Department of Parks and Wildlife
Science & Conservation Division

FORESTCHECK

REPORT OF PROGRESS 2014











PARKS AND WILDLIFE

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This report highlights preliminary results for FORESTCHECK monitoring, determined by basic analysis and field observation, for the year 2014. 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 Department of Parks and Wildlife web site at www.dpaw.wa.gov.au .

Cover photos: The filmstrip represents biota monitored in FORESTCHECK: *from left*, forest structure and coarse woody debris, reptiles, macrofungi, invertebrates, lichens, mammals, birds and vascular flora. *Main photo*: mature virgin reference forest at Hunt forest block. *Above left*, *Banksia* (*Dryandra*) *sessilis*; *centre left*, *Lecidea ochroleuca* (crustose lichen) and *bottom left*, Parks and Wildlife animal handlers Renee Ettridge and Graeme Liddelow trapping small mammals at Hunt block (photos: R. Robinson).

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EXECUTIVE SUMMARY

In 2014, seven new FORESTCHECK monitoring grids were established and monitored in the Sandy Basins forest ecosystem in Blackwood District. All are within the Wilga vegetation complex which is characterised as woodland of *Eucalyptus marginata* subsp. *marginata–Corymbia calophylla* on sandy gravels on low divides in the subhumid zone of the jarrah forest. Three grids are south of Wilga within Wilga and Jolly forest blocks and four east of Wilga in the Hunt and Camballan forest blocks, in forest that was either uncut or subject to timber harvesting (shelterwood and gap release treatments) under SFM Guideline No. 1. Four harvested grids and two fauna habitat zones are located in State forest and one external reference grid in proposed conservation park. Harvested sites were matched to 2007 harvest activities and all were subject to prescribed fire the same year. External reference grids at Jolly and Camballan were burnt by prescribed fire in 2005. The Hunt external reference grid was previously burnt in 1995, and subject to prescribed fire in spring 2014 during the monitoring period.

Two additional grids, one each in Plavins and Amphion forest blocks, were also established in the Perth Hills District. Combined with the existing grid in Kennedy block (FC24, established in 2003) they create a time-since-fire series (81, 39 and 9 years since fire) in forest that was last subject to selective harvesting 75–94 years ago. All three grids are in the Dwellingup 1 vegetation complex of the jarrah forest which is characterised as open forest of *Eucalyptus marginata* subsp. *marginata–Corymbia calophylla* on lateritic uplands in mainly humid and sub-humid zones.

At all grids, forest attributes including forest structure, regeneration stocking, coarse woody debris and litter loads were measured and species richness and abundances of macrofungi, cryptogams (lichens and bryophytes), invertebrates, terrestrial vertebrates and vascular plants were recorded.

FORESTCHECK monitoring is contributing to increased knowledge of jarrah forest biodiversity and ecology, and underpins the concept of sustainable forest management in jarrah forest in Western Australia. The results presented here provide a preliminary analysis of the data. Highlights from monitoring undertaken in Blackwood District in 2014 include:

- Stands have a lower basal area and trees are generally smaller than those in higher rainfall areas of jarrah forest, with even mature stands having relatively few trees larger than 70cm dbh. However, lignotuberous advance growth of jarrah and marri was abundant allowing stands to regenerate readily following timber harvesting.
- The volume of coarse woody debris (CWD) in harvested grids was substantially greater than in unharvested reference grids (consistent with previous findings from surveys of the initial 48 grids), but litter loads at both Wilga/Jolly and Hunt are lower than in more productive stands in higher rainfall areas of the jarrah forest.
- The diversity and abundance of macrofungi in the Jarrah Sandy Basins was low compared to other ecosystems monitored. The richness and abundance of mycorrhizal species was similar in all treatments but saprotrophic species were 2–3 times higher in harvested treatments compared to external reference grids.
- Mean species richness per grid for lichens, mosses and liverworts was similar in all treatments. The majority of cryptogams were recorded on the ground with crustose lichens being the dominant life-form.
- The overall mean species richness of plants was similar in all treatments, but the mean abundance of plants was consistently lower in the harvested grids compared to the external reference grids.
- Variation in richness and abundance of invertebrates between sample grids was high relative to differences between treatments indicating no significant influence by silvicultural treatments.
- Leaf gleaning, and branch and trunk feeding species made up for the majority of birds recorded during the survey period. Leaf gleaning species were similar across all treatments, but birds like scarlet and western yellow robins that prefer a more open understorey were more prevalent in external reference grids.

- Brush-tailed pussums accounted for 35% of the total animals recorded on the grids. Their presence was impacted by silvicultural treatment with 65%, 34% and 6% of records being in the external reference, sheltwerwood and gap release treatments respectively. In contrast 64% of dunnart records were in the harvested treatments.

Highlights from surveys on fire chronsequence grids in Perth Hills District in 2014 include:

- Thick bark accumulated on trees in the absence of fire for long periods should be recognised as an important component of the fuel load available for combustion, particularly under dry summer conditions.
- The very large volume of CWD at the very long unburnt (81 years) Amphion grid, compared with the Kennedy (39 years) and Plavins (9 years) grids, demonstrates clearly the critical role that fire history plays in the amount and condition of CWD in the jarrah forest.
- The rate of litter accumulation declines as time since fire increases but bark and CWD may continue to accumulate well after the litter load has attained an equilibrium loading.
- With increasing time since fire, litter accumulation may impact ground dwelling cryptogams but, larger logs and retention of CWD has the potential to provide habitat for wood dwelling cryptogams.
- Time since fire appeared to have a significant effect on species richness and abundance of plants with species richness declining but abundance increasing with time since fire. The structure of the understorey vegetation also became sparse and contained more dead material with increasing time since fire.
- Invertebrate species composition is affected by time since fire, but the influence is complex and needs further investigation.
- Leaf gleaning, and branch and trunk feeding species made up for the majority of birds recorded, and leaf gleaning species were generally similar on all grids.
- Although there were suitable habitat trees with hollows on all three grids, 82% of the brush-tailed possums recorded were on the intermediate (39 years) fire aged grid at Kennedy block. Mardos favoured the deep litter layer on the longest unburnt (81 years) grid at Amphion block, with 91% of the total individuals recorded there.

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 2016 analysis of the previous 10 years of data will be undertaken.

This report, and previous reports, can be viewed and downloaded from the Department of Parks and Wildlife website at www.dpaw.wa.gov.au .

Dr Margaret Byrne
Director
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June 2016

INTRODUCTION

Scope

This report provides a summary of activities from the FORESTCHECK monitoring project during 2014. The aim of the report is to detail activities carried out in 2014 in the Jarrah Sandy Basins forest ecosystem in the eastern part of the Blackwood District and to present preliminary descriptive interpretations and analyses of the data collected. Data are also presented from three grids in the Jarrah North West ecosystem in Perth Hills District that provide a chronosequence of 81, 39 and 9 years since the last fire. More detailed and robust analyses are conducted on a five-year basis and following the peer-review process are published in relevant scientific journals. Previous reports and publications can be viewed at www.dpaw.wa.gov.au .

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.

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 (Codd 1999), and was included as an operational program in the previous Forest Management Plan 2003–2013 and continues to be so in the current Forest Management Plan 2014–2023 (Conservation Commission 2014). 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 recognized as an appropriate strategy for managing under conditions of uncertainty and change.

The Science and Conservation Division in the Department of Parks and Wildlife 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 (then Conservation and Land Management), 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 Operations Plan. Annual Progress Reports, the Concept Plan and Operations Plan may be viewed on the Department's website at www.dpaw.wa.gov.au (input 'forestcheck' in search box).

Monitoring strategy

From 2004 to 2013 timber harvesting in jarrah forests was undertaken according to Sustainable Forest Management Guideline No.1 (Anon. 2004), which recognizes three distinct silvicultural objectives:

1 Thinning to promote growth on retained trees.
2 Release of regeneration by gap creation to encourage existing advance growth to develop unimpeded by the removal of competing overstorey.
3 Regeneration establishment by shelterwood to encourage seedlings 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.

Selective cutting based on the removal of individual trees has in the past been common practice in areas of jarrah forest where the proportion of sawlog is low. The outcome of commercial harvesting is considered to be a selective cut if the basal area of cull trees is too great (> 12 m^2 ha^{-1}) to make follow-up silviculture uneconomic.

Gap creation and shelterwood treatments have been given priority for FORESTCHECK monitoring as these are the most widespread operations and involve a relatively hight level of disturbance to the forest. Selective cutting is also monitored where the structure of the forest dictates that this treatment is appropriate on a significant scale.

FORESTCHECK monitoring sites have been established at a number of locations throughout the jarrah forest, and stratified according to recognized ecological gradients of rainfall, evapo-transpiration and soil fertility. Forest ecosystem mapping (Mattiske and Havel 1998, 2000) 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 has up to four sampling grids. Grids have been established in forest subject to the following treatments:

1 Gap release;
2 Shelterwood (and/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 is undertaken within a two hectare sampling grid (Fig. 1). The main grid is 200 x 100 m, with a central area of 100 x 100 m. A range of ecosystem attributes are monitored on each grid including:

1 forest structure and regeneration stocking;
2 foliar and soil nutrients;
3 soil disturbance;
4 coarse woody debris and leaf litter;
5 macrofungi;
6 cryptogams;
7 vascular flora;
8 invertebrate fauna;
9 vertebrate fauna (birds, herpetofauna, and mammals).

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

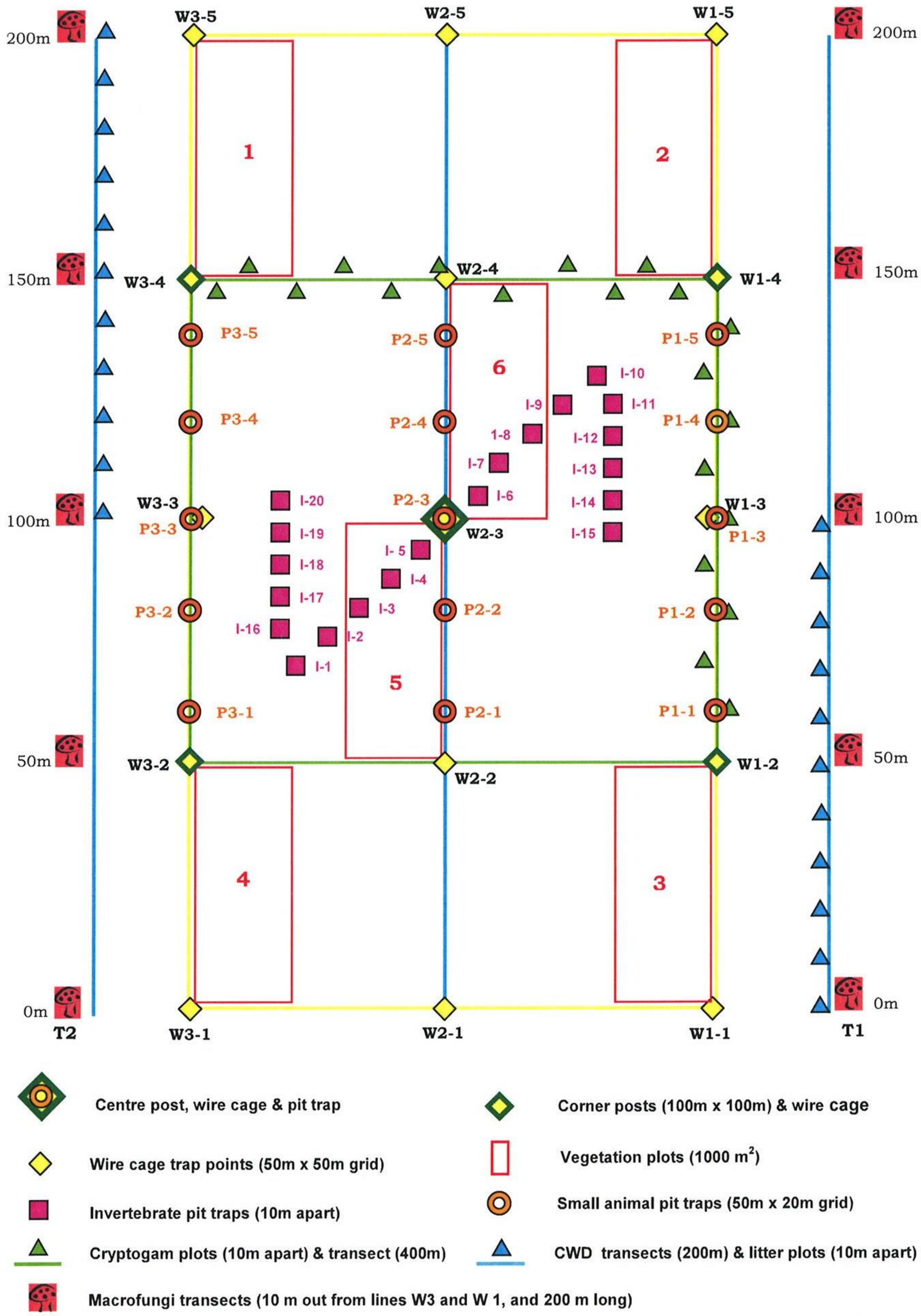


Figure 1. FORESTCHECK grid layout

Monitoring in the Blackwood District 2014

In the summer of 2013–14, seven FORESTCHECK monitoring grids were established within two locations within the Sandy Basins forest ecosystem in the Blackwood District. Three grids (FC57, FC58 & FC59) were established south-east of the Wilga settlement in Wilga and Jolly forest blocks and four (FC60, FC61, FC62 & FC63) east of Wilga in Hunt and Camballan forest blocks (Figs 2 & 3).

Figure 2. Locations of FORESTCHECK monitoring grids established in Wilga and Jolly forest blocks in 2014

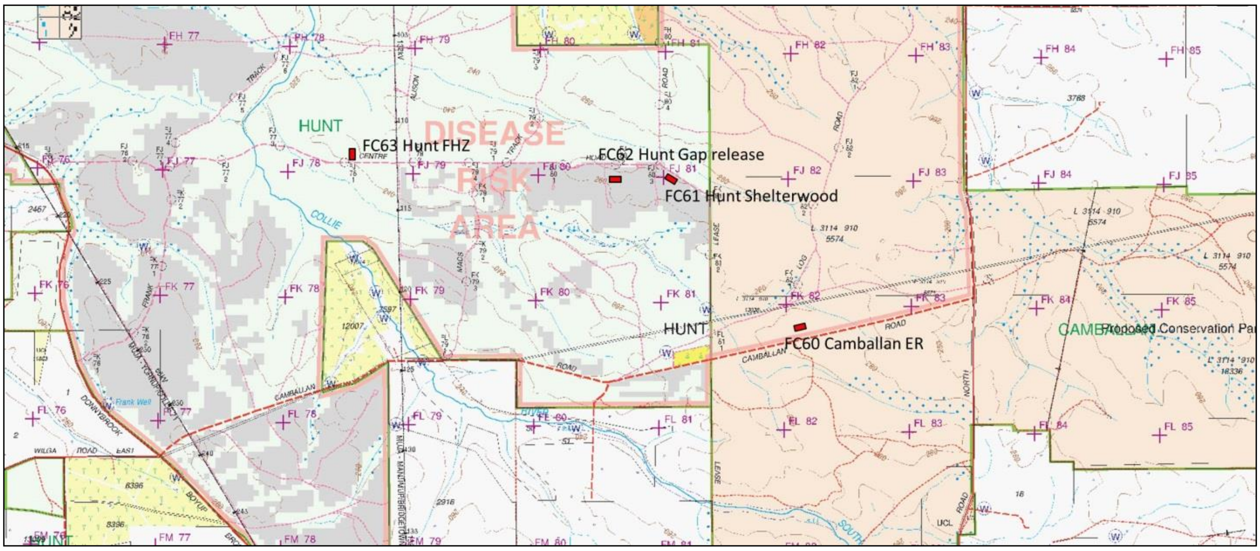


Figure 3. Locations of FORESTCHECK monitoring grids established in Hunt and Camballan forest blocks in 2014

All grids have the Wilga vegetation complex on them which is characterised as woodland of *Eucalyptus marginata* subsp. *marginata*–*Corymbia calophylla* on sandy gravels on low divides in the subhumid zone of the jarrah forest (Mattiske & Havel 1998) (Table 1). The external reference grid in Camballan (FC60) is situated in uncut forest within a proposed conservation park; however, as a result of selective harvesting in the decade 1970–79 a small number of stumps is present. The other external reference grids (FC57 & FC63) are located within fauna habitat zones (FHZ) adjacent harvested forest in Wilga and Jolly blocks respectively. There is no record of any harvesting activity in the Wilga FHZ, but the Jolly FHZ has a small number of stumps resulting from selective harvesting in the decade 1950–59. The remaining grids in Wilga and

Hunt blocks are in forest that was harvested in 2007 during the period of the Forest Management Plan 2004–2013 (Conservation Commission 2004). The silvicultural outcome of harvested grids was either shelterwood or gap release (Table 1).

Table 1. Location (forest block) and site attributes of each FORESTCHECK monitoring grid in the Blackwood District in 2014

Treatment/grid number and location	Burnt		Harvested		Vegetation Complex[2]
	Year and type of burn[1]	Years since	Year	Years since	
External reference					
FC57 Jolly	2005 (prescribed)	9	Uncut		Wilga
FC60 Camballan	2005 (prescribed)	9	Uncut		Wilga
FC63 Hunt	1995/Sp 2014 (prescribed)*	19*	Uncut		Wilga
Shelterwood					
FC58 Wilga	Sp 2007 (prescribed)	7	2007	8	Wilga
FC61 Hunt	Au 2007 (prescribed)	8	2007	8	Wilga
Gap release					
FC59 Wilga	Sp 2007 (prescribed)	7	2007	8	Wilga
FC62 Hunt	Au 2007 (prescribed)	8	2007	8	Wilga

1 Su = summer, Sp= spring, Au = autumn

2 The Wilga vegetation complex is found in woodland of *Eucalyptus marginata* subsp. *marginata–Corymbia calophylla* on sandy gravels on low divides in the subhumid zone of the jarrah forest (Mattiske & Havel 1998)

* The Hunt external reference grid (FC63) was prescribe burnt following the spring monitoring period in 2014

An additional two grids, one each in Plavins (FC64) and Amphion (FC65) forest blocks, were also established in the Perth Hills District (Fig. 4). They were combined with the existing grid in Kennedy block (FC24, established in 2003) to create a series of fire chronosequence grids in mature forest. The Kennedy and Amphion grids are located within fire exclusion reference areas. They were logged heavily prior to 1930 but have not been harvested since. All three grids are in the Dwellingup 1 vegetation complex of the jarrah forest which is characterised as open forest of *Eucalyptus marginata* subsp. *marginata–Corymbia calophylla* on lateritic uplands in mainly humid and sub-humid zones (Mattiske and Havel 1998) (Table 2).

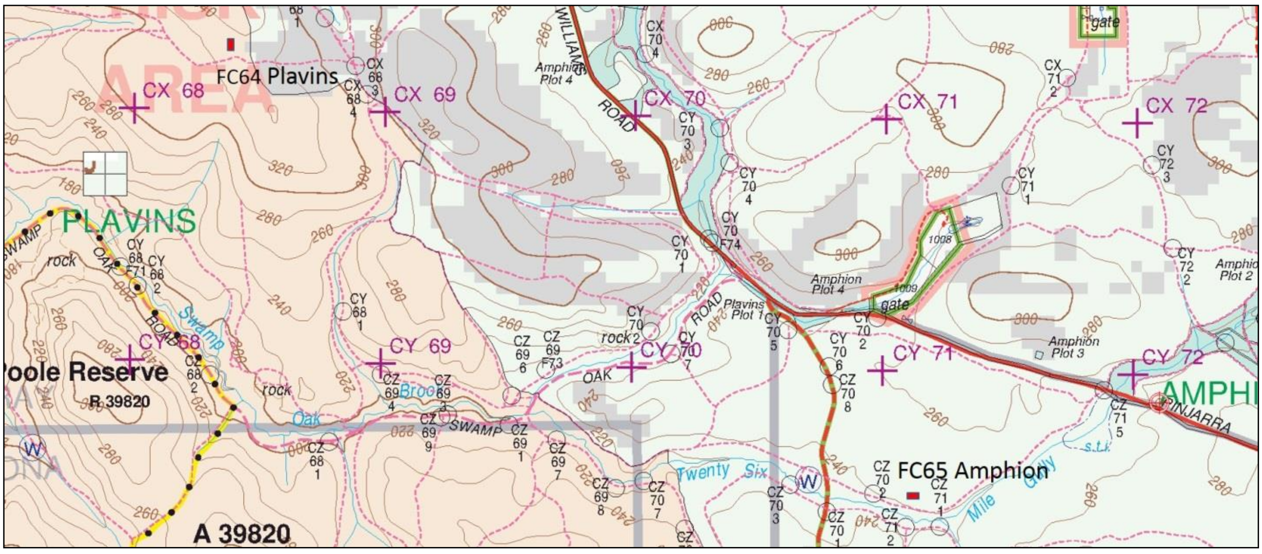


Figure 4. Locations of two fire chronosequence grids established in the Perth Hills District near Dwellingup in 2014

Table 2. Location (forest block) and site attributes of each fire chronosequence grid established in the Perth Hills District in 2014

Treatment/grid location	Burnt		Harvested		Vegetation Complex[2]
	Year and type of burn[1]	Years since	Year	Years since	
Fire chronosequence					
FC24 Kennedy	Au 1975 (prescribed)	(28, 34) 39	1930–34	(71, 77) 82	Dwellingup 1
FC64 Plavins	2005 (prescribed)	9	1930–39	>75	Dwellingup 1
FC65 Amphion	1933 (unknown)	81	Pre 1920	>94	Dwellingup 1

[1] Su = summer, Sp= spring, Au = autumn
[2] The Dwellingup 1 vegetation complex of the jarrah forest which is characterised as open forest of *Eucalyptus marginata* subsp. *marginata–Corymbia calophylla* on lateritic uplands in mainly humid and sub-humid zones (Mattiske and Havel 1998)

Grid photographs

Reference photographs of each grid (Figs. 5–14) were taken in June/July 2014 from a standard photo point at peg W2-1 looking towards the centre peg (W2-3) (refer to Fig. 1). Using a standard reference point allows changes in vegetation structure and condition to be observed accurately in subsequent photographs.

