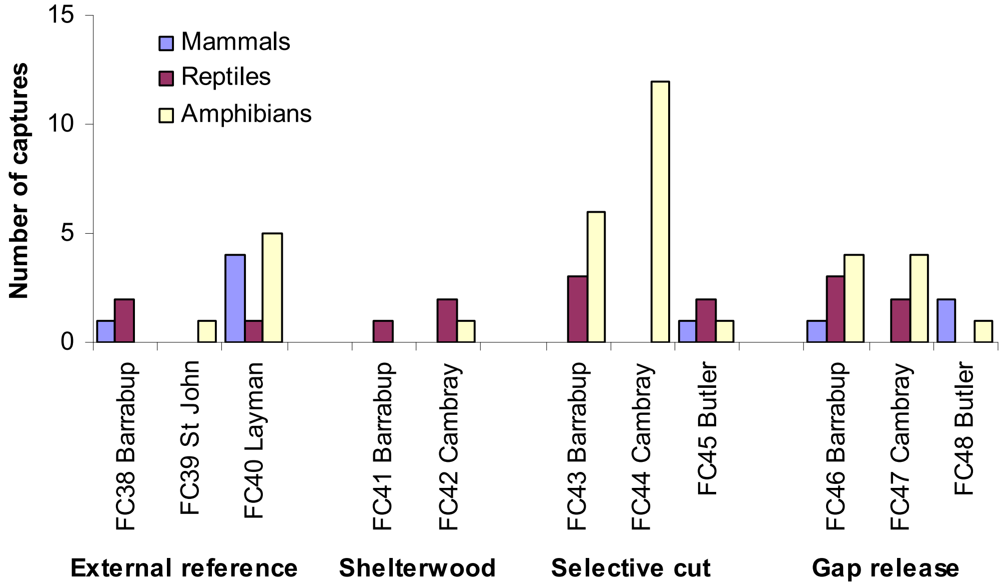


Figure 7. Total number of mammals, reptiles and amphibians recorded in pit fall traps in (a) autumn and (b) spring at Blackwood Plateau FORESTCHECK grids in 2012.

Comparing trapping results from 2005–06 with 2012

Since 2005–06, trap nights were increased from four to eight (which is now the standard for all FORESTCHECK terrestrial vertebrate monitoring). Overall mammal captures increased from 147 in 2005–06 to 210 in 2012. The common brushtail possum accounted for the majority of the increase (Table 3).

Table 3. Trapping results at Blackwood Plateau FORESTCHECK grids for 2005–06 and 2012 (Sp = spring, Au = autumn).

Species	Common name	2005–06 (8 trap nights)			2012 (16 trap nights)		
		Sp	Au	Total	Sp	Au	Total
MAMMALS							
Antichinus flavipes	Mardo	2	2	**4**	6	3	**9**
Bettongia penicillata	Woylie	1		**1**	4	1	**5**
Cercartetus concinnus	Mundarda	12	4	**16**	2		**2**
Dasyurus geoffroii	Chuditch		3	**3**			
Isoodon obesulus	Quenda					3	**3**
Sminthopsis spp.	Dunnart (species uncertain)	9	2	**11**	7	7	**14**
Trichosurus vulpecula	Common brushtail possum	31	81	**112**	105	72	**177**
REPTILES							
Acritoscincus trilineatum	South western cool skink				1	1	**2**
Aprasia pulchella	Western granite worm lizard	6	1	**7**			
Ctenotus catenifer	Chain-striped Ctenotus		1	**1**		1	**1**
Ctenotus labillardieri	Red-legged Ctenotus	13		**13**			
Egernia napoleonis	Southwest crevice skink	22		**22**	3	7	**10**
Glaphromorphus gracilies	Southwestern mulch skink	1		**1**			
Hemiergis peroni	Peron's earless skink	17	3	**20**	2	9	**11**
Hemiergis quadrilineata	Two-toed earless skink		1	**1**	1		**1**
Lerista distinguenda	South western orange-tailed slider	10		**10**		1	**1**
Lerista elegans	West coast four-toed skink				1		**1**
Menetia greyii	Common dwarf skink	3		**3**	1	3	**4**
Morethia lineocellata	Western pale flecked morethia	8		**8**	2		**2**
Morethia obscura	Southern pale flecked morethia	7		**7**	6	2	**8**
Tiliqua rugosa	Bobtail / Shingle back	7		**7**	4		**4**
Varanus rosenbergi	Southern heath monitor	2		**2**			
Christinus marmoratus	Marbled Gecko	2		**2**	1		**1**
Ramphotyphlops australis	Southern blind snake	10		**10**			
Parasuta gouldii	Gould's snake	1		**1**			
Parasuta nigriceps	Black-backed snake				1		**1**
Rhinoplocephalus bicolor	Square-nosed snake	1	2	**3**			
AMPHIBIANS							
Crinia georgiana	Quacking frog				6	6	**12**
Crinia glauerti	Clicking froglet				1		**1**
Crinia subinsignifera	South coast froglet		1	**1**			
Heleioporus eyrei	Moaning frog	3	1	**4**	18	6	**24**
Limnodynastes dorsalis	Sand frog	2		**2**	9	1	**10**
Litoria adelaidensis	Slender tree frog	2		**2**			
Litoria moorei	Motorbike frog / Western bell frog				1		**1**
Total		172	102	**274**	182	123	**305**