Wilga/Jolly Grids

Figure 5. FC57 Jolly external reference (fauna habitat zone)

Figure 6. FC58 Wilga shelterwood

Figure 7. FC59 Wilga gap release

Camballan/Hunt grids:

Figure 8. FC60 Camballan external reference

Figure 9. FC63 Hunt external reference (fauna habitat zone)

Figure 10. FC61 Hunt shelterwood

Figure 11. FC62 Hunt gap release

Perth Hills fire chronosequence grids:

Figure 12. FC64 Plavins grid 9 years since fire

Figure 13. FC24 Kennedy grid 39 years since fire

Figure 14. FC65 Amphion grid 81 years since fire

Funding
The annual operational budget for the program is provided through the Forest and Ecosystem Management Division of the Department of Parks and Wildlife via a works agreement with the Forest Products Commission. Salaries of all staff involved in the project are paid by the Department of Parks and Wildlife.

2015 Activities
Analysis of ten years of monitoring data collected between 2001 and 2012 is currently in progress. A comparison of the first (2001–2006) and second (2007–2012) 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 review the Operations Plan for FORESTCHECK in 2016. This will enable the project to fully utilise data already collected, to further enhance outcomes defined in the current Forest Management Plan 2014–2023, to reflect recent trends and developments in monitoring activities and to maximise the resources currently available.

References
Anonymous 2004. *Silvicultural Practice in the Jarrah Forest*. *Sustainable Forest Management Guideline No. 1*. Department of Conservation and Land Management, Perth, Western Australia.

Codd, M. 1999. *Forest Management Plan 1994–2003: Mid-Term EPA Report on Compliance*. Environmental Protection Authority, Perth.

Conservation Commission of Western Australia 2004. *Forest Management Plan 2004–2013.* Conservation Commission of Western Australia. 144p + maps.

Conservation Commission of Western Australia 2013. *Forest Management Plan 2014–2023.* Conservation Commission of Western Australia. 208p + maps.

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.

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

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. 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 subject to harvesting and silvicultural treatment in south-west forests.

Natural regeneration is the preferred method of regeneration in the jarrah forest. Silvicultural management encourages the production of seed crops *in-situ* and promotes the growth of existing lignotuberous seedlings, ground coppice and saplings where they exist. For uneven-aged stands, the current stand structure and stocking level of saplings and ground coppice will influence the silvicultural method applied (Department of Parks and Wildlife 2014).

Forest managers also require information about stand structure, species composition and rates of tree mortality 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.

Field assessment

Forest structure and regeneration stocking were assessed on seven monitoring grids in jarrah forest in the Wilga vegetation complex of the Jarrah Sandy Basins ecosystem in the eastern part of Blackwood District, and on three grids in the Dwellingup 1 complex of the Jarrah North West ecosystem in Perth Hills District. The grids included three external reference (FC57, FC60, FC63), two shelterwood (FC58, FC61) and two gap release grids (FC59, FC62) in the Sandy Basins ecosystem and three fire chronosequence grids (FC24, FC64 and FC65) in uncut forest in the Jarrah North West ecosystem. Time since fire on the Perth Hills grids was nine (FC64, Plavins), 39 (FC24 Kennedy) and 81 years (FC65 Amphion). Field work was undertaken during August 2014.

Assessment methods were as per the FORESTCHECK Operating Plan (DEC 2006), and included measurement of cut stumps and surveys of regeneration stocking density and species composition by the triangular tessellation method. All trees taller than 2m were measured along transects 100m long by 4m wide located between marker pegs W1-2 to W1-4 and W3-2 to W3-4 (see Fig. 1 p.5). All stems ≥20cm diameter at breast height (dbhob) were identified with a numbered tag to facilitate reliable long term measurement of tree growth, mortality and tree fall. The height and species of regeneration was assessed at four locations on each grid to indicate the status of regrowth.

Projected foliage cover was recorded in spring 2014 as part of the vegetation cover assessment during vascular plant surveys. Intercepts with foliage were recorded at 240 points around the perimeter of four 30m x 30m vegetation quadrats using a vertical periscope fitted with a fine crosshair. Intercepts were recorded as foliage present or absent in height classes of 2–15m and >15m. Contacts with eucalypt foliage were recorded separately to contacts with other plant species.

In addition to the normal stand structural attributes we also measured bark depth for 25 jarrah trees on each of the fire chronosequence grids in Perth Hills. Trees were chosen from three diameter classes based on dbhob (30–39cm, n=10; 40–49cm, n=10; 50–70cm, n=5). On each tree bark depth was measured on four sides of the stem (N, E, S, W) at three heights above ground (0.5m, 1.3m, 3.0m). Bark depth was measured to the cambium using a syringe type gauge with a hardened steel probe.

Data management

Stem diameter (overbark) measurements for individual trees were entered into the FORESTCHECK stand database. Individual tree basal areas were calculated and summed.

Results

Jarrah Sandy Basins

Stand structure and species composition

Eucalypt basal area on external reference grids ranged from 21–29m^2ha^{-1} (Table 1). Jarrah was dominant on the Hunt external reference grid, but proportions of jarrah and marri were approximately equal on the Jolly and Camballan reference grids. The two shelterwood grids had a total eucalypt basal area of 26–29m^2ha^{-1}, similar to that of the external reference grids, with jarrah being the predominant species. Gap release grids had a total eucalypt basal area of 18m^2ha^{-1} with the Hunt grid dominated by jarrah and the Wilga grid having similar contributions

Table 1. Basal area of eucalypts >2 m tall on FORESTCHECK grids in the Sandy Basins in 2014

Treatment/Grid	Basal area (m^2 ha^{-1})				
	Live			Dead	
	Jarrah	Marri	Total live	Jarrah	Marri
External reference					
FC57 Jolly	15.26	11.83	27.09	7.49	0.10
FC60 Camballan	10.35	10.73	21.08	0.00	0.01
FC63 Hunt	19.85	0.47	28.19	0.09	0
Shelterwood					
FC58 Wilga	12.87	9.06	28.93	6.81	0
FC61 Hunt	20.44	8.49	26.45	5.87	11.88
Gap release					
FC59 Wilga	9.63	8.23	17.86	0	0
FC62 Hunt	14.90	3.85	18.75	1.08	0.05

Mid-storey species did not contribute significantly to total stand basal area other than at the Hunt external reference grid where dense patches of *Xanthorrhoea preissii* added 7m^2ha^{-1} of basal area.

Only cut stumps of jarrah were encountered during the survey. Cut stumps from timber harvesting in the decade 1950–59 were recorded on transects in the Wilga shelterwood grid, and stumps from harvesting in the decade 1970–79 were recorded in external reference grids at Camballan and Hunt and in the gap release grid at Hunt (Table 2). Records indicate widespread harvesting in Wilga and Jolly blocks during the first two decades of the twentieth century but no stumps from this period were encountered during sampling, probably because they had vanished due to the combined effects of fire and wood decay. Basal area removals resulting from harvesting between 2004 and 2013 were lower at Hunt than at Wilga for both shelterwood and gap release treatments. Non-commercial felling conducted as part of the silvicultural treatment at the Wilga gap release reduced the jarrah basal area by 6.1m^2ha^{-1} in addition to the 14.8m^2ha^{-1} removed by commercial timber harvesting.

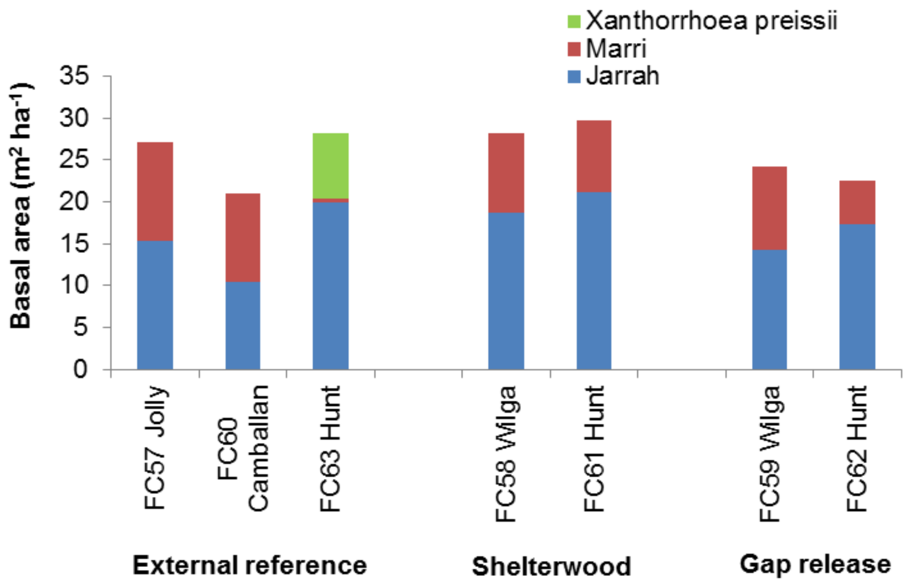


Figure 1. Basal area (m^2ha^{-1}) of jarrah, marri and mid-storey species on FORESTCHECK grids in the Sandy Basins in 2014

Table 2. Basal area (m^2ha^{-1}) of eucalypt cut stumps from recent and earlier harvesting on FORESTCHECK grids in the Sandy Basins in 2014

Treatment/Grid	**Cut stump basal area (m^2ha^{-1})**				
	Harvesting 2004-2013		Earlier harvesting		
	Jarrah	Marri	Jarrah	Marri	Decade
External reference					
FC57 Jolly	nil	nil	nil	nil	1950–59, 1900–19
FC60 Camballan	nil	nil	14.9	nil	1970–79
FC63 Hunt	nil	nil	2.45	nil	1970–79
Shelterwood					
FC58 Wilga	6.29	nil	6.29	nil	1950–59, 1900–19
FC61 Hunt	2.45	nil	nil	nil	1970–79
Gap release					
FC59 Wilga	14.75, 6.14[a]	nil	nil	nil	1950–59, 1900–19
FC62 Hunt	9.44	nil	12.55	nil	1970–79

[a] Basal area removed by non-commercial felling as part of post-harvest silviculture

Stem diameter distributions of eucalypts on grids in each treatment are shown in Figures 2 and 3. The largest tree recorded was a jarrah with a diameter of 86 cm on the Hunt gap release grid. Most trees were less than 60 cm diameter, even in the external reference grids.

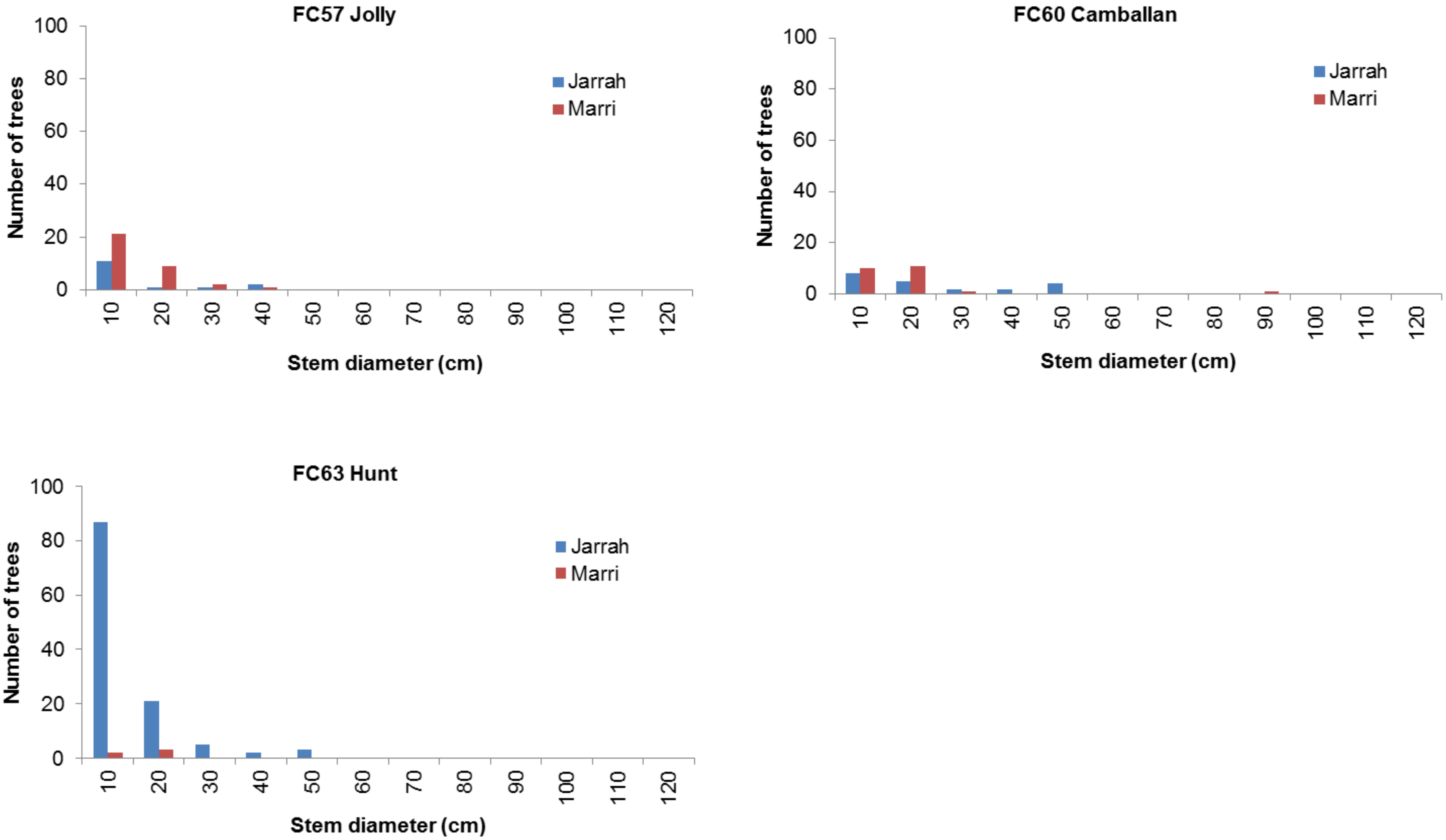


Figure 2. Stem diameter distribution by 10cm classes (0–9cm, 10–19cm etc.) for three external reference grids in the Sandy Basins in 2014

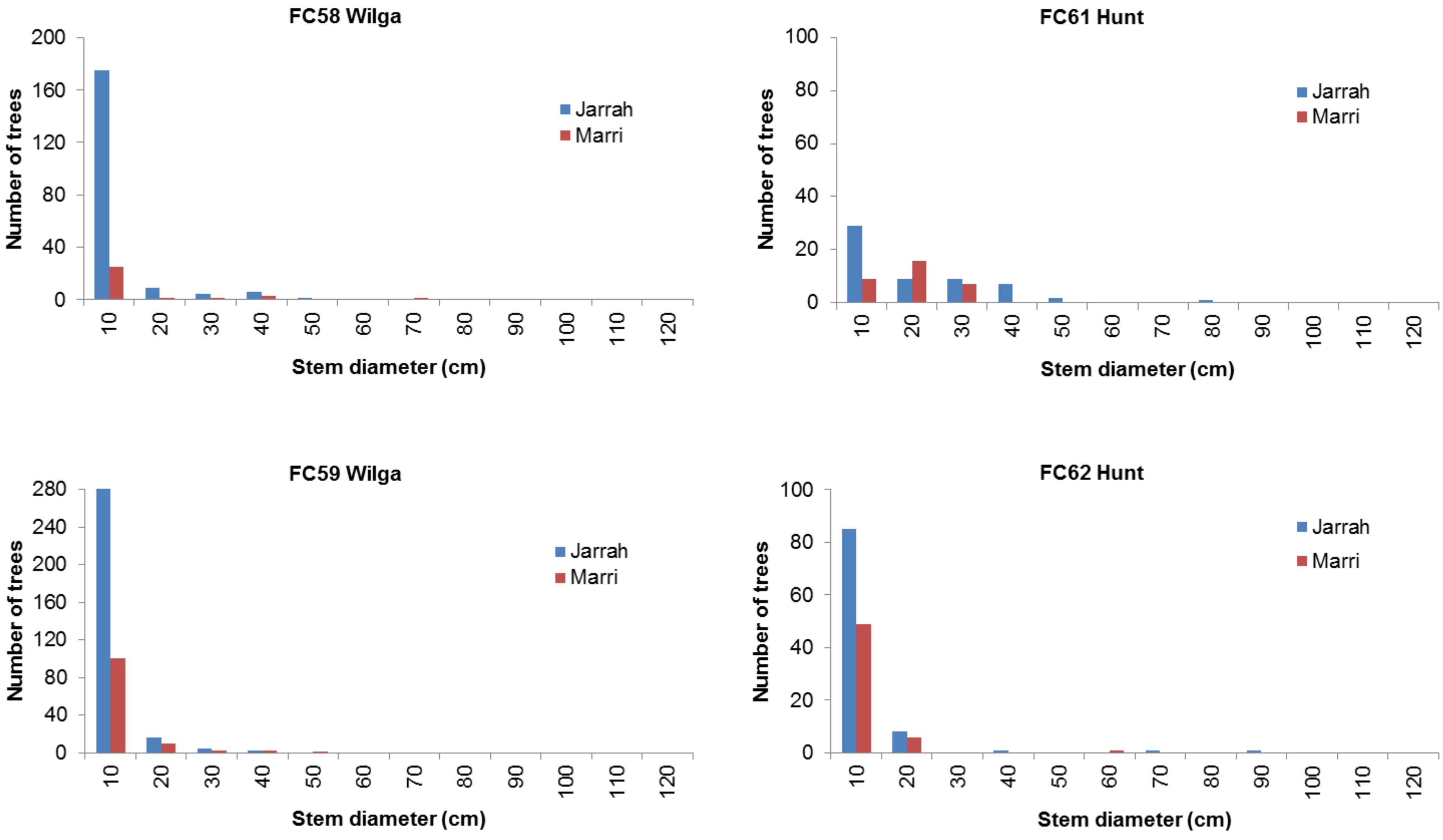


Figure 3. Stem diameter distribution by 10cm classes (0–9cm, 10–19cm etc.) for shelterwood (top) and gap release (bottom) grids in the Sandy Basins in 2014. Note the different scales on the vertical axis for the Wilga grids.

Regeneration stocking surveys indicated that ≥80% of sample points in shelterwood and gap release grids were stocked with saplings or a combination of saplings and ground coppice (Table 3). Lignotuberous seedlings were recorded at the Hunt shelterwood but made a negligible contribution to regeneration stocking because of the abundance of saplings and ground coppice. The Hunt external reference had a well-developed understorey of jarrah saplings (Fig.4) indicating successful recruitment and dynamic growth in the presence of a mature overstorey. More than 48 per cent of sample points in all grids were within 4m of an overwood tree.

Table 3. Eucalypt regeneration stocking assessed by the triangular tessellation method on grids in the Sandy Basins in 2014

Treatment/Grid	**Per cent of sample points**				
	Within 4 m of overwood tree	Stocked with saplings	Stocked with saplings and/or ground coppice	Stocked with lignotuberous seedlings	Not stocked to standard
External reference					
FC57 Jolly	64	30	60	N/A[1]	10
FC60 Camballan	62	8	70	N/A	22
FC63 Hunt	56	38	32	N/A	30
Shelterwood					
FC58 Wilga	54	74	16	0	10
FC61 Hunt	62	34	44	2	20
Gap release					
FC59 Wilga	50	58	26	N/A	16
FC62 Hunt	48	32	52	N/A	16

[1] N/A = not applicable

Figure 4. Jarrah sapling cohort beneath the mature overstorey at the Hunt external reference grid

Jarrah comprised at least 40% of saplings and ground coppice on all grids, and tended to be more abundant on the harvested grids than on external reference grids (Fig.5).

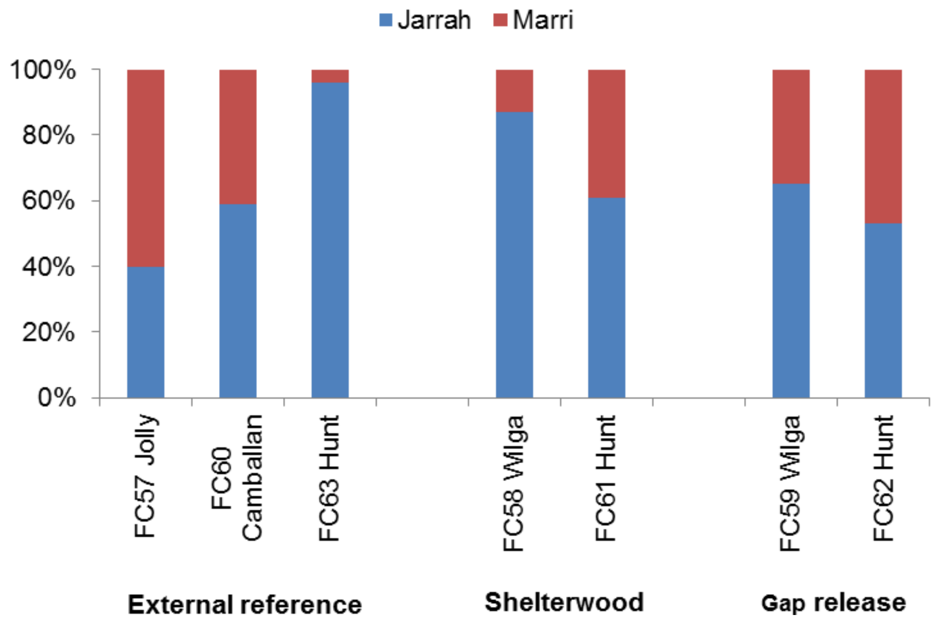


Figure 5. Species composition of sapling and ground coppice regeneration assessed by the triangular tessellation method for seven grids in the Sandy Basins in 2014

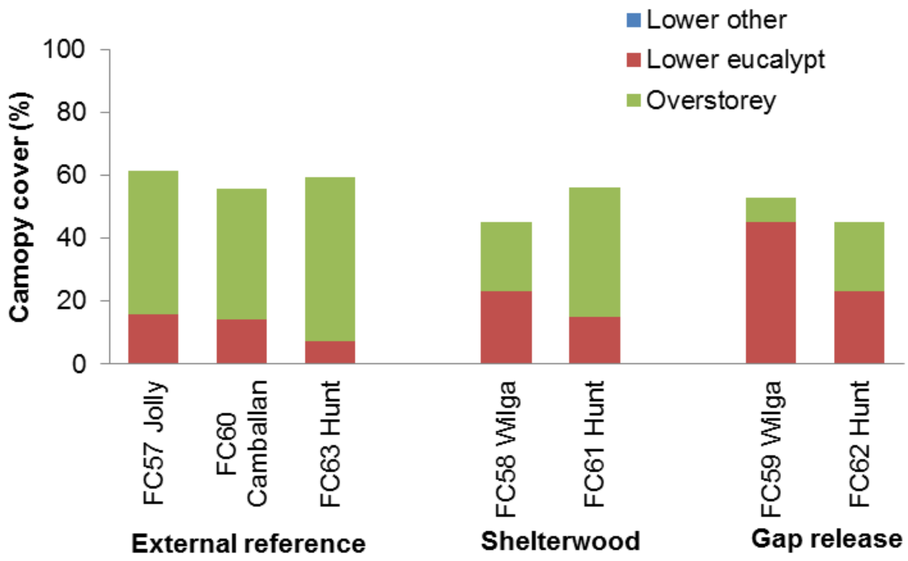


Figure 6. Projected foliage cover of eucalypts and other species divided into lower storey (2–15m) and overstorey (>15m) strata

External reference grids had a projected foliage cover of 55 to 60% (Fig. 6) with eucalypt foliage from the overstorey (>15m height) comprising the largest proportion of cover and eucalypt foliage from the lower storey contributing up to a further 15% foliage cover. Projected cover was only slightly less on harvested grids (45–55%) with eucalypt foliage from the lower storey (2–15m) making a greater contribution, particularly on the Wilga gap release grid. Non eucalypt foliage made negligible contribution to cover on any of the Blackwood grids.

Discussion

All of the seven grids established in the Sandy Basins forest ecosystem in Blackwood District had been logged at least once prior to the harvesting and silvicultural treatment that took place during the period of the Forest Management Plan 2004–2013 (Conservation Commission 2004). Surveys of stumps remaining from cutting prior to 1980 showed that the reduction in basal area resulted from selective removal of mature jarrah, with no marri stumps recorded. The Jolly and Wilga grids showed few direct indicators of the cutting that took place in this area during the first two decades of the 20th century, although this cutting would have changed the structure of the forest in places where large trees were removed. Relatively few trees with a diameter >70 cm were recorded, even on the external reference grids. This is likely to reflect the inherently low productivity of the Sandy Basins forest ecosystem, together with the effects of past selective harvesting. The relatively open nature of these forests is also reflected in the low basal area and foliage projected cover of non-eucalypt mid-storey trees, except in the Hunt external reference where *Xanthorrhoea preissii* was locally abundant in patches.

Harvesting and silvicultural treatment undertaken under the Forest Management Plan 2004–2013 has removed 3–6m^2ha^{-1} of jarrah basal area in shelterwood grids and 9–15m^2ha^{-1} in gap release grids. Post-harvest silvicultural treatment also removed a further 6m^2ha^{-1} of jarrah from the Wilga gap release grid, most of this being in the form of small diameter trees that would not have contained a commercial wood product. The four harvested grids have a cohort of jarrah saplings of at least 350stems ha^{-1}, supplemented by marri saplings, with the Wilga gap release having up to 3500stems ha^{-1} of jarrah saplings. All harvested grids exceed the current regeneration standards in terms of stocking density and species composition.

Fire Chronosequence, Dwellingup
Stand structure and species composition

Eucalypt basal area on the fire chronosequence grids ranged from 41–49m^2ha^{-1} and was dominated by jarrah (Table 4). Standing dead trees added a further 3–8m^2ha^{-1} to the total stand basal area at Amphion and Plavins. Mid-storey species contributed 2m^2ha^{-1} to total stand basal area at Plavins, but were negligible at Amphion and Kennedy (Fig. 7).

Table 4. Basal area of eucalypts >2 m tall for three FORESTCHECK fire chronosequence grids near Dwellingup in 2014

Grid	**Years since fire**	**Basal area (m^2 ha^{-1})**				
		Live			Dead	
		Jarrah	Marri	Total live	Jarrah	Marri
FC65 Amphion	80	40.91	0.88	41.79	3.38	5.09
FC24 Kennedy	39	31.13	9.63	40.76	0.66	0.01
FC64 Plavins	9	43.43	5.16	48.59	3.31	0

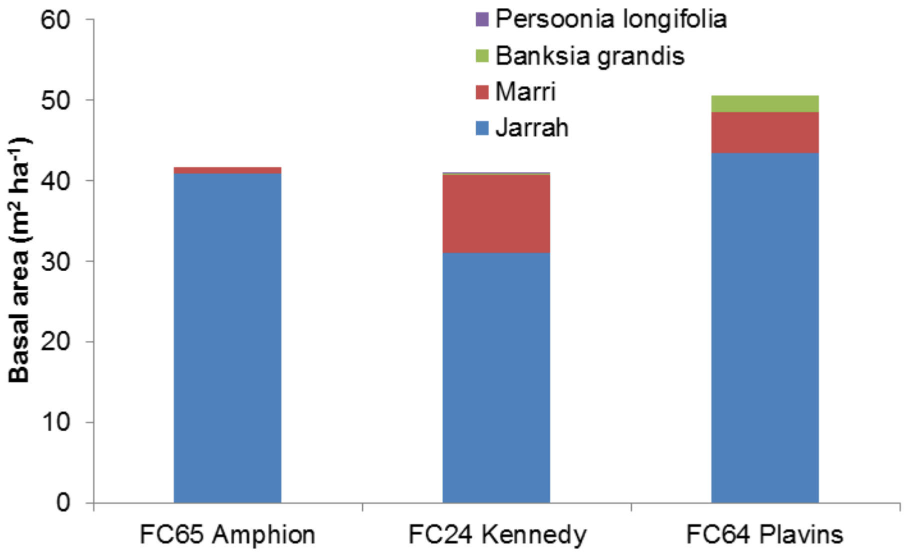


Figure 7. Basal area (m^2ha^{-1}) of jarrah, marri and mid-storey species on fire chronosequence grids near Dwellingup in 2014

Cut stumps from large jarrah trees harvested prior to 1940 were recorded on grids at Amphion ($11.88m^2ha^{-1}$) and Plavins ($16.59m^2ha^{-1}$). No stumps were recorded during the survey of the Kennedy grid although the remains of scattered burnt-out stumps were observed in the area. The Kennedy grid was burnt by high intensity experimental fire in the summer of 1975 and it is likely that most stumps had burnt away as a result of this fire.

Stem diameter distributions of eucalypts on grids in each treatment are shown in Figure 8. Trees of 10-40cm diameter were most frequent at Amphion and Plavins whereas the Kennedy grid included a greater number of saplings <10cm diameter. All trees with a diameter >50cm were jarrah, the largest tree being recorded on the Plavins grid with a diameter of 103cm.

Regeneration surveys revealed a low stocking of saplings on all grids which is not unexpected given the high level of overwood competition (Table 5). Ground coppice was moderately abundant at Kennedy and Plavins, but uncommon at Amphion. Jarrah comprised 82% and 89% of saplings and ground coppice at Amphion and Kennedy respectively, but a lower proportion at Plavins (65%). Marri was the only other eucalypt recorded during regeneration surveys.

Table 5. Eucalypt regeneration stocking assessed by the triangular tessellation method on fire chronosequence grids near Dwellingup in 2014

Grid	**Per cent of sample points**				
	Within 4 m of overwood tree	Stocked with saplings	Stocked with saplings and/or ground coppice	Stocked with lignotuberous seedlings	Not stocked to standard
FC65 Amphion	78	6	12	N/a	82
FC24 Kennedy	88	2	44	N/a	56
FC64 Plavins	76	2	46	N/a	52

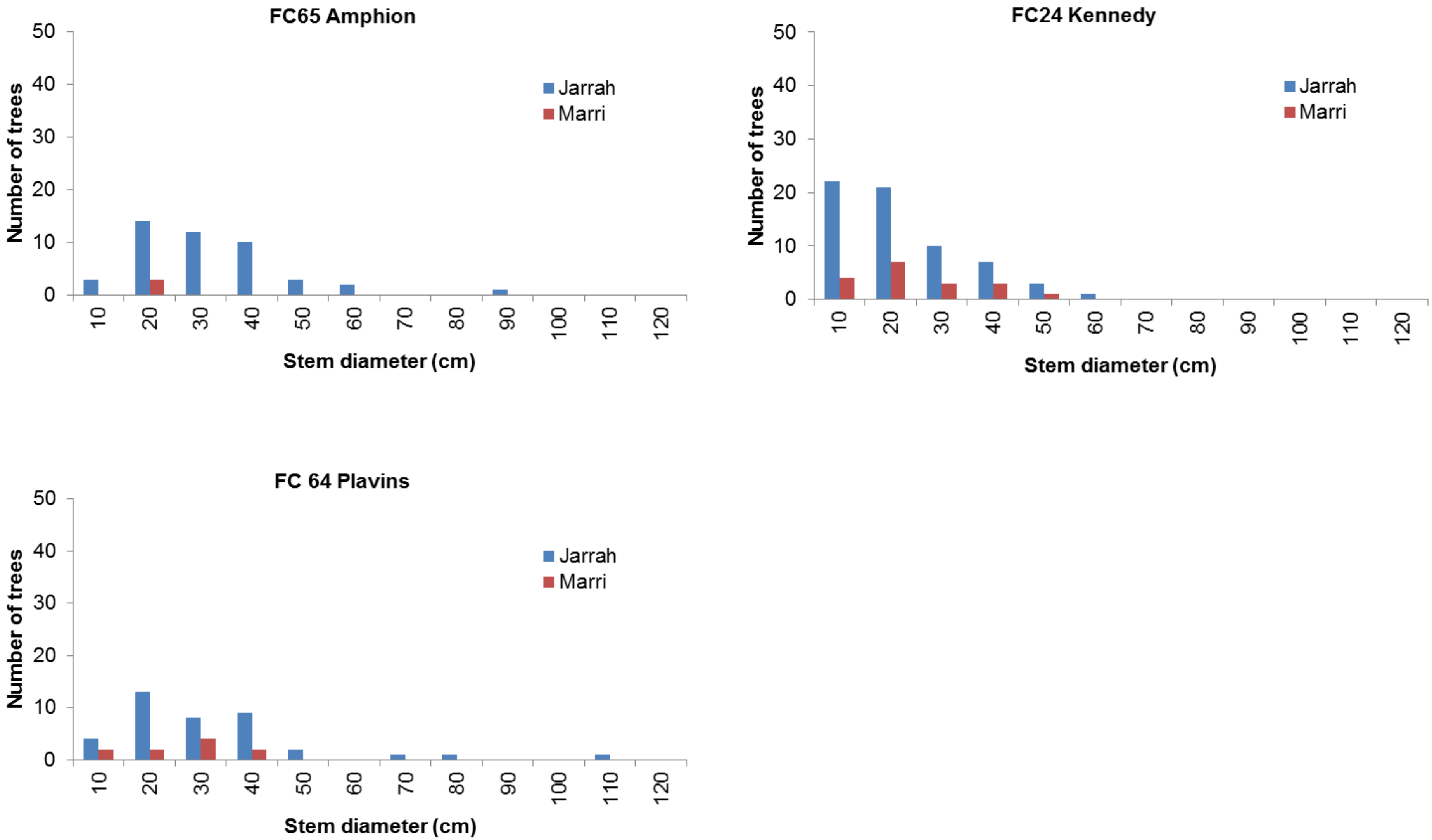


Figure 8. Stem diameter distribution by 10cm classes (0–9cm, 10–19cm etc.) for fire chronosequence grids near Dwellingup in 2014

Projected foliage cover ranged from 68–85% and was dominated by the eucalypt overstorey strata (Fig. 9). Non-eucalypt foliage contributed greater cover than eucalypt foliage in the lower strata.

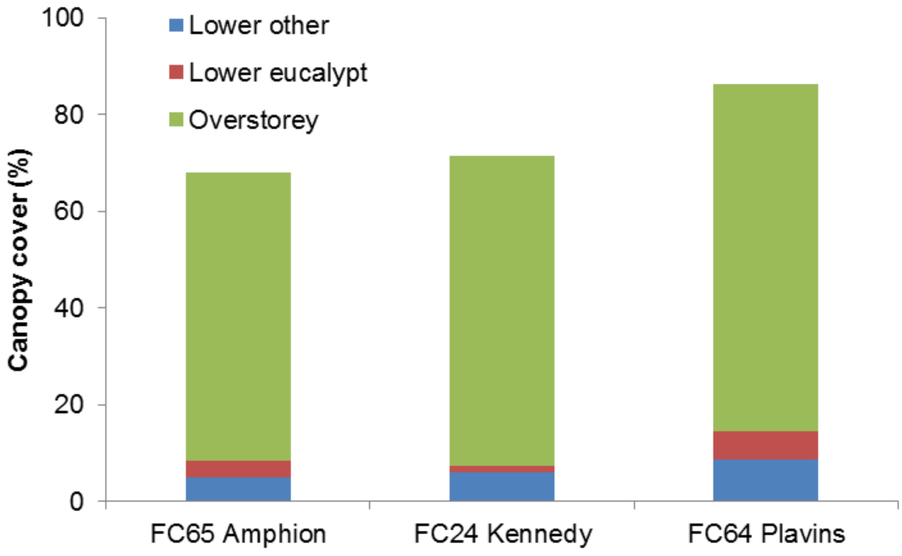


Figure 9. Projected foliage cover of eucalypts and other species divided into lower storey (2–15m) and overstorey (>15m) strata in fire chronosequence grids near Dwellingup in 2014

Bark depth was greatest at 0.5m above ground and reduced with increasing height up the stem (Fig. 10). This pattern was common to all grids regardless of tree size or time since fire. However, the relationship between bark depth and time since fire did vary with tree size. For trees 30–39cm diameter bark depth was greatest at Amphion, but bark depths at each measurement height differed little between Kennedy and Plavins. For trees 40–49cm bark depth was greatest at Amphion, intermediate at Kennedy and least at Plavins. For trees 50–79cm there was little difference in bark depth between Amphion and Kennedy, but the bark was at least 10mm thinner for each measurement height at the Plavins grid.

Bark depth was least variable on smaller trees and most variable on the larger trees, as demonstrated by the standard errors.

The relationship between bark depth, tree size and previous fire history appears to be complex and worth of further examination. In the case of Amphion, bark has been accumulating on stems since 1933 and most trees would not have experienced fire since the sapling growth stage. Scattered large veterans remaining from the original stand would have been burnt periodically prior to fire being deliberately excluded from this compartment. In the case of Plavins, the notably thinner bark on trees 50–79cm suggests that bark depth has been reduced by one or more past fires and remains well below its potential maximum value. Knowledge of the frequency and intensity of previous fires will be critical to a better understanding of these patterns. Bark on standing trees can make a significant contribution to fuel load and total heat output during a bushfire, and is the dominant source of firebrands for propagation by spotting during fires in the jarrah forest (Gould *et al*. 2007).

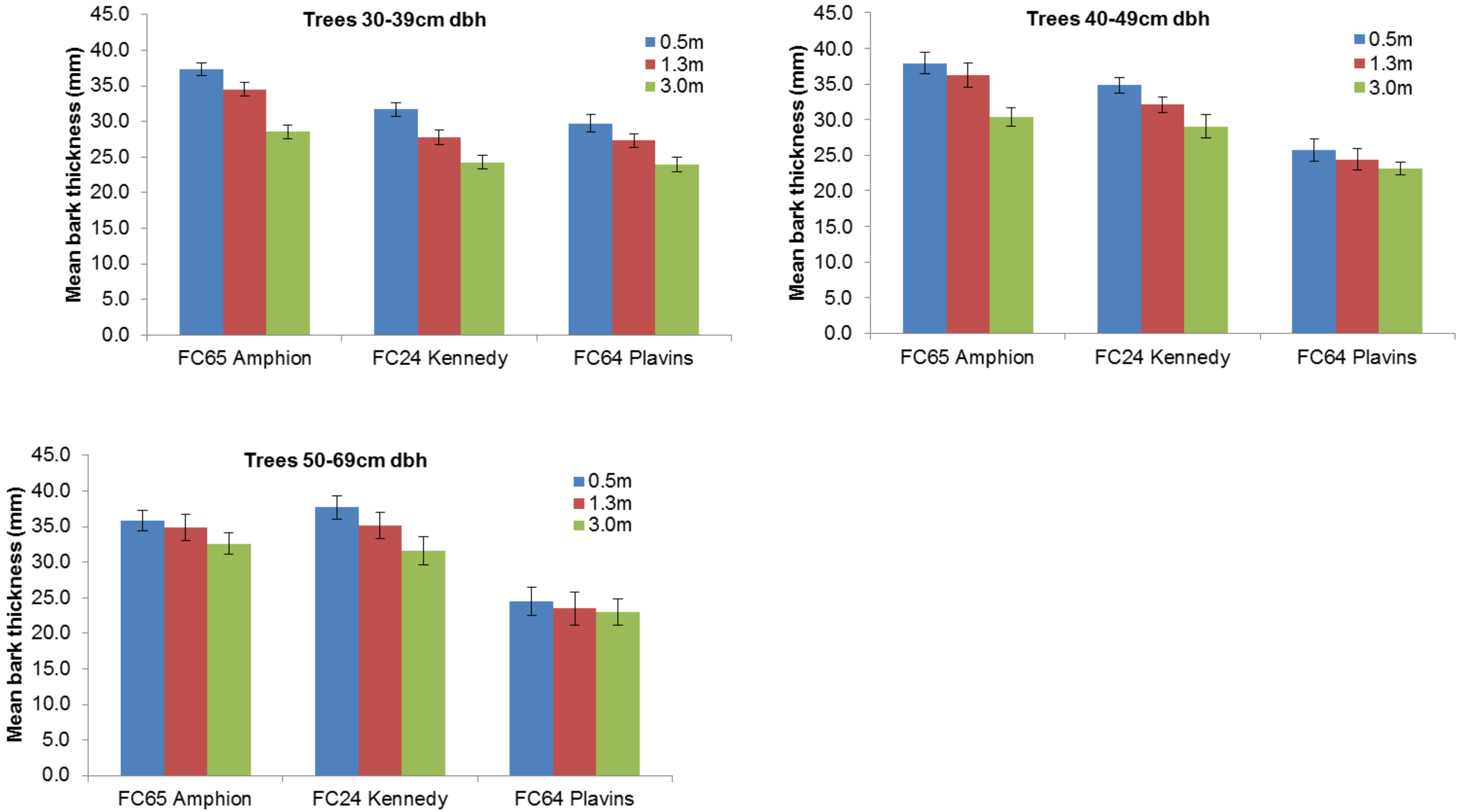


Figure 10. Bark depth on eucalypts of three diameter classes measured at 0.5m, 1.3m and 3.0m above ground on fire chronosequence grids in Perth Hills District

Conclusions

Broad observations following measurement of stand structure at the Sandy Basins FORESTCHECK grids in 2014 include:

- Eucalypt basal area of mature stands is typically 20–30m^2ha^{-1} which is lower than in more productive stands in higher rainfall areas of jarrah forest.
- Trees are generally smaller than those in higher rainfall areas of jarrah forest, with even mature stands having relatively few trees larger than 70cm dbh.
- Lignotuberous advance growth of jarrah and marri was abundant, allowing stands to regenerate readily following timber harvesting.

Broad observations following measurement of stand structure at the fire chronosequence grids near Dwellingup 2014 include:

- These stands are fully stocked with trees of intermediate size (20–50cm dbh), mostly jarrah, that regenerated following heavy cutting in the early decades of the 20th century.
- Bark continues to accumulate on the stem of jarrah trees for many decades after fire, and should be recognised as an important component of the fuel load available for combustion, particularly under dry summer conditions.

References

Commonwealth of Australia 1998. *A framework of regional (sub-national) level criteria and indicators of sustainable forest management in Australia*. Department of primary Industries and Energy, Canberra, ACT.

Conservation Commission of Western Australia 2004. *Forest Management Plan 2004–2013.* Conservation Commission of Western Australia. 144p + maps.

DEC 2006. *FORESTCHECK: Monitoring Biodiversity in the South-West Forests. Operating Plan.* Department of Environment and Conservation, Kensington, Western Australia.

Department of Parks and Wildlife 2014. Silviculture Guideline for Jarrah Forest. Sustainable Forest Management Series, FEM Guideline 1.

Gould, J., McCaw, L., Cheney, N.P., Ellis, P.F., Knight, I.K. and Sullivan, A.L. 2007. *Project Vesta. Fire in dry eucalypt forest: fuel structure, fuel dynamics and fire behavior*. CSIRO and Department of Environment and Conservation, Western Australia.

COARSE WOODY DEBRIS, SMALL WOOD AND TWIGS, AND LITTER

Richard Robinson Lachie McCaw and Kim Whitford

Introduction

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. Coarse woody debris (CWD), small wood and twigs (SWT) and litter are important structural and biological components of forest ecosystems. Disturbances such as timber harvesting and fire 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, SWD and litter on the ground in jarrah forest managed for silviculture (i.e. gap release and shelterwood treatments) and in uncut forest;
- analyse trends within and between the treatments over time; and .
- provide data for analysis of distribution patterns of other organisms such as invertebrates, small mammals, fungi and cryptogams.

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

Field and laboratory assessment

Coarse woody debris, small wood and twigs and litter assessments were undertaken on seven FORESTCHECK monitoring grids in the Sandy Basins ecosystem in Blackwood District. All the grids were located in the Wilga vegetation complex and included three external referance (FC57, FC60, FC63), two shelterwood (FC58, FC61) and two gap release grids (FC59, FC62). In addition, sampling was also undertaken on three fire chronosequence grids (FC24, FC64 and FC65) in the Jarrah North West ecosystem in the Perth Hills District. These grids were all located in the Dwellingup 1 vegetation complex and time since fire was nine (FC64, Plavins block), 39 (FC 24 Kennedy block) and 81 years (Amphion block). The grids in Kennedy and Amphion forest blocks are located within fire exclusion reference areas. These grids were logged heavily prior to 1930 but have not been harvested since.

CWD was assessed along three 200m-long transects on each grid using the line intercept technique (van Wagner 1968). The process of assessment of CWD volume (m^3 ha^{-1}) and condition are described in Whitford *et al*. (2008). The Sandy Basins (FC57–FC62), Plavins (FC64) and Amphion (FC65) grids were all measured during autumn and winter in 2014. The Kennedy external reference grid (FC24) was previously assessed in 2003 and 2009.

Small wood and twigs and litter assessments, at both the Sandy Basins grids and the fire chronosequence grids, were conducted from 4–7 November 2014. Twenty-two samples each of SWT and litter were collected from each monitoring grid as per the methods detailed in the FORESTCHECK Operations Plan (DEC 2006). Briefly, on each grid, litter samples were collected from 11 plots, each $0.05m^2$, along each of two 100m transects. SWT samples were collected from $1m^2$ plots, directly adjacent each litter plot. All samples were oven dried for 24 hours and dry weights used to determine loads in tonnes per hectare (t ha^{-1}).