To compare trapping results from both monitoring years, capture rates (total and mean captures per night, cpn) were determined. In 2005–06, 274 captures were recorded over 8 nights at a capture rate of 34.3 cpn, compared to 305 captures over 16 nights in 2012 at a rate of 19.1 cpn. This represents an overall decrease of 44% for captures per night in 2012 (Table 3, Fig. 8).

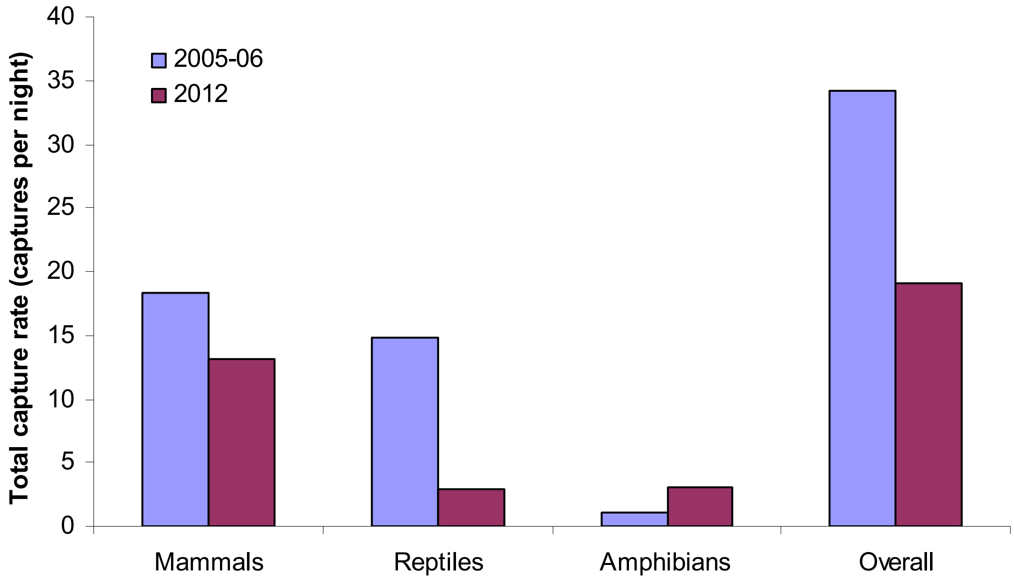


Figure 8. Total capture rates for terrestrial vertebrates at Blackwood Plateau FORESTCHECK grids in 2005–06 and 2012.

Although total mammal captures increased, the total capture rate decreased by 28%, from18.3 to 13.1 cpn (Fig. 8). Brushtail possums accounted for the majority of captures within mammals. The increased trapping effort resulted in an increase of total captures from112 in 2005–06 to 177 in 2012. However, the total capture rate decreased in all treatments except the gap release (Fig. 9). Three chuditch (*Dasyurus geoffroii*) and three quenda *(Isoodon obesulus)* captures were recorded in 2005–06 but none were trapped in 2012.

Despite the extra trapping effort, the overall total number of reptile captures declined from 118 (cpn 14.8) in 2005–06 to 47 (cpn 2.9) in 2012 (Fig. 8). The cool and wet weather conditions experienced during spring of 2012 a likely accounted for the decline. However, autumn captures in 2012 were greater in total and in capture rate compared to autumn 2006 with 24 captures (3 cpn) recorded in 2012 compared to eight (2 cpn) in 2006.