Results and discussion
Sandy Basins
Coarse woody debris (CWD)

The loads of CWD measured on the Sandy Basins grids ranged from 29–160m^3 ha^{-1} (mean 74 ± 19 m^3ha^{-1}) (Table 1) which are generally light compared to those measured and reported for other FORESTCHECK grids (see Forestcheck Reports of Progress for 2009–10 and 2013). Within the external reference treatment, the largest volume was measured on the Hunt grid (FC63) which had been unburnt for 10 years longer than grids located in both Jolly and Camballan forest blocks (Fig. 1). Within the harvested grids, those situated in Wilga forest block carried almost 2–3 times the volume of CWD than that measured on the grids in Hunt forest block.

Table 1. FORESTCHECK grids assessed in 2014 for coarse wood debris (CWD) volume and condition. Grids are grouped by treatment type.

Grid	Location	Treatment	Year grid established	Year of most recent harvest	Years since fire	Mean CWD volume (m^3ha^{-1} ± se)
FC57	Jolly	Fauna habitat zone	2014		9	29 ± 4
FC60	Camballan	External reference	2014		9	40 ± 23
FC63	Hunt	Fauna habitat zone	2014		19	51 ± 15
FC58	Wilga	Shelterwood	2014	2006	7	129 ± 26
FC61	Hunt	Shelterwood	2014	2006	8	43 ± 18
FC59	Wilga	Gap release	2014	2006	7	160 ± 27
FC62	Hunt	Gap release	2014	2006	8	69 ± 21
Mean						74 ± 19

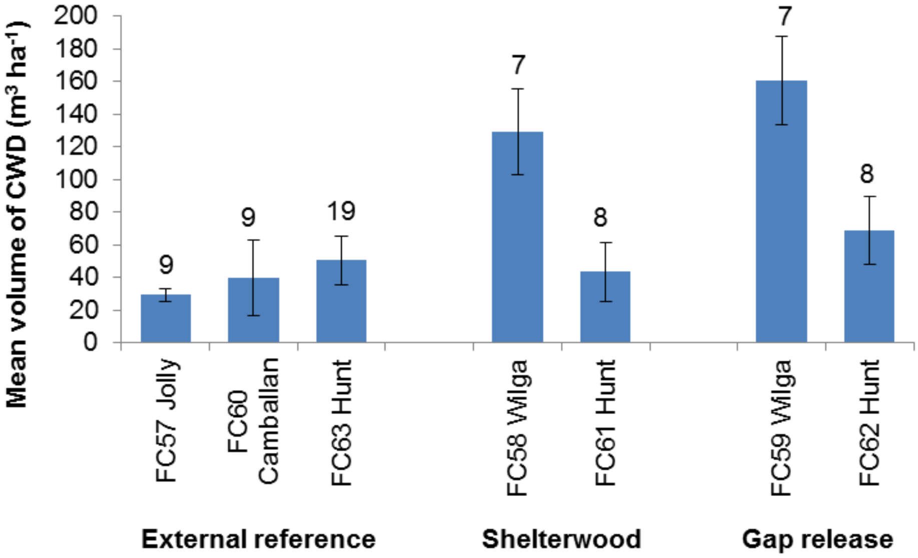


Figure 1. Mean loads (m^3ha^{-1} ± se) of coarse woody debris (CWD) > 2.5cm in diameter at each FORESTCHECK grid in the Sandy Basins ecosystem in 2014. Numbers above columns indicate the years since fire on each grid.

On shelterwood treated grids, about 40% of the CWD was attributed to harvesting debris, while on the gap release treated grids it was about 45% (Fig. 2).

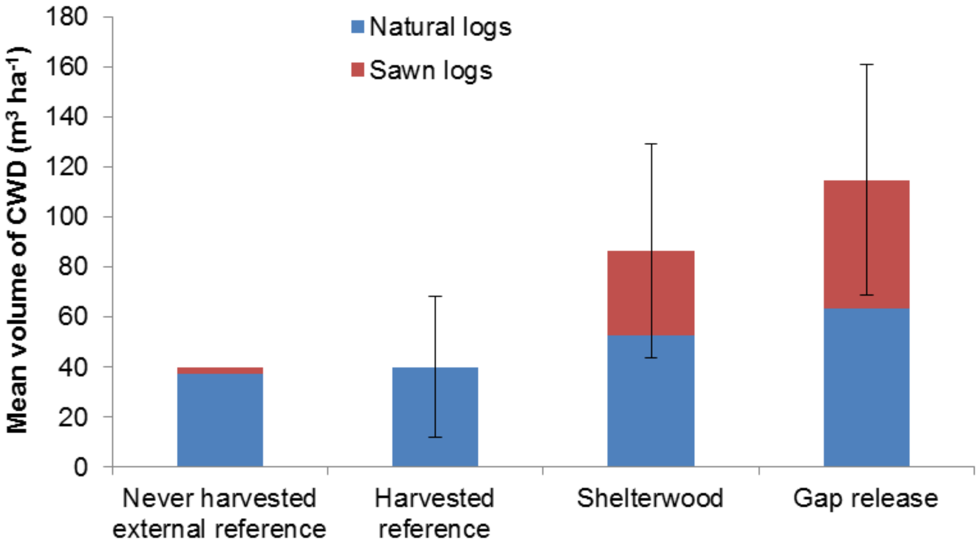


Figure 2. Mean loads (m³ha⁻¹ ± se) of coarse woody debris (CWD) > 2.5cm in diameter derived from felled and 'natural' logs on never harvested and various harvested FORESTCHECK treatments in the Sandy Basins ecosystem in 2014

Small wood and twigs (SWT) and litter

SWT and 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. The amounts of SWT and litter recorded on most grids generally reflected time since fire (Figs 3 and 4). However, SWT loads recorded on the Hunt shelterwood (FC61) and the longer unburnt Hunt external reference (FC63) grids were noticeably low.

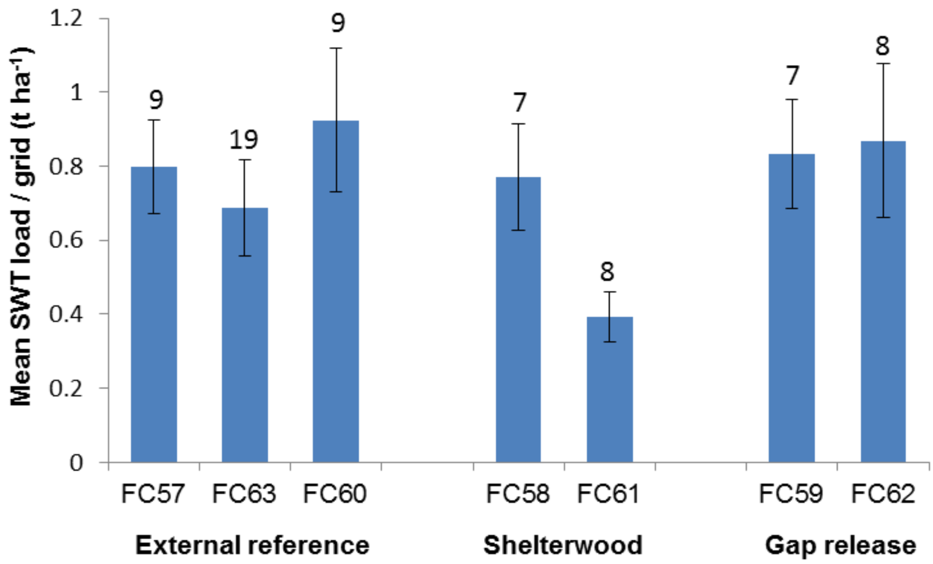


Figure 3. Mean loads (t ha⁻¹) of small wood and twigs (SWT) measured on each FORESTCHECK grid in the Sandy Basins ecosystem in 2014. Numbers above columns indicate years since fire.

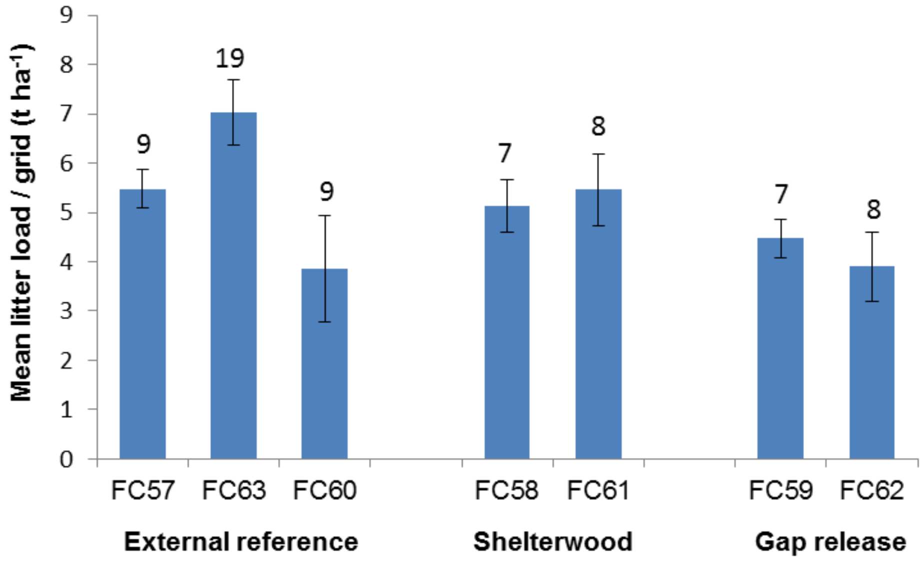


Figure 4. Mean litter loads (t ha^{-1} ± se) calculated on each FORESTCHECK grid in the Sandy Basins ecosystem in 2014. Numbers above columns indicate years since fire.

Fire chronosequence, Dwellingup

Coarse woody debris (CWD)

The largest volume of CWD was measured on the Amphion grid, which was also unburnt for about 40 years longer than the Kennedy grid and 70 years longer than the Plavins grid. Although the Plavins grid was burnt only 9 years prior to measurement, a larger volume of CWD was measured in it than on the Kennedy grid which was unburnt for 39 years (Table 2). The Kennedy grid was burnt in the summer of 1975 as part of an experimental high intensity fire and it is likely that this fire consumed a large proportion of the CWD that remained from the harvesting that took place during the decade 1920–29.

Table 2. Fire chronosequence monitoring grids assessed for coarse wood debris (CWD) volume and condition near Dwellingup in 2014.

Grid	Location	Treatment	Year grid established	Year of most recent harvest	Years since fire	Mean CWD volume (m^3ha^{-1} ± se)
FC64	Plavins	External reference	2014		9	104 ± 14
FC65	Amphion	External reference	2014		81	302 ± 72
FC24	Kennedy	External reference	2003	1920	39	91 ± 7
Mean						166 ± 68

NB Kennedy and Amphion grids are located within fire exclusion reference areas

About 40% of the CWD measured on the Amphion grid had been sawn (Fig. 5), and would have resulted from the initial harvesting that took place before 1920. Silvicultural treatment including cull falling and ringbarking undertaken during the Great Depression of the 1930s may have added further to the quantity of CWD. The long exclusion of fire at FC65 has meant that most CWD has persisted, with termites and decay being the mechanisms of decomposition. The very large volume of CWD on this resulted from a high frequency of log pieces with a diameter 50–100cm, rather than from the dominance of a few very large logs.

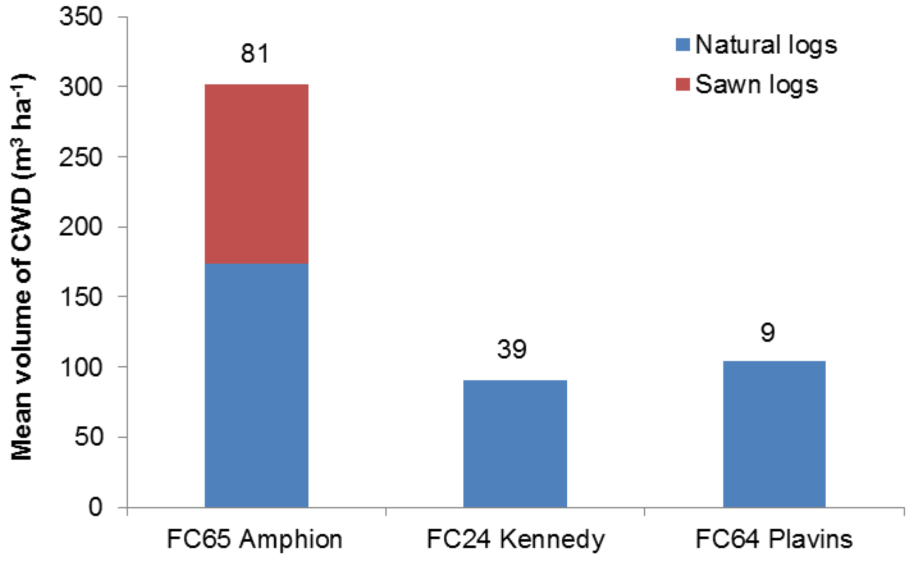
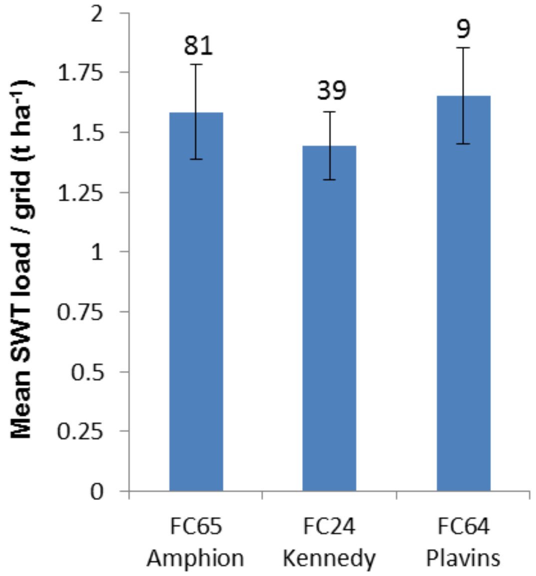


Figure 5. Mean loads (m^3ha^{-1} ± se) of coarse woody debris (CWD) > 2.5cm in diameter recorded on each fire chronosequence grid near Dwellingup in 2014. Numbers above columns indicates the years since fire on each grid.

Small wood and twigs (SWT), and litter

The amounts of SWT recorded all the grids were similar (Fig. 6, left). Litter loading reflected time since fire (Fig. 6, right), although the difference in load between Amphion and Kennedy grids was small.



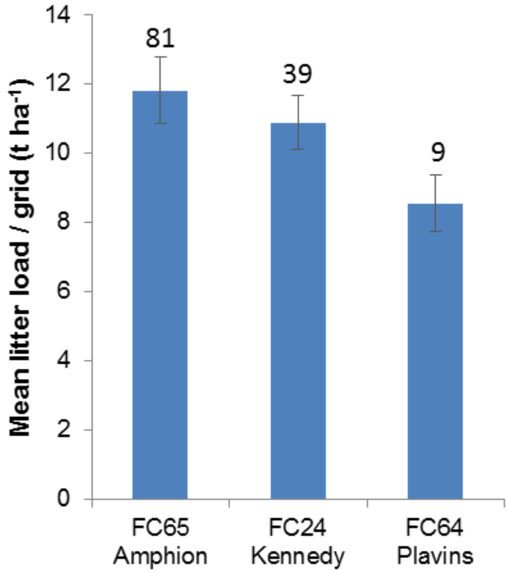


Figure 6. Mean small wood and twigs (SWT, left) and litter (right) loads (t ha^{-1} ± se) recorded on each fire chronosequence grid near Dwellingup in 2014. Numbers above columns indicate years since fire.

Conclusions

Broad observations resulting from CWD, SWT and litter sampling at the Sandy Basins FORESTCHECK grids in 2014 include:

- The volume of CWD in harvested grids is substantially greater than in unharvested reference grids, consistent with previous findings from surveys of the initial 48 grids.

- The volume of CWD added as a result of recent harvesting was greater at Wilga than at Hunt, consistent with the greater reduction in stand basal area at Wilga.
- Litter loadings at both Wilga/Jolly and Hunt are lower than in more productive stands in higher rainfall areas of the jarrah forest.

Broad observations resulting from CWD, SWT and litter sampling at the fire chronosequence grids near Dwellingup in 2014 include:

- The very large volume of CWD at the Amphion grid, compared with the Kennedy and Plavins grids, demonstrates clearly the critical role that fire history plays in the amount and condition of CWD in the jarrah forest.
- Litter loads at Amphion and Kennedy are greater than in more recently burnt forest of comparable structure and productivity, but the rate of litter accumulation declines as time since fire increases. This asymptotic pattern of fuel accumulation has been well documented in eucalypt forests, and indicates that rates of litter fall and decomposition reach a dynamic equilibrium. Other components of the fuel complex, including bark and CWD, may continue to accumulate well after the litter load has attained an equilibrium loading.

Acknowledgements

Thank you to Rob Hill for assistance with CWD assessment and to Graeme Liddelow, Bruce Ward, Colin Ward, Chris Vellios and Dave Pickett for assistance with litter & SWT sample collection.

References

DEC (2006) *FORESTCHECK: Monitoring biodiversity in south-west forests. Operating Plan*. Department of Environment and Conservation, Kensington, Western Australia.

van Wagner, C.E. (1968) The line intersect method in forest fuel sampling. *Forest Science* **14**, 20–26.

Whitford, K., Guja, L. and Phelan, G. (2008) *FORESTCHECK coarse woody debris assessment procedure*. Internal report. Department of Conservation and Land Management. 22pp.

MACROFUNGI

Richard Robinson and Melanie Schindler

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 that species assemblages change with time since disturbance. Knowledge on fungal diversity and the ecological roles that fungi play is of importance to forest managers in making decisions regarding sustainable forest management.

The objectives of this component of FORESTCHECK are 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 utilization over time; and
- generate detailed descriptions of unknown or unnamed species.

Field survey

Macrofungi surveys were conducted on seven FORESTCHECK monitoring grids in the Sandy Basins ecosystem in Blackwood District in 2014. The grids included three unlogged reference (one in conservation reserve, FC60, and two in fauna habitat zones, FC57 and FC63), two shelterwood (FC58, FC61) and two gap release grids (FC59, FC62). Macrofungi were not monitored at the three fire chronosequence grids near Dwellingup in 2014.

Two surveys were conducted, the first from 23–27 June and the second from 10–18 July. Surveys are conducted when the Soil Dryness Index (SDI) indicated 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 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), indicating fully saturated conditions in the upper soil. The closest automatic weather stations are located at Bridgetown and Collie East. At the time of survey both stations registered similar SDI conditions. During surveys, the SDI was about 30 at Bridgetown and 10 at Collie East for the first survey. It reached zero on 23 June at Collie East (Fig. 1) and on 2 July at Bridgetown and fluctuated around 5 at both stations for the second survey.

In each survey, all seven grids were monitored. All macrofungal species and their abundance were recorded along 2 x 200m transects on each grid (see Grid setup on p. 5). All new or previously unrecorded taxa were photographed *in situ* and vouchers collected. For wood decay fungi such as *Stereum hirsutum*, individual hymenia (s. hymenium = spore-bearing layer of a fruit body) were counted irrespective of whether they arose from the same cluster or not, and for resupinate fungi such as *Mycoacea subceracea* or *Hypoxylon* spp., individual 'patches' of hymenium on the wood surface were counted irrespective of their size. For a small number of species that fruited in clusters, like *Calocera guepinoides*, fruit bodies were counted up to 20 then visually estimated in steps of five up to 50. Larger clusters were scored at 75 or 100+. Substrates on which species were growing were also recorded and included: soil, leaf litter, bark, twigs (<2.5cm), branches (2.5–5cm), wood (>5cm), dung, other fungi and fruits of vascular plants. Host species were also recorded for parasitic and saprotrophic fungi.

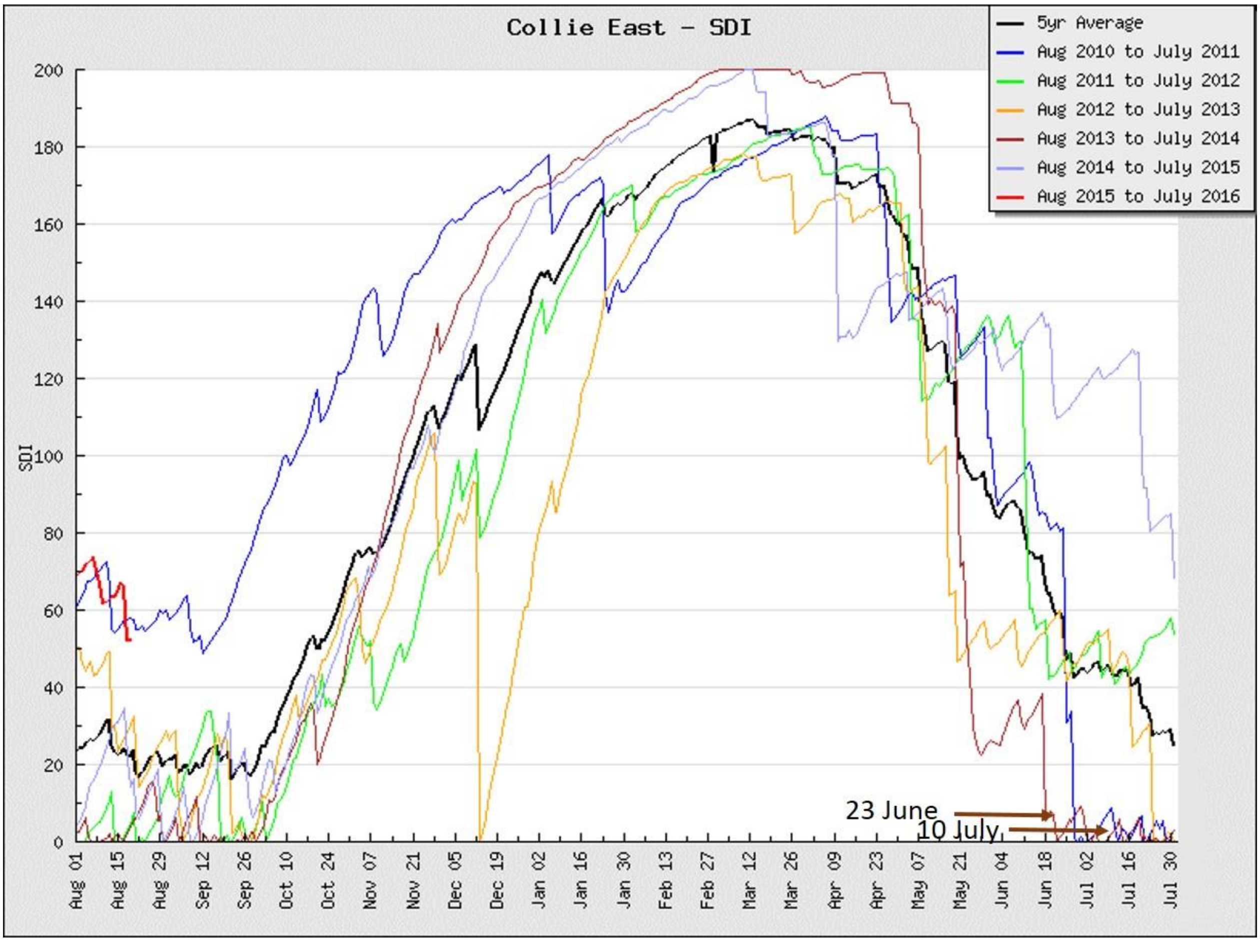


Figure 1. Daily soil dryness index (SDI) from the Collie East automatic weather station during the period August 2010 to July 2016 (Bureau of Meteorology). The SDI at the start of each FORESTCHECK macrofungi monitoring period in 2014 is indicated by the brown arrows.

Since 2002, a species list and field guide has been compiled from annual surveys and used to identify taxa based on morphological characteristics of fruit bodies. The list and field guide is reviewed annually to update nomenclature and species determinations.

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 or on the next morning. Detailed descriptions of the macroscopic characters of fresh specimens were compiled for each collection that represented a putative new species or represented noticeable variation in species concepts already determined. Following documentation, all collections were air dried at 35º C. At the completion of the field surveys, selected dried specimens were examined microscopically and detailed measurements of basidia, spore and hyphal structure were undertaken to either verify their identity or confirm undescribed species.

A species list has been compiled (Appendix 1). In total, 32 voucher collections were made representing 29 species. Only five 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

A total of 139 species of macrofungi and 8041 fruit bodies were recorded in the Sandy Basins monitoring grids in 2014 (Appendix 1). Ninety-eight species were recorded in the June survey and 95 in the second survey in July. Thirty-eight percent 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.

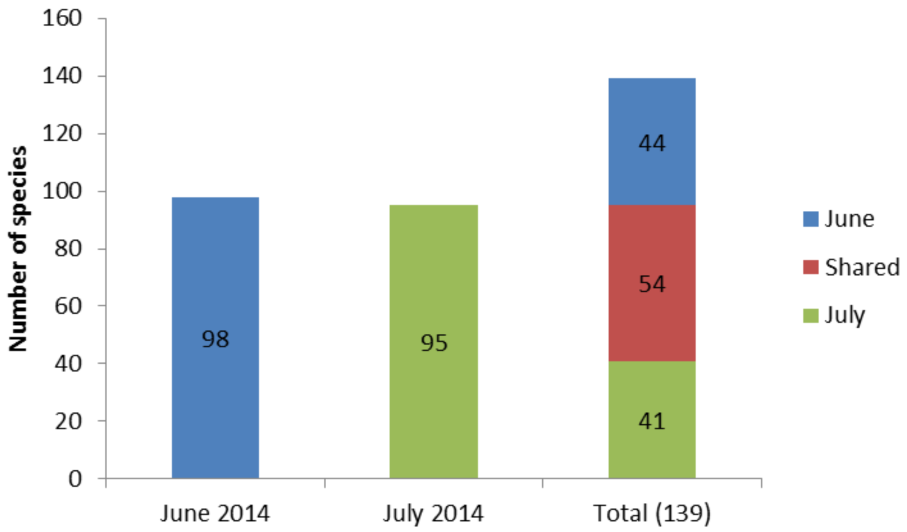


Figure 2. Total number of macrofungi species recorded in June and July surveys on FORESTCHECK monitoring grids in the Sandy Basins ecosystem in 2014

Total species richness and abundance was markedly higher on the Wilga/Jolly grids compared to the Hunt/Camballan grids (Fig. 3). Fruit body abundances on the Hunt/Camballan grids were very low. At both locations, richness and abundances were higher on harvested grids than on reference grids. Time since fire did not appear to influence total species richness or abundance.

Mean species richness and abundance per grid

Overall mean species richness and mean fruit body abundances per grid showed a similar trend to that of total richness and abundance. Although differences between treatments were not significant, there was large variation within each treatment which masked the higher richness and abundances in harvested treatments (Fig. 4).

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. More species and many more fruit bodies were recorded on soil and wood on all harvested grids at Wilga/Jolly than at Hunt/Camballan (Fig. 5). At both locations fewer species and fruit bodies were recorded on wood in all external reference grids, but a larger number of fruit bodies was recorded on litter on external reference grid in Jolly (FC57). Overall, mean species richness of species fruiting on soil was lower on gap release grids while on wood it was lowest on external reference grids. Mean abundance of fruit bodies recorded on wood was highest in harvested treatments (Fig. 6). Although the number of species recorded on soil was high, their abundances were relatively low.

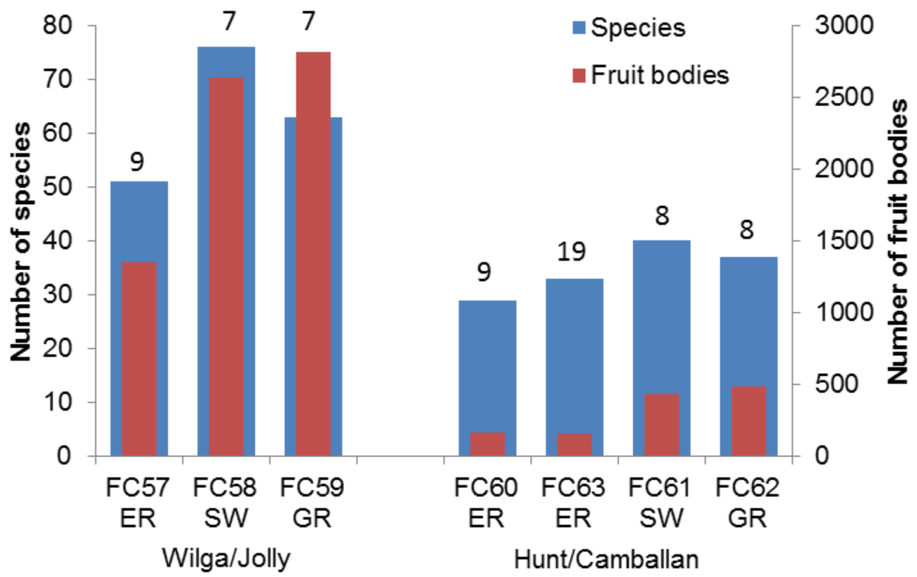


Figure 3. Total number species and fruit bodies of macrofungi recorded on each FORESTCHECK monitoring grid in the Sandy Basins ecosystem in 2014. ER = external reference, SW = shelterwood and GR = gap release treatment. Numbers above columns indicate years since the last fire.

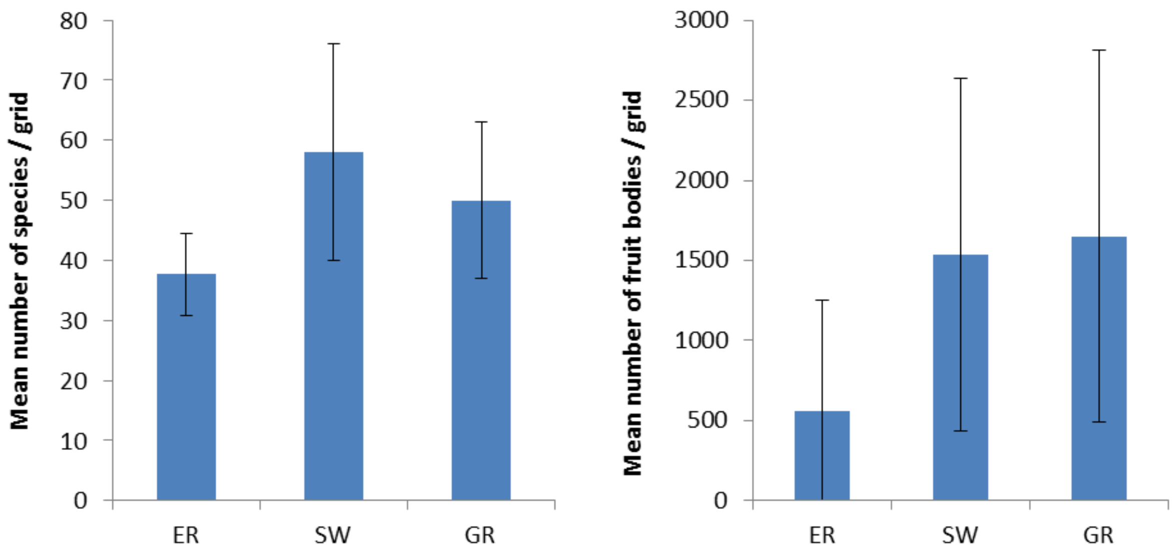


Figure 4. Mean number of species (left) and fruit bodies (right) of macrofung per grid (± se) recorded in each treatment in the Sandy Basins ecosystem in 2014. ER = external reference, SW = shelterwood and GR = gap release treatment.

Trophic status

Fungi are associated with two of the most beneficial ecological processes involved in ecosystem functioning; the formation of mycorrhizae, and decomposition. At Sandy Basins in 2014, 31% of the species recorded were mycorrhizal and 65% saprotrophic. More saprotrophic species were recorded on Wilga/Jolly grids and their abundances were markedly higher than that recorded at Hunt/Camballan (Fig. 7). The mean number of saprotrophic species and their abundances per grid was higher in harvested grids, while the mean abundances of mycorrhizal species were noticeably low in all treatments (Fig. 8).

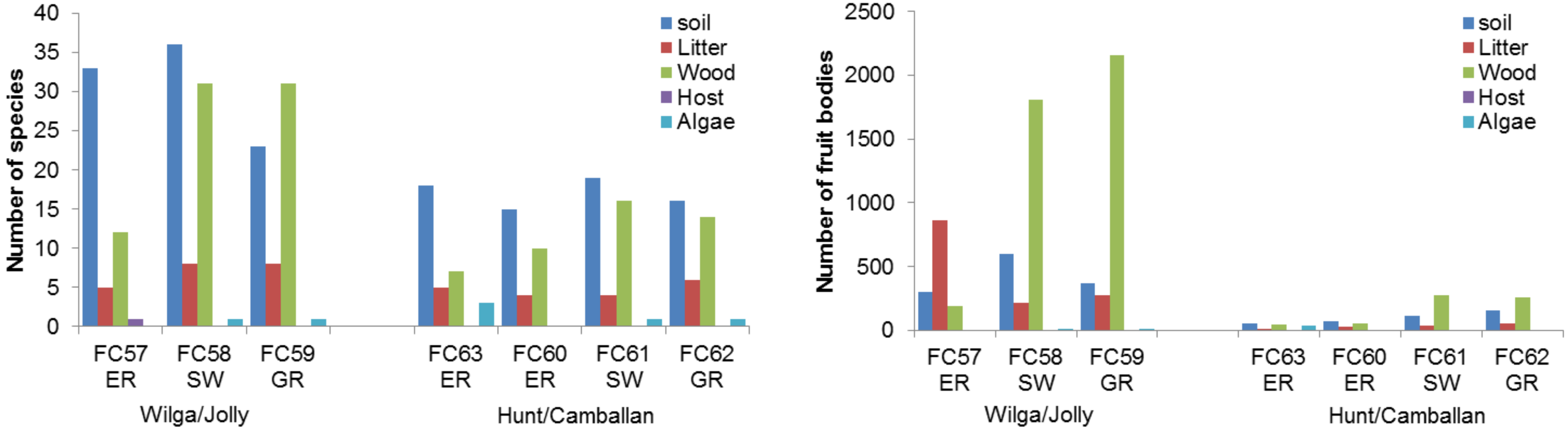


Figure 5. Number of species (left) and fruit bodies (right) of macrofungi recorded fruiting on soil, litter, wood and other substrates on each FORESTCHECK grid in the Sandy Basins ecosystem in 2014

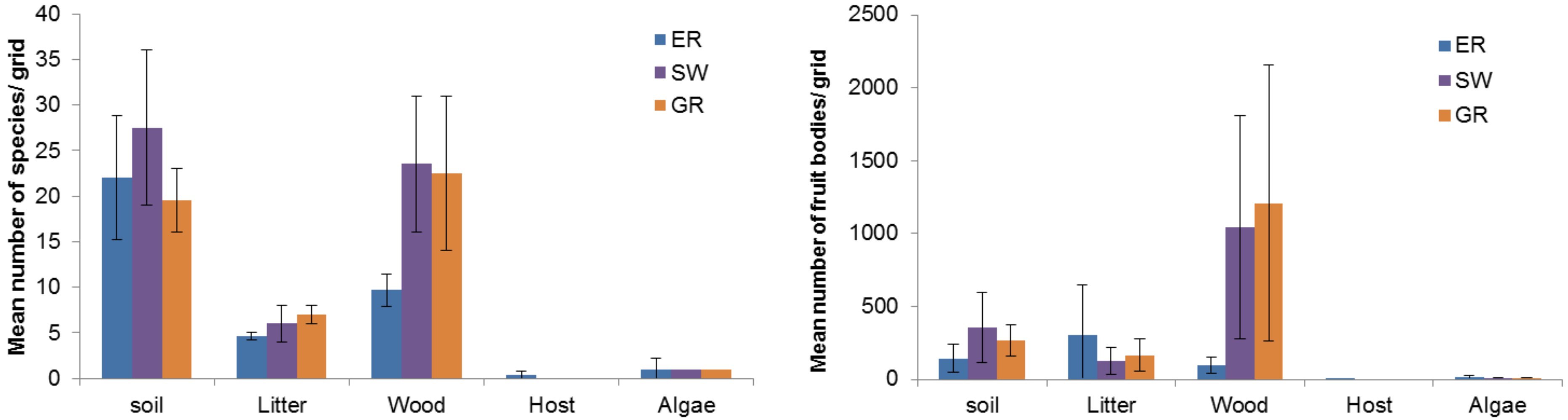


Figure 6. Mean number of species (left) and fruit bodies (right) of macrofungi per grid (± se) recorded fruiting on soil, litter, wood and other substrates in each treatment at the Sandy Basins FORESTCHECK monitoring grids in 2014

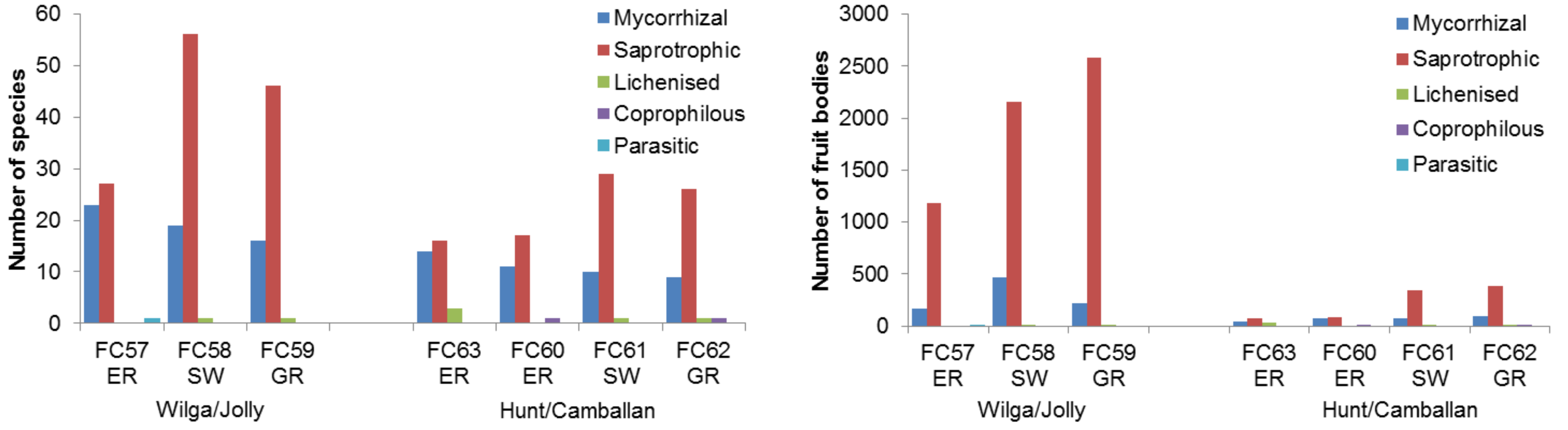


Figure 7. Number of species (left) and fruit bodies (right) of mycorrhizal, saprotrophic, lichenised, coprophilous and parasitic macrofungi recorded on each FORESTCHECK grid in the Sandy Basins ecosystem in 2014

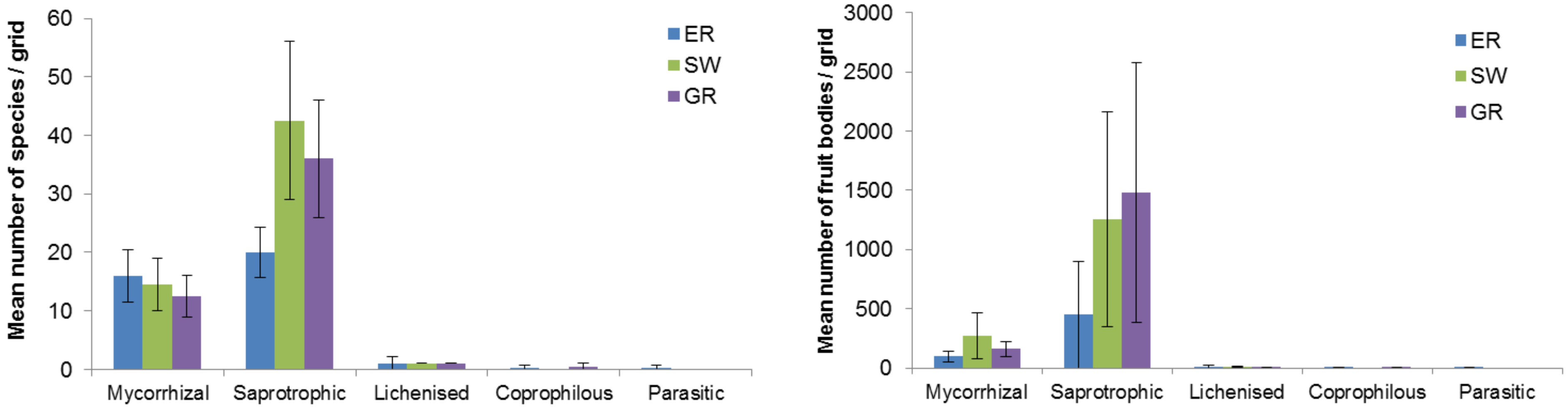


Figure 8. Mean number of species (left) and fruit bodies (right) of mycorrhizal, saprotrophic, lichenised, coprophilous and parasitic macrofungi recorded per grid (± se) on the Sandy Basins FORESTCHECK monitoring grids in 2014

The most common mycorrhizal species was *Laccaria* sp. B ‘pale’ (Fig. 9a). It was most common on shelterwood and gap release grids, where it favoured open recently burnt patches and fruited amongst moss and charcoal, but was also recorded in low numbers on external reference grids. Similarly *Coltriciella dependens* (Fig. 9b), a mycorrhizal species that fruits on the underside of recently burnt wood was also common in all treatments. The most common saprotrophic species were *Gymnopilus* sp. 85 ‘slender’ (Fig. 9c) and *G. allantopus*. Both species fruit on fallen branch wood and logs and fruited in large numbers on harvested grids. Both species were also present on external reference grids, but in comparatively low numbers. *Panus fasciatus* (Fig. 9c), a species commonly found on fallen dead branch wood and logs in the drier jarrah forest regions, was also common on gap release grids and recorded in low numbers on shelterwood and external reference grids. *Pholiota highlandensis* (Fig. 9e), a saprotrophic species, that fruits in well-rotted litter and on bark, was recorded in large numbers on harvested grids. Three species of lichenised fungi were recorded. *Lichenomphalia* sp. 431 ‘orange brown’ (Fig. 9f) and *L. chromacea* were only recorded on the Hunt external reference grid (FC63) and *L. umbellifera,* was recorded in low numbers in all treatments. See Appendix 1 for data on these and other taxa.

Figure 9. (a) *Laccaria* sp. B, (b) *Coltricia dependens*, (c) *Gymnopilus* sp. 85 ‘slender’, (d) *Panus fasciatus*, (e) *Pholiota highlandensis* and (f) *Lichenomphalia* sp. ‘orange brown’.

Species richness and abundance at all locations from 2002–2014

Locations within the southern jarrah forest region, i.e. Donnelly 1 & 2 (JS) and Blackwood Plateau (JB), appear to be the most species rich in fungi. The years 2008 and 2013 stand out as favourable for macrofungal diversity, with richness and abundance being particularly high in 2013. The drier Wellington East location (JNE) is also species rich, while the northern Perth Hills (JNW-N) and Sandy Basins (JSB) locations are less species rich and produce fewer fruit bodies (Fig. 10). In general, fruit body abundance reflected species richness, but in 2013 it was very high relative to species richness.

Despite favourable conditions when survey was undertaken in 2014, species richness and abundance were low on the Sandy Basins grids. Whether this season was typical or uncharacteristically low is not known as it was the first time surveys have been conducted in this ecosystem.

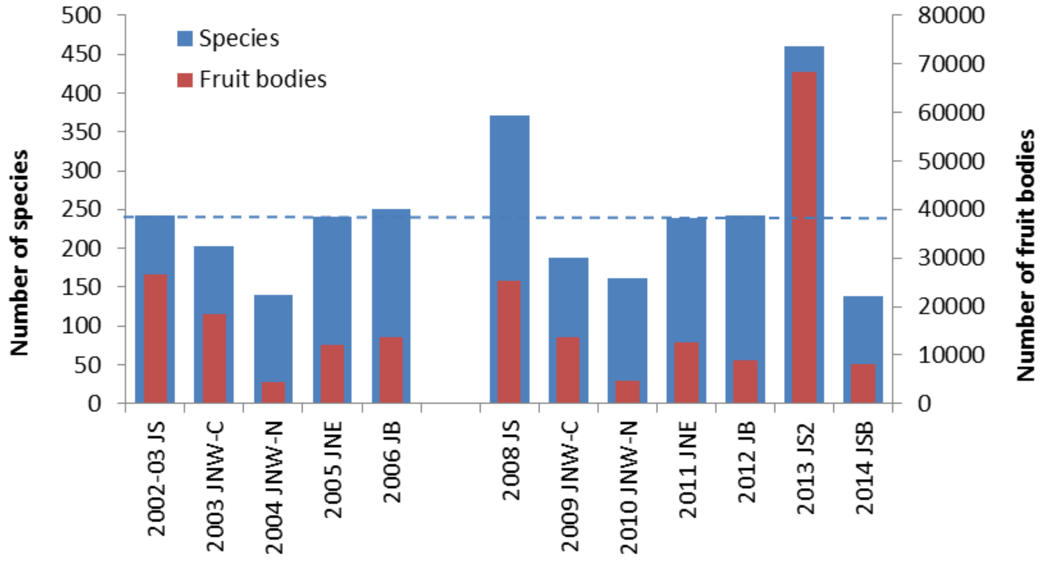


Figure 10. Total number of species and fruit bodies recorded at each FORESTCHECK location from 2002–2014. The dotted line represents the average number of species recorded per year (239). JS = Jarrah South, JNW-C = central region of the Jarrah North West, JNW-N = northern region of the Jarrah North West, JNE = Jarrah North East, JB = Jarrah Blackwood Plateau and JSB = Jarrah Sandy Basins ecosystem.