Amphibian numbers increased both in number and capture rate in 2012 (Fig. 8). In 2005–06, nine captures (1.1 cpn), representing four species, were recorded. In 2012, 48 captures (3 cpn), representing five species, were recorded. The cool wet spring in 2012 accounted for most of the increase. Within the treatments, total frog captures in selective cut grids increased from one in 2005–06 to 25 in 2012, and from one to nine in external reference grids.

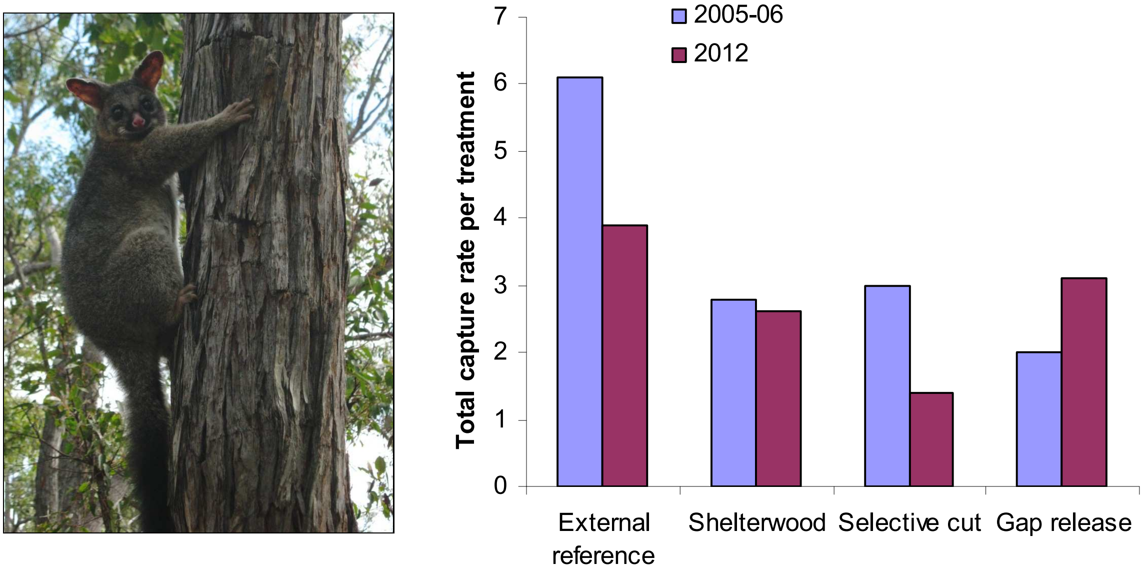


Figure 9. Common brushtail possum (left) and comparison of total brushtail possum capture rates each treatment at Blackwood Plateau FORESTCHECK grids in 2005–06 and 2012 (right).

In 2005–06, the shelterwood treatment had a higher mean capture rate per grid than other harvested treatments (selective cut and gap release). In 2012, mean capture rates per grid were lower than those in 2005–06 for all treatments (including the external reference), but there were no apparent differences between the treatments.