Species accumulation across all locations from 2002–2014

The total number of species of macrofungi recorded on FORESTCHECK monitoring grids between 2002 and 2014 is 775 (following revision of the list in 2013). The number of species has steadily increased from 235 in 2002–03 by an average of 49 species per year. The largest increase was 97, experienced in both 2008 and 2013, and the lowest was five in 2014 (Fig. 16).

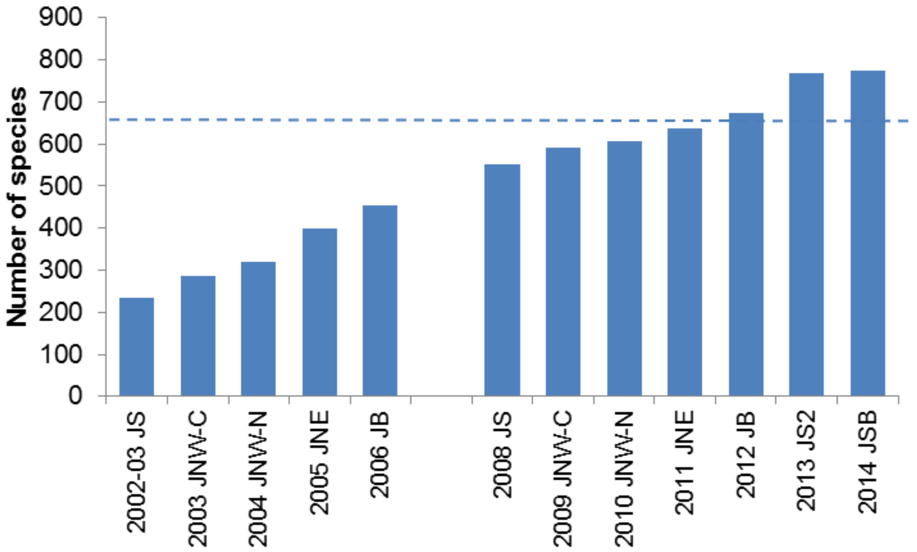


Figure 16. Species accumulation for macrofungi recorded on FORESTCHECK grids from 2002-2014. JS = Jarrah South, JNW-C = central region of the Jarrah North West, JNW-N = northern region of the Jarrah North West, JNE = jarrah North East and JB = Jarrah Blackwood Plateau, JSB = Jarrah Sandy Basins ecosystems.

The accumulation curve appeared to plateau after 2009 at about 600 species, but rose again from 2011–2013. The average annual increase from 2010–2012 was about 27 species per year compared to 59 per year for the period 2002–2009. The average annual accumulation during the first monitoring period of FORESTCHECK locations (2002–2006) was 55 species per year and 44 during the second monitoring period (2008–2012). In 2013, 97 new species were recorded, but only five in 2014.

The annual accumulation is closely related to survey intensity and is expected to decrease further (i.e. plateau), especially if monitoring continues on the same grids. Despite a spike in 2013, the number of new records can be expected to decline as monitoring continues.

Conclusions

The main observations made following monitoring of macrofungi in the Jarrah Sandy Basins ecosystem in 2014 included:

- Low species richness and abundances were recorded on grids in the Jarrah Sandy Basins compared to other ecosystems monitored.
- Macrofungi at the Wilga/Jolly location was substantially richer and more abundant then the Hunt/Camballan location.
- Richness and abundance of mycorrhizal species was similar in all treatments.
- Richness and abundance of saprotrophic fungi was 2 and 3 times higher respectively in harvested treatments compared to the external reference.
- The abundance of fungi on soil was very low compared to that fruiting on wood.

Acknowledgements

Thank you to Verna Tunsell for assistance with data entry and processing and data basing voucher collections, Katrina Syme for assistance in the laboratory and with species identifications and Maddie Robinson for assistance in the field.

References

Burrows, N.D. 1987. *The soil dryness index for use in fire control in the south-west of Western Australia*. Department of Conservation and Land Management, Technical Report No. 17.

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. 24-27th September 2007, Adelaide, SA., 86.

APPENDIX 1. Species and number of fruit bodies recorded at the Sandy Basins FORESTCHECK grids in 2014. ER = external reference, SW = shelterwood and GR = gap release treatment.

Sp #	Species	Treatment			Total
		ER	SW	GR	
39	*Agaricus austrovinaceus* Grgur. & T.W.May		1		1
71	*Agaricus* sp. small flat red stain (R.M. Robinson & R.H. Smith FC123)			1	1
120	*Aleuria rhenana* Fuckel	5			5
126	*Aleurina ferruginea* (W. Phillips) W.Y. Zhuang & Korf	14	2	20	36
206	*Amanita ananiceps* (Berk.) Sacc.	2			2
186	*Amanita brunneibulbosa* O.K.Mill.	1	1		2
283	*Amanita eucalypti* O.K.Mill.			1	1
531	Amanita spp. unidentified		2		2
6	*Amanita xanthocephala* (Berk.) D.A.Reid & R.N.Hilton			1	1
99	*Boletus* sp. yellow-red with blue staining flesh (R.M. Robinson & R.H. Smith FC398)		3		3
9	*Calocera guepinioides* Berk.		70	422	492
187	*Campanella gregaria* Bougher		55		55
364	*Chlorociboria aeruginascens* subsp. *australis* P.R. Johnst., FC1227	2			2
351	*Clavulina* sp. creamy white (R.M. Robinson & R.H. Smith FC690)	2			2
458	*Clavulina* sp. pinkish brown, red-brown tips (R.M. Robinson & R.H. Smith FC805)	1			1
143	*Clitocybe* aff. *clitocyboides* (Cooke & Massee) Pegler		7		7
197	*Clitocybe semiocculta* Cleland	2	1	10	13
985	*Clitocybe* sp. large light grey (R.M. Robinson & M. Schindler FC2158)		17		17
15	*Coltricia cinnamomea* (Jacq.) Murrill	19	31	15	65
532	*Coltriciella dependens* (Berk. & M.A.Curtis) Murrill	23	81	29	133
128	*Coprinus* sp. basal hairs *sensu* Bougher & Syme		5		5
224	*Coprinus* sp. micaceus (R.M. Robinson, R.H. Smith & K. Pearce FC372)	1			1
615	Corticioid. Creamy grey maze (R.M. Robinson FC1134)		12	7	19
454	Corticioid. Creamy jagged ridged crust (R.M. Robinson, R.H. Smith & K. Syme FC795)		5		5
158	*Cortinarius microarcherii* Cleland (FC1183)	1			1
154	*Cortinarius* sp. chestnut (R.M. Robinson & J. Fielder FC 918)	4	12	9	25
453	*Cortinarius* sp. decurrent gills and deep stem with double ring (R.M. Robinson, R.H. Smith & K. Syme FC790)	5	20		25
98	*Cortinarius* sp. pointy cap (R.M. Robinson & R.H. Smith FC134)			1	1
670	*Cortinarius* sp. small fibrillose in moss (R.M. Robinson & J. Fielder BFF 84), WFM722	6		20	26
267	*Cortinarius* sp. snowy chestnut (R.M. Robinson & R.H. Smith FC478)	7			7
237	*Cortinarius* sp. yellow with orange brown fibrils (R.M. Robinson & R.H. Smith FC403)	1	1	3	5
354	*Cortinarius* sp. yellow-brown cap with lavender/brown gills and white/lavender stem (R.M. Robinson & R.H. Smith FC698), FC1446	1			1
184	*Cortinarius* spp. (unidentified)	5	2		7
290	*Cortinarius violaceus* (L. : Fr.) Gray		30		30
16	*Cotylidia undulata* (Fr.) P. Karst.	6	11	56	73
419	*Creopus gelatinosus* (Tode) Link		30		30
118	*Crepidotus nephrodes* (Berk. & M.A.Curtis) Sacc.		14	3	17

Sp #	Species	Treatment			Total
		ER	SW	GR	
148	*Crucibulum laeve* (Huds. : Pers.) Kambly	15		12	27
307	*Cyathus* sp. (R.M. Robinson & K. Pearce FC591)	130	69	13	212
289	*Dacrymyces capitatus* Schwein.		30	25	55
340	*Dermocybe clelandii* mini, yellow mycelium		1		1
168	*Dermocybe* sp. jarrah (R.M. Robinson & R.H. Smith FC301), FC578	5		15	20
123	*Discinella terrestris* (Berk. & Broome) Denni	45	55	58	158
243	Discomycete. Orange discs on marri nuts (R.M. Robinson & R.H. Smith FC798)	5			5
858	*Entoloma* sp. conical grey brown, shiny cream stem (R.M. Robinson WFM623)		3		3
30	*Entoloma* sp. creamy white (R.M. Robinson & R.H. Smith FC29)		1		1
986	*Entoloma* sp. Olive brown domes (R.M. Robinson & M.L. Robinson FC2174)	2			2
159	*Exidia glandulosa* (Bull. : Fr.) Fr.		6	12	18
41	*Fistulina spiculifera* (Cooke) D.A.Reid		1		1
19	*Fomitopsis lilacinogilva* (Berk.) J.E.Wright & J.R.Deschamps		3	2	5
11	*Galerina* sp. hanging gills and conic (R.M. Robinson & R.H. Smith FC11)	70	91	93	254
58	*Galerina* sp. small cap, eccentric stipe - on wood (R.M. Robinson & R.H. Smith FC63)	53	207	71	331
8	*Gymnopilus allantopus* (Berk.) Pegler	60	288	269	617
690	*Gymnopilus ferruginosus* B.J.Rees		69		69
174	*Gymnopilus* sp. red cap yellow gills red stem (R.M. Robinson, R.H. Smith & K. Pearce FC314)		1		1
85	*Gymnopilus* sp. slender (R.M. Robinson & R.H. Smith FC110)	71	437	457	965
56	*Heterotextus peziziformis* (Berk.) Lloyd			3	3
422	*Hohenbuehelia atrocaerulea* (Fr. : Fr.) Singer		5		5
87	*Hydnellum* sp. red brown (R.M. Robinson & R.H. Smith FC113)	6			6
381	*Hygrocybe cantharellus* (Schwein. : Fr.) Murrill		3		3
416	*Hymenochaete semistupposa* Petch		1		1
268	*Hypomyces* sp. brown/yellow-orange on *C. cinnamoni* (R.M. Robinson, R.H. Smith & K. Pearce FC483)	1			1
984	*Hypoxylon* aff*. subcorticeum* Y.M. Ju & J.D. Rogers			5	5
1	*Inocybe australiensis* Cleland & Cheel	55	17	45	117
398	*Inocybe fibrillosibrunnea* O.K. Mill. & R.N. Hilton	2		11	13
948	*Inocybe* sp. (R.M. Robinson & S.J.M. McMullan-Fisher FC1994)			1	1
113	*Inocybe* sp. radially fibrillose with pink stem (R.M. Robinson & R.H. Smith FC162)		2		2
53	*Inocybe* sp. tan skirt (R.M. Robinson & R.H. Smith FC60)	20	11	18	49
286	*Inocybe* sp. umbonate, shaggy (R.M. Robinson & K. Pearce FC576)			11	11
36	*Laccaria lateritia* Malençon	19			19
765	*Laccaria* sp. burnt orange (R.M. Robinson, K. Syme & J. Mccalmont WFM460)	3			3
74	*Laccaria* sp.B 'pale' (similar to *Laccaria* aff. *masonii*)	61	302	111	474
142	*Lactarius eucalypti* O.K.Mill. & R.N.Hilton	1			1
76	*Lepiota alopochroa* (Berk. & Broome) Sacc.	1	2		3
166	*Lepiota subcristata* Cleland		1		1
431	*Lichenomphalia* sp. orange brown	17			17
112	*Lichenomphalia chromacea* (Cleland) Redhead, Lutzoni, Moncalvo & Vilgalys	10			10
127	*Lichenomphalia umbellifera* (L.) Redhead, Lutzoni, Moncalvo &	8	14	15	37

Sp #	Species	Treatment			Total
		ER	SW	GR	
	Vilgalys				
24	*Lycoperdon* sp. (R.M. Robinson & R.H. Smith FC22)		1		1
561	*Macrotyphula* sp. simple white clubs R.M. Robinson, K. Syme & P. Anderson WFM552)		2		2
443	*Marasmius* sp. tan (R.M. Robinson FF770, WFM129)	2	3		5
341	*Marasmius* sp. tiny red on twigs (R.M. Robinson & K. Syme WFM 495)			3	3
22	*Melanotus hepatochrous* (Berk.) Singer			25	25
64	*Mycena adscendens* (Lasch) Maas. Geest.		1		1
134	*Mycena albidocapillaris* Grgur. & T.W.May	5		19	24
80	*Mycena carmeliana* Grgur.	5	149	148	302
144	*Mycena kuurkaceae*Grgur.	13	8	8	29
50	*Mycena mijoi* Grgur.	4	26	28	58
66	*Mycena pura* (Pers. : Fr.) P.Kumm.	2			2
308	*Mycena* sp. grey brown cap no bleach (R.M. Robinson & J. Fielder FC1038)	1			1
18	*Mycena* sp. light brown-olive (R.M. Robinson & R.H. Smith FC86) - Check *Hydropus* sp		18		18
756	*Mycena* sp. orange striate on litter (R.M. Robinson & K. Syme WFM424)	252	11	24	287
295	*Mycena* sp. small buff (R.M. Robinson & K. Pearce FC558)		12		12
165	*Mycena* sp. small grey - bleach (R.M. Robinson & R.H. Smith FC394)			3	3
163	*Mycena subgallericulata* Cleland		27	40	67
51	*Mycena yirukensis* Grgur.	499	79	68	646
238	*Mycena yuulongicola* Grgur.	3		2	5
311	*Panus fasciatus* (Berk.) Pegler	5	7	31	43
524	*Peziza thozetii* Berk.		2		2
70	*Phellodon* aff. *niger* (Fr. : Fr.) P.Karst.	5			5
160	*Pholiota highlandensis* (Peck) Quadr.	37	141	231	409
119	*Pholiota multicingulata* E.Horak	4	117	128	249
133	*Pluteus atromarginatus* (Konrad) Kühner - check Pluteus concentricus Horak FoNZ series		1	3	4
47	*Pluteus flammilipes* var. *depauperatus* E.Horak			7	7
47	*Pluteus lutescens* (Fr.) Bres. - yellow green	2	1	3	6
4	*Pluteus* sp. brown velvet (R.M. Robinson & R.H. Smith FC4, BFF150)		1		1
236	*Postia pelliculosa* (Berk.) Rajchenb.	2	1		3
177	*Psilocybe coprophila* (Bull. : Fr.) P.Kumm.	4		1	5
349	*Psilocybe musci* Cleland & Cheel			3	3
129	*Pulvinula tetraspora* (Hansf.) Rifai	15	15	12	42
176	*Pycnoporus coccineus* (Fr.) Bondartsev & Singer		26	29	55
52	*Ramaria capitata* (Lloyd) Corner	7	2		9
52	*Ramaria capitata* sensu (Lloyd) Corner burnt		7		7
102	*Ramaria ochraceosalmonicolor* (Cleland) Corner	2	2		4
86	*Ramaria* sp. orange-red with yellow stem (R.M. Robinson & R.H. Smith FC112)			12	12
79	*Resupinatus cinerascens* (Cleland) Grgur.		12		12
811	*Rhodocybe* sp. grey with decurrent gills R.M. Robinson & K. Syme WFM508)			2	2
969	*Rhodocybe* sp. brown convex cap (R.M. Robinson & S.J.M. McMullan-Fisher FC2114)	1	2		3

Sp #	Species	Treatment			Total
		ER	SW	GR	
209	*Rickenella fibula* (Bull. & Vent. : Fr.) Raithelh.	4	7	1	12
89	*Russula clelandii* complex O.K.Mill. & R.N.Hilton	2			2
202	*Russula flocktoniae* Cleland & Cheel			1	1
10	*Russula* sp. white white white (R.M. Robinson & R.H. Smith FC 8)	2		2	4
12	*Simocybe tabacina* E. Horak			5	5
62	*Stereum hirsutum* (Willd. : Fr.) Pers.		40	3	43
773	*Stereum* sp. black with purple brown merulioid hymenium (R.M. Robinson, K. Syme FC1458)		38	164	202
5	*Stereum* sp. grey brown, hirsute, white margin, purple hymenium (R.M. Robinson & R.H. Smith FC468)		134	200	334
974	*Stereum* sp. light brown zoned hymenium (R.M. Robinson & S.J.M. McMullan-Fisher FC1945)		5	7	12
587	*Tephrocybe* sp. dark brown with grey brown gills (R.M. Robinson & J. Fielder FC1036)			1	1
301	*Tephrocybe* sp. dark grey with dimpled cap (R.M. Robinson & K. Pearce FC580)	1			1
266	*Thelephora* sp. white with orange margin (R.M. Robinson & R.H. Smith FC476)	1	2		3
669	*Trametes velutina* (Pers. : Fr.) G.Cunn.	6		7	13
63	*Trametes versicolor* (L. : Fr.) Lloyd	2	91	221	314
685	*Tremella globispora* D.A.Reid		8		8
60	*Tremella mesenterica* Retz. : Fr.	12		1	13
288	*Tremella* sp. yellow buttons (R.M. Robinson, R.H. Smith & K. Pearce FC540)		25	12	37
109	*Trichaptum byssogenum* (Jungh.) Ryvarden	1			1
54	*Tricholoma eucalypticum* A.Pearson	3	2		5
111	*Tubaria serrulata* (Cleland) Bougher & Matheny		9		9
2	*Xerula mundroola* (Grgur.) R.H.Petersen		1		1
	Number of species	74	87	71	139
	Number of fruit bodies	1672	3069	3300	8041

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 stabilization of bare soil. Lichens, mosses and liverworts are a major component of the biodiversity of forest ecosystems. Most species in Western Australia have poorly known distributions and many are yet to be named.

The objectives of this component of FORESTCHECK are to:

- record all species of lichen, moss and liverwort present on each FORESTCHECK grid;
- record species habitat and substrate preference;
- analyse trends in species composition and richness and over time.

Additional objectives are to:

- monitor the presence of 41 monitoring (or indicator) species;
- determine successional trends in communities.

Field survey

Cryptogams were surveyed on seven FORESTCHECK monitoring grids in the Wilga vegetation complex in the Sandy Basins ecosystem in Blackwood District and on three grids in the Dwellingup 1 vegetation complex in the Jarrah North West ecosystem in the Perth Hills District. The grids included three external reference (FC57, FC60, FC63), two shelterwood (FC58, FC61) and two gap release grids (FC59, FC62) in the in the Sandy Basins ecosystem and three fire chronosequence grids (FC24, FC64 and FC65) in uncut forest in the Jarrah North West ecosystem near Dwellingup. Time since fire on the Perth Hills grids was nine (FC64, Plavins block), 39 (FC 24 Kennedy block) and 81 years (Amphion block).

Monitoring was conducted from 8 June to 9 September (mid-winter–early spring), when most cryptogams are well hydrated and actively growing, and they are more easily found and identified. Surveys were conducted along a 400m transect around the perimeter of the central 1ha area of each grid (see grid layout on p. 5). All species of lichen, moss and liverwort encountered in each 50m section of transect were recorded. This frequency statistic (a score out of 8 on each grid) demonstrates how common a species is on each grid. Twenty 1m^2 plots placed 10m apart along 200m of the monitoring transect (from W1-2–W1-4–W3-4) were used to assess habitat colonisation and the presence of life-form types on each grid. Taxa that could not be identified positively in the field were collected and examined in detail in the laboratory. An illustrated field guide, compiled from previous FORESTCHECK surveys, was used to facilitate recognition and identification of species encountered. The field guide is continually updated to include new taxa identified during the surveys.

Voucher specimens, to verify species identifications and new species records, are routinely collected from grids or surrounding forest. All specimens collected in 2014 were identified to species or given informal field names. Increased knowledge in taxonomy, and re-examination of some specimens collected during previous FORESTCHECK surveys resulted in name changes for several species listed on the Western Australian Herbarium databases. Several additional species were also recorded during this survey and the new collections have been processed and prepared for submission into the WA Herbarium.

Results and discussion
Sandy Basins
Species richness

A total of 99 species of cryptogam were recorded from all the monitoring grids including 71 lichens, 17 mosses and 11 liverworts (Table 1). Twenty one lichens, six mosses and five liverworts were recorded on all seven grids. Ten lichens, two mosses and one liverwort were unique to the external reference treatment, while 22 lichens, three mosses and five lichens were recorded only in harvested treatments. A new, as yet undetermined, liverwort was recorded (Sp. 380, Genus sp. 'green balls'), along with six new mosses and 10 lichens.

Table 1. The total number of species recorded and the distribution of unique and shared species within and between treatments at the Sandy basins FORESTCHECK grids in 2014

	Lichen	Moss	Liverwort	Total
Total	71	17	11	99
Unique to ER	10	2	1	13
Unique to SW	15	2	2	19
Unique to GR	7	1	3	11
Common to all treatments	21	6	5	32
Common to 2 treatments	18	6	0	24

Lichens were the most common group on all grids (Fig. 1). Similar numbers of lichens were recorded on both gap release grids, but varied on grids within the external reference and shelterwood treatments. The number of moss species also varied on grids within all treatments. No liverworts were recorded on the Wilga shelterwood grid (FC58).