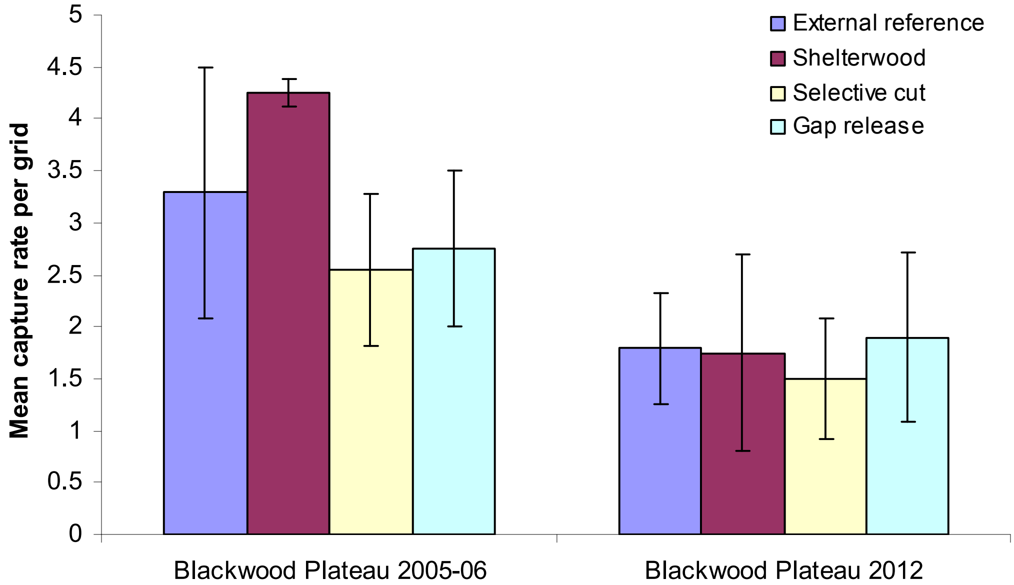


Figure 10. Mean capture rates per grid for each treatment at Blackwood Plateau FORESTCHECK grids in 2005–06 and 2012.

Conclusions

Observations made following monitoring of terrestrial vertebrates at Blackwood Plateau FORESTCHECK grids in 2012 were:

- Increasing total trap nights from eight in 2005–06 to 16 in 2012 resulted in an overall increase in captures but the capture rate per night decreased for mammals and reptiles.
- The greatest increase in captures was observed in brushtail possum numbers, which increased from 112 to 177, however, total brushtail possum capture rates decreased in all treatments except the gap release.
- In 2012, there was no apparent differences in mean capture rates per grid between treatments.
- Cool wet weather in spring 2012 resulted in a low number of reptile captures in 2012, but an increase in amphibian captures and species recorded.
- Road surveys and spotlight surveys were not undertaken in 2012, due to the increased work load associated with new trapping guidelines introduced in spring 2012.

Acknowledgements

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DATA MANAGEMENT AND STORAGE

Verna Tunsell

Introduction

The FORESTCHECK data management and storage service is responsible for entering and storing all data collected from the project into an electronic format, and databasing collected voucher specimens (Flora, Cryptogams and Fungi) into the Western Australian Herbarium (PERTH).

Data entry

All information from the field sheets are entered into individual Microsoft Excel® or Access® spreadsheets. The majority of the spreadsheets are formatted with drop down boxes for appropriate fields; e.g. scientific names. The spreadsheet is then checked and supplied to the leader of each individual monitoring group.

Data storage

The individual sampling data is saved and backed up as individual files on the network drive. The data are saved and secured when the DEC network drive is backed up daily. The final validated version is also backed up on an external hard drive, printed and filed and will be archived in the Conservation Science library at the completion of the project. All field data sheets are presently filed at the Manjimup Research Centre.

Voucher specimens

The vascular plant, fungi and cryptogam specimens collected during the period, have been identified (as far as possible) and curated. The vascular plants and cryptogams are lodged and housed at PERTH. The fungi collection is lodged at the Western Australian Herbarium housed at the Tony Annels Herbarium in Manjimup, to enable work on descriptions and identification to be completed. Many of the lichen and fungi collections represent unnamed and previously unknown taxa.

Vascular plant specimens are pressed and dried, then mounted, with specialised herbarium tape, on card, and placed in separate folders. Cryptogams are dried (friable specimens are stabilised with emulsion), placed on a card with adhesive to keep the specimen together (mosses are washed prior to drying to remove debris). The specimens are then secured in cardboard boxes to prevent damage.

Fungi specimens are also dried, then wrapped in greaseproof paper inside zip-lock bags and put into boxes to prevent damage. Very large specimens remain unboxed but sealed in airtight plastic bags.

Each plant, cryptogam and fungi collection is allocated a unique barcode so that it is readily identified and easily located by electronic and physical means. Collections are data based on the Max system and submitted electronically to Western Australian Herbarium (PERTH) for incorporation into the herbarium database. Max was developed by Simon Woodman and Paul Gioia (DEC) and is used as the primary means of submitting specimen information to the WA Herbarium. While there are many facets to Max, the sections used for FORESTCHECK are the collecting book and reporting facilities.

Invertebrate voucher collections are housed at the Manjimup Insectary. The collection contains a large number of unnamed and previously unknown taxa. Specimens are either pinned or stored in 80% alcohol. Non voucher specimens are bulked according to site, date of capture and capture method. Light trap specimens are dried and stored in sealed plastic bags and pitfall and active capture samples are stored in alcohol. Therefore these specimens are available for further examination. The whole collection is managed using a Microsoft Access® database linked to photos, collection details and taxon descriptors. Taxa are reviewed annually to update and consolidate new taxa.