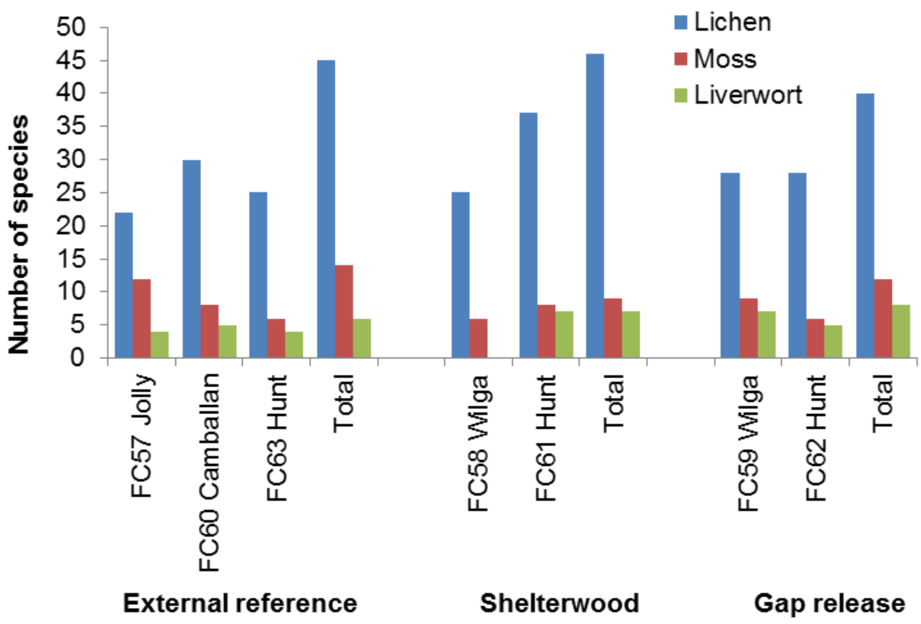


Figure 1. Total number of lichens, moss and liverwort species recorded on each FORESTCHECK monitoring grid at the Sandy Basins in 2014

Mean species richness of lichens, mosses and liverworts was similar for each treatment (Fig. 2). The frequency, or how common each species was on each grid, was not analysed in detail for this report.

Twenty one lichens were recorded on all seven grids; the most common being *Thysanothecium scutellatum, Usnea inermis, Cladia aggregata, C. shizopora, Cladonia rigida, and Hypocenomyce scalaris;* six mosses were recorded; *Campylopus introflexus, C. bicolor*, *Funaria hygrometrica, Barbula calycina, Rosulabryum capillare* and *Ptychostomum angustifolium;* and five liverwortswere recorded; *Cephaloziella exilliflora*, *Lethocolea pansa*, *Fossombronia altilamellosa, F. pusilla* and *Chaetophyllopsis whiteleggei* (Table 1).

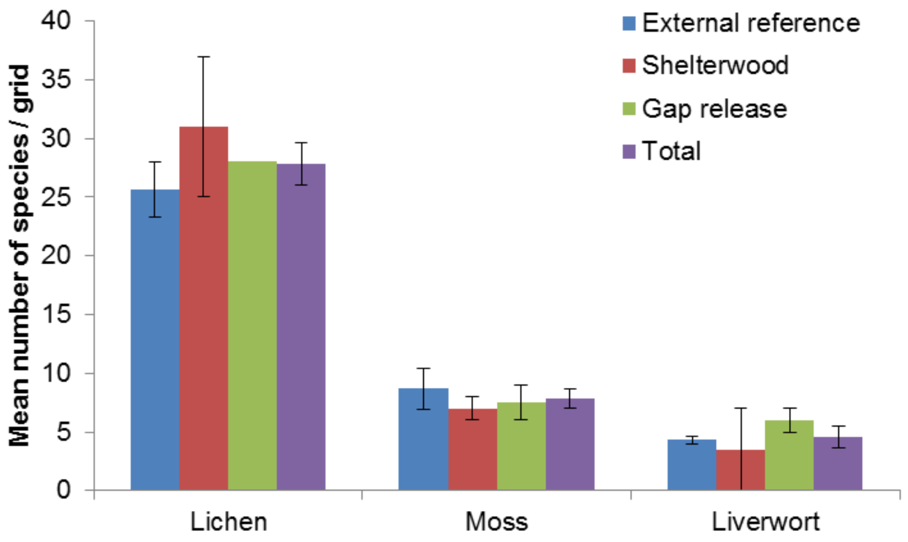


Figure 2. Mean number of lichen, moss and liverwort species per grid recorded in each treatment at the Sandy Basins FORESTCHECK monitoring grids in 2014. ER = external reference, SW/SC = shelterwood/selective cut and GR = gap release treatment.

Colonisation of strata layers

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 on every grid (Fig. 3). However, on the Hunt external reference (FC63) and the Wilga gap release (FC59), only half the plots had cryptogams recorded on the ground. Few plots (generally <4) in all treatments recorded cryptogams in the shrub layer (31cm–3m). The epiphytic tree layer (>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, epiphytic tree species were only recorded from two plots within the gap release treatment—demonstrating the importance of mature habitat tree retention in harvested treatments for the preservation of crown dwelling cryptogams, especially lichens.

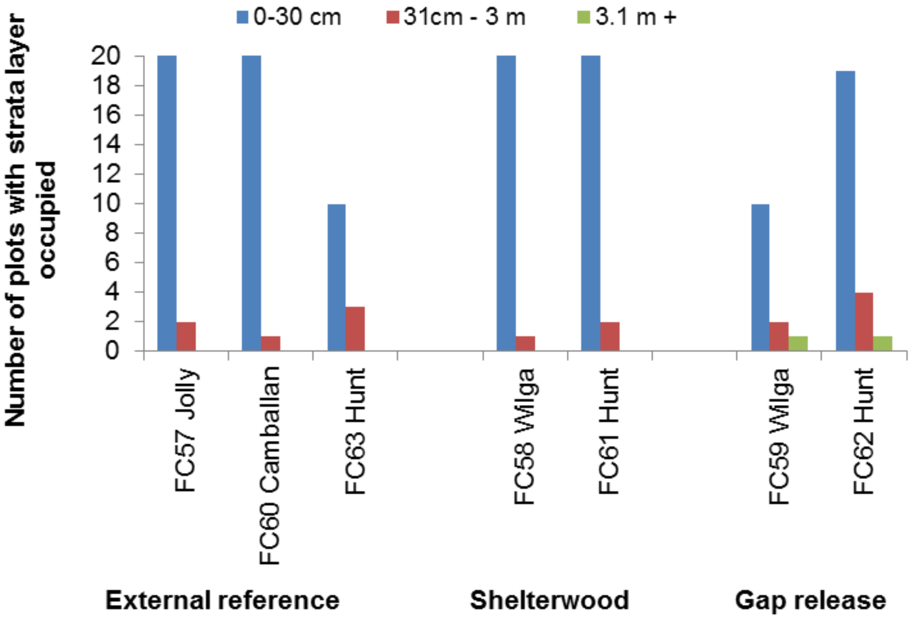


Figure 3. Habitat strata levels occupied by cryptogams in each of 20 plots on each Sandy Basins FORESTCHECK grid in 2014

Life forms

The majority of cryptogams can be grouped according to their morphology. Most lichens are foliose (leaflike, with flat sheets of tissue not tightly bound), crustose (crustlike, growing tight against the substrate), fruticose (free-standing branching tubes) and a few can be leprose (powdery) or squamulose (tightly packed pebble-like mass); mosses are creeping or tufted and liverworts are thallose or leafy. These groups are referred to as life or growth forms, and species in each group generally have similar life strategies. Crustose and fruticose lichens and tufted mosses were the most common forms on all grids. Only one creeping moss was recorded, *Sematophyllum subhumile* var. *contiguum*, that being in one plot on the Hunt shelterwood (FC61). Both leafy and thalline liverworts were recorded in a small number of plots in all grids except the Wilga shelterwood (FC58) where none were present (Figs 4 and 5).

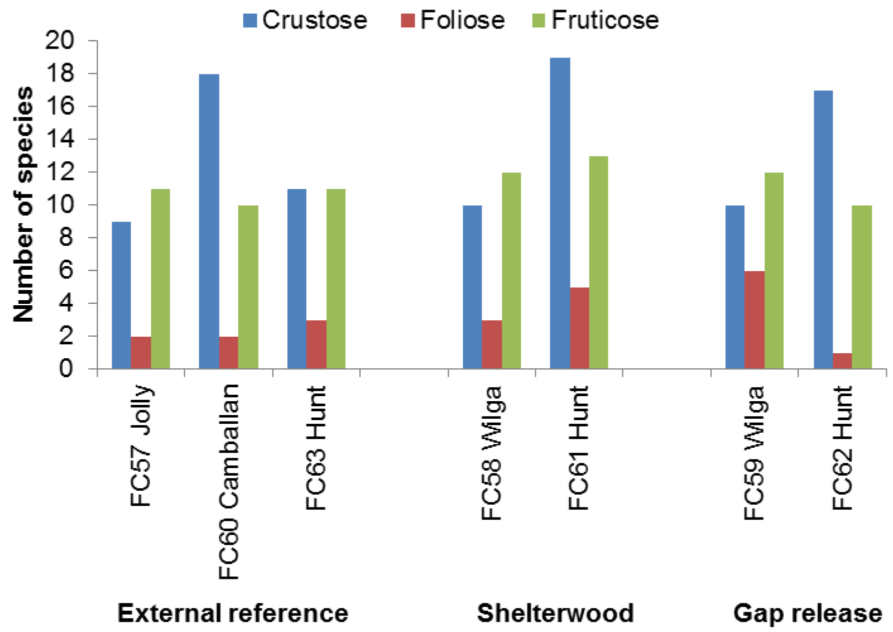


Figure 4. Presence of lichen life forms recorded in each of 20 plots on each Sandy Basins FORESTCHECK grid in 2014

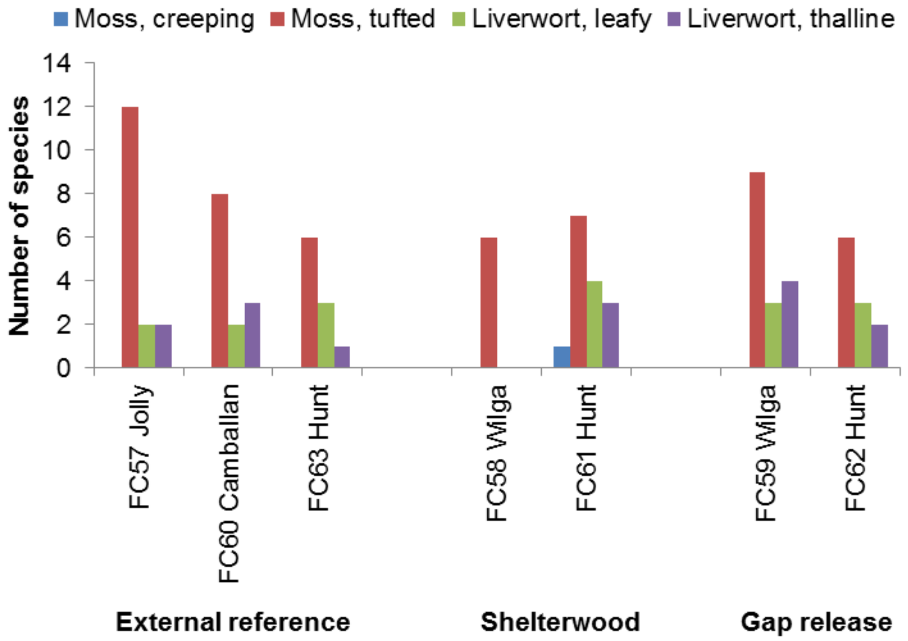


Figure 5. Presence of moss and liverwort life forms recorded in each of 20 plots on each Sandy Basins FORESTCHECK monitoring grid in 2014

Monitoring potential indicator species

Thirty five taxa were initially selected to monitor as potential indicator species (see FORESTCHECK Report of Progress 2011–12). Species 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. The list was recently increased to 41, with the addition of two lichens (Genus sp. grey green slick & *Ainoa mooreana*), three mosses (*Rosulabryum capillare*, *Campylopus bicolor* & *Orthodontion lineare*) and a liverwort (*Fossombronia altilamellosa*). However, *Glonium circumserpens* was recently re-classified as a lichen and has been removed. Presently 27 lichens, eight mosses and five liverworts are included on the monitoring list.

In 2014, a total of 30 monitoring species were recorded during the Sandy Basins surveys; 21 lichens, six mosses and three liverworts (Table 2, Appendix 2). Only six of the monitoring species were unique to a treatment including four lichens (*Hypogymnia subphysodes* var. *subphysodes* in the external reference, and *Diploschistes sticticus, Flavoparmelia haysomii* and *Parmotrema reticulatum* in the external reference treatment), one moss and one liverwort (*Sematophyllum subhumile* var. *contiguum* and *Fossombronia intestinalis* respectively in the shelterwood). The majority were recorded in all treatments.

To test the reliability of this list of (monitoring) 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 (Fig. 6). The proportion of lichens was lower and mosses higher in the shelterwood when just the monitoring species were surveyed. Similarly the proportion of liverworts was also lower within the monitoring species, but this relates to only one species difference.

When a similar comparison was done using mean species richness per grid, there was no difference in the number of species per treatment when all the species were monitored or just the selected monitoring species (Fig. 7).

The suitability of monitoring this selected short list of species is continually under review. Jarrah forest covers a large region encompassing a variety of ecosystem types and vegetation complexes (as represented by the seven established FORESTCHECK locations; Donnelly, Wellington 1, Perth Hills, Wellington East, Blackwood Plateau, Donnelly 2 and Sandy Basins) a number of monitoring species have specific environmental requirements and do not occur in all locations. Others occur in all locations, and in all treatments, and their suitability is as indicators of change are continually being assessed. The use of 'indicator' species to monitor changes in cryptogam communities following disturbance appears to have potential.

Table 2. The number of monitoring species recorded and the distribution of unique and shared species within and between treatments at the Sandy basins FORESTCHECK grids in 2014

	Lichen	Moss	Liverwort	Total
Total	21	6	3	30
Unique to ER	1	0	0	1
Unique to SW	0	1	1	2
Unique to GR	3	0	0	3
Common to all treatments	13	5	2	20
Common to 2 treatments	4	0	0	4

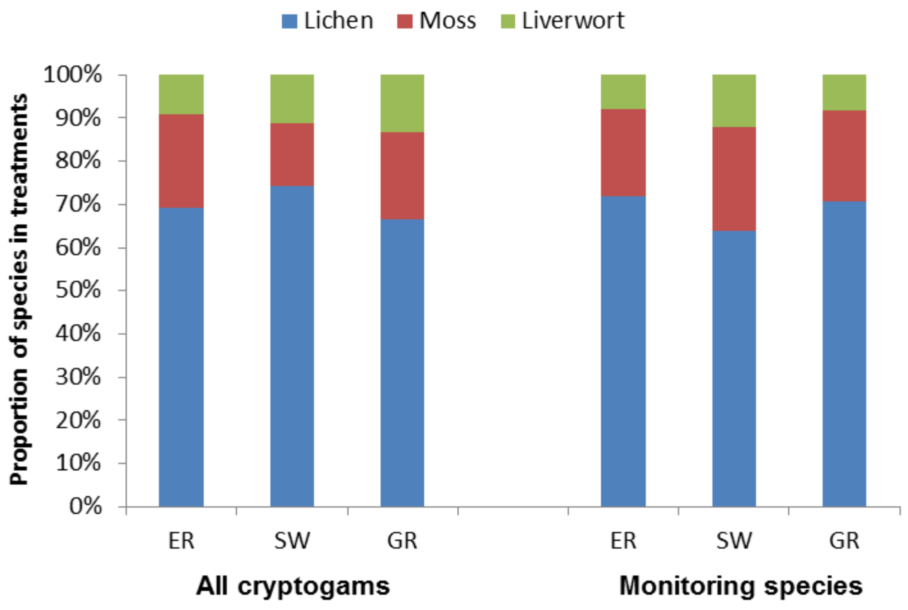


Figure 6. Proportion of lichen, moss and liverwort species in each treatment when considering all cryptogams (left) and only the selected list of potential indicator species recorded at the Sandy Basins FORESTCHECK grids in 2014

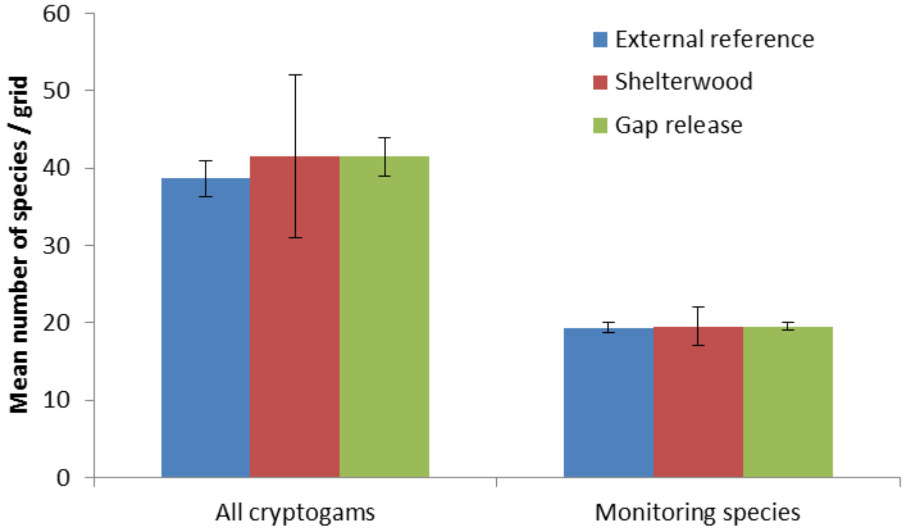


Figure 7. Mean species richness per grid for all cryptogams (left) and the selected monitoring species (right) recorded on the Sandy basins FORESTCHECK grids in 2014

Fire chronosequence, Dwellingup
Species richness

Sixty four species of cryptogams were recorded from the three fire-chronosequence grids; 50 lichens, 11 mosses and 3 liverworts (Table 3, Appendix 2). The intermediate time since fire (39 years) had the richest lichen flora (Fig. 8). The number of mosses was similar in all grids, but more liverwort species were recorded in the Plavins grid with the shortest time since fire interval (9 years). About half the lichens were unique to a single time since fire while the other half were recorded in two or all three fire ages (Table 3).

The response of lichens and other cryptogams to fire in Western Australia is virtually unknown but some species do have very slow growth rates and require a long time to achieve reproductive maturity. For example, field observations suggest that *Hypogymnia subphysodes* requires about 16 years to re-colonise and to develop fruiting bodies following fire.

Chaetophyllopsis whiteleggei is a liverwort normally recorded in wetter more southerly forest regions. In this survey it was recorded in the most recently burnt grid at Plavins block, representing a northerly shift of its known range and habitat.

Table 3. Number of species recorded and the distribution of unique species and shared species on grids of different times since fire near Dwellingup in 2014, YSF = years since fire.

	Lichen	Moss	Liverwort	Total
Unique to 9 YSF	4	0	2	6
Unique to 39 YSF	11	0	0	11
Unique to 81 YSF	8	2	0	10
Common to all fire ages	15	7	1	23
Common to 2 fire ages	12	2	0	14
Total	50	11	3	64

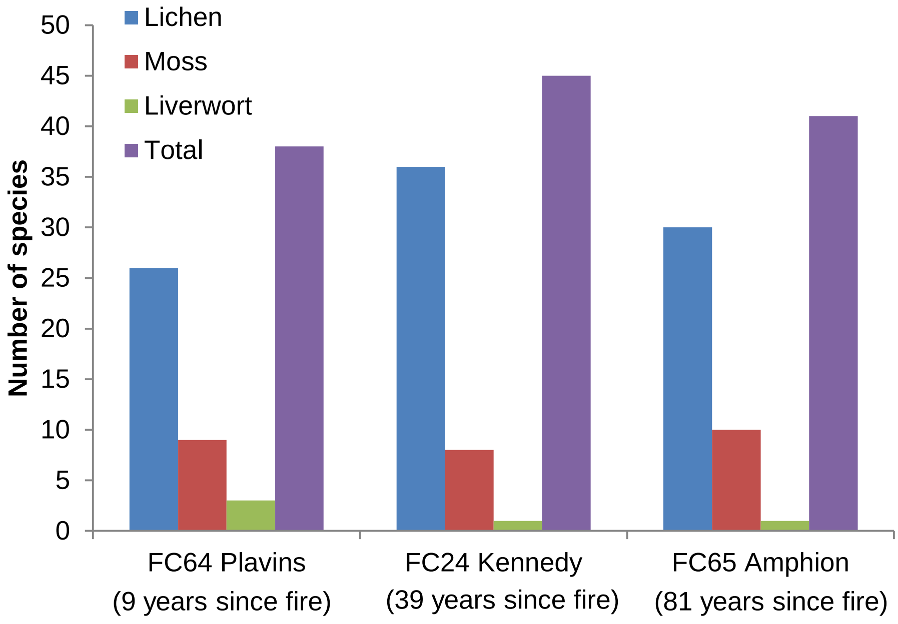


Figure 8. Total number of lichens, moss and liverwort species recorded on each fire chronosequence grid near Dwellingup in 2014

Monitoring potential indicator species

Twenty one of the 40 monitoring species were recorded on the fire chronosequence grids near Dwellingup in 2014 (Table 4). The majority were recorded in two or all three fire ages. No species were unique to the longest unburnt (81 years since fire) grid. None of the liverworts included on the potential monitoring species list were recorded.

Table 4. Number of potential monitoring species recorded and the distribution of unique species and shared species on grids of different times since fire near Dwellingup in 2014, YSF = years since fire.

	Lichen	Moss	Liverwort	Total
Unique to 9 YSF	2	0	0	2
Unique to 39 YSF	3	0	0	3
Unique to 81 YSF	0	0	0	0
Common to all fire ages	11	5	0	16
Common to 2 fire ages	5	1	0	6
Total	21	6	0	27

Although none of the potential monitoring liverworts were recorded, the proportion of lichens and mosses recorded on each grid was similar whether all species were recorded or just those listed as potential monitoring species (Table 9).