All collections (flora, cryptogams, macrofungi and invertebrates) are actively maintained including regular treatment (freezing) to minimise degradation and pest contamination. Descriptions of new taxa are compiled from fresh and then preserved collections to aid future taxonomic work.

Appendix 1. Example of flora collection labels generated in Max-V3

WESTERN AUSTRALIAN HERBARIUM, PERTH
Flora of Western Australia

Cassytha racemosa forma ***pilosa*** (Benth.) J.Z.Weber

Lauraceae
Identified by:

Parasitic perennial climber frequent. Hill to plain; gravelly brown sandy clay. Forest with associated vegetation of Corymbia calophylla and Eucalyptus marginata.

Loc.: Forestcheck monitoring site 5, N side of Wagelup Road 1.4 km W of railway line, Yornup Forest block

Lat.: 34°6'24.0" S **Long.:** 116°8'33.0" E (WGS84)

Coll.: R.J. Cranfield 23238 **Date:** /09/2008

Voucher: Forestcheck Monitoring Program

WESTERN AUSTRALIAN HERBARIUM, PERTH
Flora of Western Australia

Lomandra nigricans T.Macfarlane

Dasypogonaceae
Identified by:

Height to 20 cm, width to 15 cm; flowers white. frequent. Hill to plain; gravelly brown sandy clay. Forest with associated vegetation of Corymbia calophylla and Eucalyptus marginata. Percentage of population flowering: 10

Loc.: Forestcheck monitoring site 5, N side of Wagelup Road 1.4 km W of railway line, Yornup Forest block

Lat.: 34°6'24.0" S **Long.:** 116°8'33.0" E (WGS84)

Coll.: R.J. Cranfield 23239 **Date:** /09/2008

Voucher: Forestcheck Monitoring Program

WESTERN AUSTRALIAN HERBARIUM, PERTH
Flora of Western Australia

Leucopogon capitellatus DC.

Epacridaceae
Identified by:

Shrub, height to 30 cm, width to 40 cm; growth phase is active with flower buds, vegetative buds and flowers, white frequent. Hill to plain; gravelly brown sandy clay. Forest with associated vegetation of Corymbia calophylla and Eucalyptus marginata. Percentage of population flowering: 30

Loc.: Forestcheck monitoring site 5, N side of Wagelup Road 1.4 km W of railway line, Yornup Forest block

Lat.: 34°6'24.0" S **Long.:** 116°8'33.0" E (WGS84)

Coll.: R.J. Cranfield 23240 **Date:** /09/2008

Voucher: Forestcheck Monitoring Program

WESTERN AUSTRALIAN HERBARIUM, PERTH
Flora of Western Australia

Leucopogon pulchellus Sond.

Epacridaceae
Identified by:

Erect compact perennial shrub, height to 40 cm, width to 40 cm; flower buds white and pink frequent. Hill to plain; gravelly brown sandy clay. Forest with associated vegetation of Corymbia calophylla and Eucalyptus marginata. Percentage of population flowering: 30

Loc.: Forestcheck monitoring site 5, N side of Wagelup Road 1.4 km W of railway line, Yornup Forest block

Lat.: 34°6'24.0" S **Long.:** 116°8'33.0" E (WGS84)

Coll.: R.J. Cranfield 23241 **Date:** /09/2008

Voucher: Forestcheck Monitoring Program

Appendix 2. Example of flora report generated in Max V3.

27/02/2009 Forestcheck Donnelly 2007-2008 1

COLLECTOR_NO	SHEET_NO	GENUS	SPECIES	INFRA_RANK	INFRA_NAME
23250	6666795	Caladenia	arrecta		
23240	6666728	Leucopogon	capitellatus		
23243	6666752	Senecio	hispidulus		
23244	6666760	Senecio	hispidulus		
23249	6666787	Luzula	meridionalis		
23239	6666701	Lomandra	nigricans		
23241	6666736	Leucopogon	pulchellus		
23245	6666779	Senecio	quadridentatus		
23238	6666698	Cassytha	racemosa	forma	pilosa
23133	6667031	Cassytha	racemosa		
23251	6666809	Caladenia	reptans		
23242	6666744	Brachythecium	sp. FC5 (R.J. Cranfield 2324		
23133	6667023	Billardiera	variifolia		