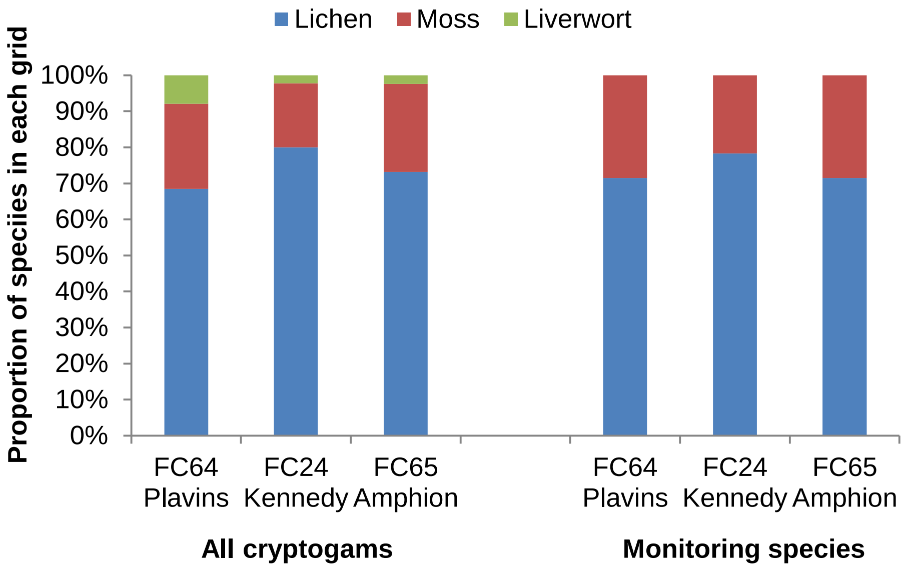


Figure 9. Proportion of lichen, moss and liverwort species in each treatment when considering all cryptogams (left) and only the selected list of potential indicator species recorded on the fire chronosequence grids near Dwellingup in 2014

Conclusions

Observations made following monitoring and analysis of cryptogams in the Jarrah Sandy Basins ecosystem in 2014 were:

- Mean species richness per grid for lichens, mosses and liverworts was similar in all treatments.
- In all treatments, the majority of cryptogams were recorded on the ground, and crustose lichens were the dominant life-form.
- No liverworts were recorded on the Wilga shelterwood (FC58).
- Only one creeping mass was recorded, *Sematophyllum subhumile* var. *contiguum*, that being in the Hunt shelterwood (FC61).

Observations made following monitoring and analysis of cryptogams on three fire chronosequence grids near Dwellingup in 2014 were:

- On long-unburnt grids, high litter densities may impact certain taxa by smothering individual plants or their preferred substrates including rocks and bare soil.
- On long-unburnt grids, fewer shade tolerant taxa may occur due to lower scrub density.
- On long-unburnt grids, larger logs and other coarse woody debris with suitable stages of decay provides increased habitat for many wood colonising taxa.
- Immediately after fire and on long-unburnt grids, increased dryness due to solar radiation will affect recovery or continued presence of some taxa, particularly liverworts.

Other observations

- The use of monitoring species may be a viable alternative for assessing the impacts of timber harvesting and silviculture on cryptogam communities.,

Appendix 1. Species of cryptogams recorded and their frequency in each treatment at the Sandy Basins Forestcheck monitoring grids. Species in bold type are the potential monitoring species (PMS).

Sp. No.	PMS No.	Taxon	Life-form[1]	Treatment[2]			Total
				ER	SW	GR	
2	31	***Barbula calycina***	B	5	7	3	15
9	38	***Campylopus bicolor***	B	23	13	14	50
10	32	***Campylopus introflexus***	B	24	16	13	53
13		***Ceratodon purpureus subsp. convolutus***	B	4		7	11
425		*Dicranoloma* sp. termite mound	B	2			2
422		*Entosthodon subnudus* var*. gracilis*	B	1		2	3
44		*Fissidens tenellus* var*. tenellus*	B	5		1	6
50	34	***Funaria hygrometrica***	B	17	16	8	41
426		*Gemmabryum inaequale*	B	1	1		2
423		*Genus* sp. tiny moss on termite mound	B	2			2
431		*Genus* sp. tiny twisted moss on rock	B		2		2
418		*Ptychostomum angustifolium*	B	4	1	3	8
295		*Rosulabryum billarderi*	B	6		4	10
336	37	***Rosulabryum capillare***	B	7	3	3	13
390		*Rosulabryum microrhodon*	B			4	4
128	35	***Sematophyllum subhumile* var*. contiguum***	B		1		1
403		*Tayloria octoblepharum*	B	2		1	3
12	27	***Cephaloziella exiliflora***	H	14	4	9	27
386		*Cephaloziella hirta*	H		1		1
380		*Chaetophyllopsis whiteleggei*	H	3	2	1	6
47	41	***Fossombronia altilamellosa***	H	11	3	6	20
45	29	***Fossombronia intestinalis***	H		3		3
46		*Fossombronia pusilla*	H	3	6	3	12
424		*Genus* sp. green ball	H	1			1
368		*Kurzia hippurioides*	H			1	1
332		*Lethocolea pansa*	H	9	6	8	23
1		*Phaeoceros laevis*	H			1	1
398		*Riccardia cochleata*	H			1	1
241		*Austroparmelina conlabrosa*	L			1	1
4		*Buellia cranfieldii*	L		4	2	6
190		*Buellia disciformis*	L	1			1
413		*Buellia dissa*	L	3			3
279		*Buellia tetrapla*	L	2		2	4
7		*Calicium victorianum* subsp*. victorianum*	L	6	1		7
420		*Caloplaca elixii*	L	1		2	3
16	1	***Cladia aggregata***	L	13	7	11	31
17	2	***Cladia schizopora***	L	20	8	11	39
252		*Cladonia capitellata*	L		1		1
23	3	***Cladonia cervicornis* var*. verticellata***	L	3	2	5	10
18		*Cladonia chlorophaea*	L	2		1	3
417		*Cladonia enantia*	L	2	1	5	8
34		*Cladonia fimbriata*	L	1	2	2	5
25		*Cladonia humilis* var*. humilis*	L			1	1
26	4	***Cladonia krempelhuberi***	L	9	2	6	17
27		*Cladonia macilenta*	L		1		1

Sp. No.	PMS No.	Taxon	Life-form[1]	Treatment[2]			Total
				ER	SW	GR	
154		*Cladonia merochlorphaea*	L	3	3	2	8
30	5	***Cladonia rigida***	L	17	6	8	31
256		*Cladonia* sp. Stockyard (R.J. Cranfield 20788)	L		1		1
37	6	***Cladonia sulcata***	L	4		4	8
38		*Cladonia tessellata*	L	6	3		9
429		*Diploschistes sp. rock*	L		1		1
221	8	***Diploschistes sticticus***	L			1	1
42		*Diploschistes thunbergianus* (ant hill)	L	4	2		6
222		*Ephebe lanata*	L		4		4
142	9	***Flavoparmelia haysomii***	L			1	1
344	36	***Genus sp. grey green slick***	L	16	4	5	25
177		*Genus* sp. grey lumps (R.J. Cranfield 18994)	L		2		2
96		*Hypocenomyce australis*	L	1		1	2
61	10	***Hypocenomyce foveata***	L	5	2	1	8
78	11	***Hypocenomyce scalaris***	L	18	6	6	30
330		*Hypogymnia subphysodes*	L	4	2	4	10
103	12	***Hypogymnia subphysodes* var*. subphysodes***	L	5			5
104		*Imshaugia aleurites*	L	1			1
416		*Lecidea ochroleuca*	L		1	1	2
376		*Lecidea sp.*	L	2		1	3
432		*Lecidea terrena*	L			1	1
350		*Lepraria coriensis*	L		1		1
408		*Menegazzia caesiopruinosa*	L			1	1
115	15	***Ochrolechia* sp. (G.S. Kantvilis 306/92)**	L	1	2		3
384		*Ochrolechia subpallescens*	L	10	3	7	20
111		*Ochrolechia subrhodotropa*	L		1		1
118	16	***Pannoparmelia wilsonii***	L	4	5	2	11
286		*Parmelia erumpens*	L	1		1	2
293	18	*Parmotrema reticulatum*	L			1	1
277		*Pertusaria georgeana* var*. occidentalis*	L	1			1
196		*Pertusaria trachyspora*	L	1			1
117		*Psoroma pholidotoides*	L	1			1
290		*Ramboldia laeta*	L	4		1	5
199		*Ramboldia petraeoides*	L		1		1
163		*Ramboldia sorediata*	L	9	2	3	14
428		*Ramboldia sp. rock*	L		1		1
52	19	***Ramboldia stuartii***	L	9	3	5	17
361		*Rhizocarpon obscuratum*	L		4		4
127		*Rhizocarpon* sp. grey (R.J. Cranfield 17914)	L	1			1
419		*Sarcogyne* sp. termite mound	L	1			1
79	20	***Tephromela alectoronica***	L	2	1		3
64	21	***Thysanothecium hookeri***	L	15	2	11	28
381		*Thysanothecium hookeri* subsp*. xanthonicum*	L	4	2	2	8
132	22	***Thysanothecium scutellatum***	L	21	13	15	49
362		*Thysanothecium sorediatum*	L		4	3	7
178		*Trapelia crystallifera*	L	5	15	3	23
379		*Trapelia lilacea*	L		13	6	19

Sp. No.	PMS No.	Taxon	Life-form[1]	Treatment[2]			Total
				ER	SW	GR	
321		*Trapeliopsis* sp. ?	L		1		1
136	23	***Usnea inermis***	L	21	14	9	44
421		*Usnea oncodeoides*	L	1			1
139		*Usnea scabrida* subsp. *scabrida*	L		1		1
208	24	***Usnea* sp. leuco (R.J. Cranfield 20195)**	L	2	3		5
339		*Xanthoparmelia antleriformis*	L		2		2
430		*Xanthoparmelia* sp.white warts	L		1		1
		Total number of species		65	62	60	99
		Total lichen		45	46	40	71
		Total moss		14	9	12	17
		Total liverwort		6	7	8	11
		Total number of monitoring species		25	25	24	30
		Monitoring lichen		18	16	17	21
		Monitoring moss		5	6	5	6
		Monitoring liverwort		2	3	2	3

[1] L = lichen, B = bryophyte (mosses) and H = heptophyte (liverwort, hornwort)
[2] ER = external reference, SW/'SC = shelterwood/selective cut, GR = gap release

Appendix 2. Species of cryptogams recorded and their frequency in each of the fire chronosequence grids near Dwellingup in 2014. Species in bold type are the potential monitoring species (PMS).

Sp. No.	PMS No.	Taxon	Life Form[1]	Years since fire			Total
				9[2]	39[3]	81[4]	
2	31	***Barbula calycina***	B	6		6	12
9	38	***Campylopus bicolor***	B	6	6	3	15
10	32	***Campylopus introflexus***	B	8	6	7	21
13		***Ceratodon purpureus* subsp. *convolutus***	B	2	4	2	8
44		*Fissidens tenellus* var. *tenellus*	B	2	1		3
40	40	***Orthodontium lineare***	B	6	3	7	16
125		*Racopilum cuspidigerum* var. *convolutaceum*	B			1	1
295		*Rosulabryum billarderi*	B	3	2	1	6
336	37	***Rosulabryum capillare***	B	4	7	6	17
128	35	***Sematophyllum subhumile* var. *contiguum***	B	1	4	5	10
403		*Tayloria octoblepharum*	B			3	3
380		*Chaetophyllopsis whiteleggei*	H	1			1
368		*Kurzia hippurioides*	H	2	2	3	7
332		*Lethocolea pansa*	H	1			1
241		*Austroparmelina conlabrosa*	L			3	3
4		*Buellia cranfieldii*	L	1	2		3
279		*Buellia tetrapla*	L			3	3
147		*Calicium abietinum*	L			2	2
5	7	***Calicium glaucellum***	L		3		3
148		*Calicium tricolor*	L		2	1	3
7		*Calicium victorianum* subsp. *victorianum*	L		1		1
16	1	***Cladia aggregata***	L	8	8	1	17
314		*Cladia inflata*	L		3		3
17	2	***Cladia schizopora***	L	7	8	6	21
23	3	***Cladonia cervicornis* var. *verticellata***	L	4			4
18		*Cladonia chlorophaea*	L	1			1
417		*Cladonia enantia*	L		2		2
34		*Cladonia fimbriata*	L	1	2	1	4
26	4	***Cladonia krempelhuberi***	L	7	6	2	15
30	5	***Cladonia rigida***	L	6	5	7	18
31		*Cladonia scabriuscula*	L			3	3
37	6	***Cladonia sulcata***	L	3	5		8
38		*Cladonia tessellata*	L	1	2	1	4
222		*Ephebe lanata*	L		2		2
142	9	***Flavoparmelia haysomii***	L		1	3	4
434		*Genus sp. green black domes*	L			1	1
344	36	***Genus sp. grey green slick***	L	4	4	5	13
75		*Genus* sp. soot (R.J. Cranfield 17945)	L		1		1
435		*Heterodea muelleri*	L			1	1
96		*Hypocenomyce australis*	L		3		3
61	10	***Hypocenomyce foveata***	L		7	5	12
78	11	***Hypocenomyce scalaris***	L	4	6	2	12
330		*Hypogymnia subphysodes*	L	2		7	9
103	12	***Hypogymnia subphysodes* var. *subphysodes***	L		5		5

Sp. No.	PMS No.	Taxon	Life Form[1]	Years since fire			Total
				9[2]	39[3]	81[4]	
416		*Lecidea ochroleuca*	L		1	1	2
115	15	***Ochrolechia* sp. (G.S. Kantvilis 306/92)**	L	1	4	2	7
384		*Ochrolechia subpallescens*	L	1	1		2
118	16	***Pannoparmelia wilsonii***	L	4	3	7	14
119	17	***Paraporpidia glauca***	L	3	7	4	14
286		*Parmelia erumpens*	L	5	3	1	9
293	18	*Parmotrema reticulatum*	L	1			1
117		*Psoroma pholidotoides*	L			3	3
433		*Ramboldia crassithallina*	L	1			1
52	19	***Ramboldia stuartii***	L		5	4	9
361		*Rhizocarpon obscuratum*	L		3		3
127		*Rhizocarpon* sp. grey (R.J. Cranfield 17914)	L		1		1
292		*Rhizocarpon tinei*	L			1	1
79	20	***Tephromela alectoronica***	L	1		3	4
64	21	***Thysanothecium hookeri***	L		1		1
132	22	***Thysanothecium scutellatum***	L	7	6	4	17
362		*Thysanothecium sorediatum*	L	2	2		4
178		*Trapelia crystallifera*	L	5	7		12
136	23	***Usnea inermis***	L	8	8	8	24
134		*Usnea subalpina*	L	1	1	1	3
		Total number of species		38	45	41	64
		Total lichens		26	36	30	50
		Total moss		9	8	10	11
		Total liverwort		3	1	1	3
		Total number of monitoring species		21	23	21	27
		Monitoring lichens		15	18	15	21
		Monitoring moss		6	5	6	6
		Monitoring liverwort		0	0	0	0

[1] L = lichen, B = bryophyte (mosses) and H = heptophyte (liverwort, hornwort)
[2] FC64 Plavins block (9 years since fire)
[3] FC24 Kennedy block (39 years since fire)
[4] FC65 Amphion block (81 years since fire)

VASCULAR PLANTS

Bruce Ward 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 (Penman *et al*. 2008).

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 aims of monitoring vascular plants for the FORESTCHECK project are 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; and
- compare species richness, abundance and composition recorded within and between silvicultural treatment grids to those in uncut reference grids.

Field survey and assessment

During September and October 2014, vascular flora was surveyed and measured on seven FORESTCHECK monitoring grids in the Wilga vegetation complex in the Sandy Basins ecosystem in Blackwood District and on three grids in the Dwellingup 1 vegetation complex in the Jarrah North West ecosystem in the Perth Hills District. The grids included three external reference (FC57, FC60, FC63), two shelterwood (FC58, FC61) and two gap release grids (FC59, FC62) in the in the Sandy Basins ecosystem and three fire chronosequence grids (FC24, FC64 and FC65) in uncut forest in the Jarrah North West ecosystem near Dwellingup. Time since fire on the Perth Hills grids was nine (FC64, Plavins block), 39 (FC 24 Kennedy block) and 81 years (Amphion block).

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 1000m^2 plots for each grid. Each plant species density was determined by summing the abundance class mid-point values for each species recorded in each plot on each grid and then converting that figure to plants per square metre for each grid. Vegetation structure was determined from Levy contact data (point samples) at various height categories up to 2m in the understorey (Levy and Madden 1933). Point samples were taken at 1m intervals on three internal trap lines (for 100 point samples per line or 300 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) and canopy cover was calculated as a percentage of the total contacts with a Y rating. 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 Operations Plan (DEC 2006).

Results and discussion
Sandy Basins
Species richness

A total of 144 vascular plant species, including four weed species, were recorded on the Sandy Basins monitoring grids (Table 1). Sixty-four species (44%) were common to all grids. Thirty percent of the species recorded on the external reference grids were unique to that treatment while only 10% of species recorded in both the shelterwood and gap release grids were unique to those treatments.

Table 1. Total number of plant species recorded and the distribution of unique and shared species between treatments at the Sandy Basins FORESTCHECK grids in 2014

Number of species:	**Treatments**[1]			
	ER	**SW**	**GR**	**Total**
Total	119	80	94	144
Unique to treatment	36	8	10	
Common to all treatments				64
Common to SW and GR (not on ER)				2
Common to ER and GR (not on SW)				18
Common to ER and SW (not on GR)				6
Weeds	2	3	3	4

[1] ER = external reference, SW = shelterwood, SC = selective cut, GR = gap release).

There was little difference in mean species richness per plot between treatments (Fig. 1). The Hunt external reference grid (FC63) was the most species rich. However, this grid also contained more unique species (Table 1), suggesting it may have been in a transitional development phase or on a site with higher characteristic species richness. Competitive exclusion amongst plants varies through the successional stages and generally in the earliest stages of succession, plant species composition is not affected by species interactions. However over time larger species may dominate, outcompete and eventually exclude many of the less productive, smaller species (Aarssen *et al.* 2003).

Plant abundance and density

Plant species abundances can be influenced by disturbance associated with silviculture treatments and bushfires. However, not all species are equally affected as their responses depend on the type and intensity of disturbance. For example, in the northern jarrah forest a mild intensity prescribed fire may promote a richer ground flora whereas high intensity bushfire can result in the dominance of leguminous species, such as *Bossiaea aquifolium and Acacia browniana* (Peet 1971).

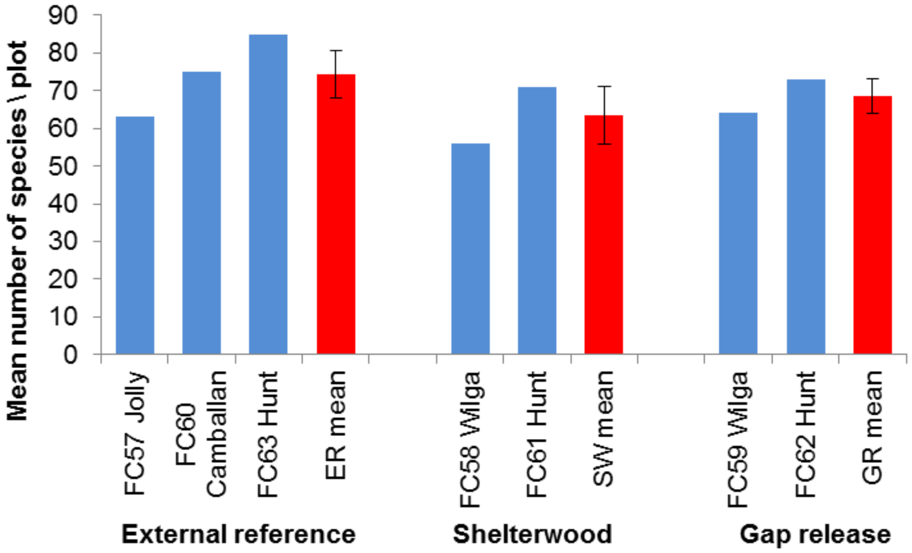


Figure 1. Mean number of plant species per plot recorded in each grid and mean (± se) number of plants per plot in each treatment at the Sandy Basins FORESTCHECK grids in 2014

Although all grids were at what could be considered an advanced successional stage (7–9 and 19 years since fire) with respect to fire, the highest plant density was measured in the long-unburnt Hunt external reference grid; burnt 19 years previously. The lowest densities were on those grids burnt 7–8 years previously (Fig. 2).

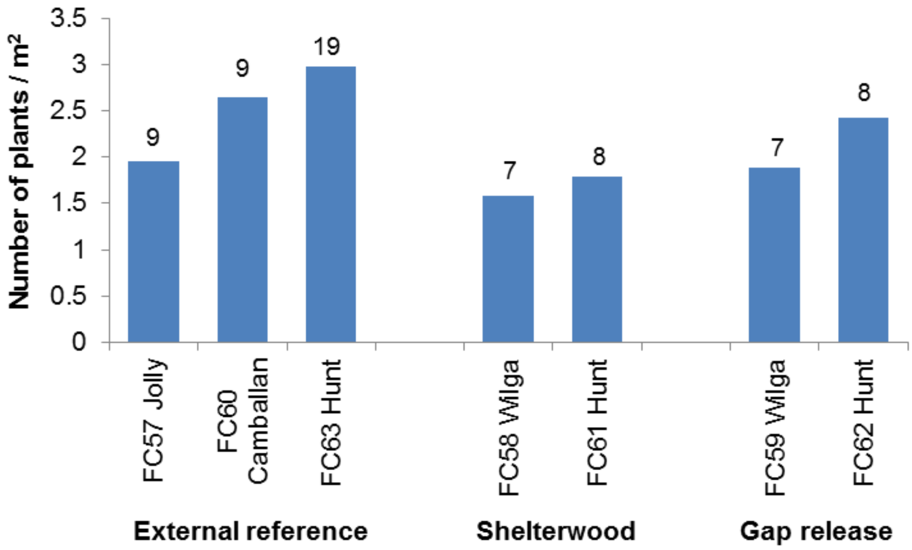


Figure 2. Total numbers of plants per square metre on each Sandy Basins FORESTCHECK grid in 2014. Numbers above columns indicate years since fire on each grid.

Generally in jarrah forest, when time since fire exceeds about 10 years many plants die out; either through competitive interactions or they exceed their normal life span. This provides more light and space and allows other species such as annual herbs, grasses and geophytes to become established and proliferate; mostly with very high abundances. This was very apparent on the Hunt external reference grid where annual herbs such as *Trachymene pilosa, Hydrocoyle alata* and *Levenhookia pusilla* and geophytes including *Caladenia reptans, Stylidium ciliatum and Stylidium brunonianum*, were the most abundant plants.

The frequency (number of species in each abundance category) with which plant species contribute to the community suggests that the majority of species are present in low numbers (many less than 10 plants, the majority less than 100) (Fig. 3). This trend was apparent throughout all treatments.

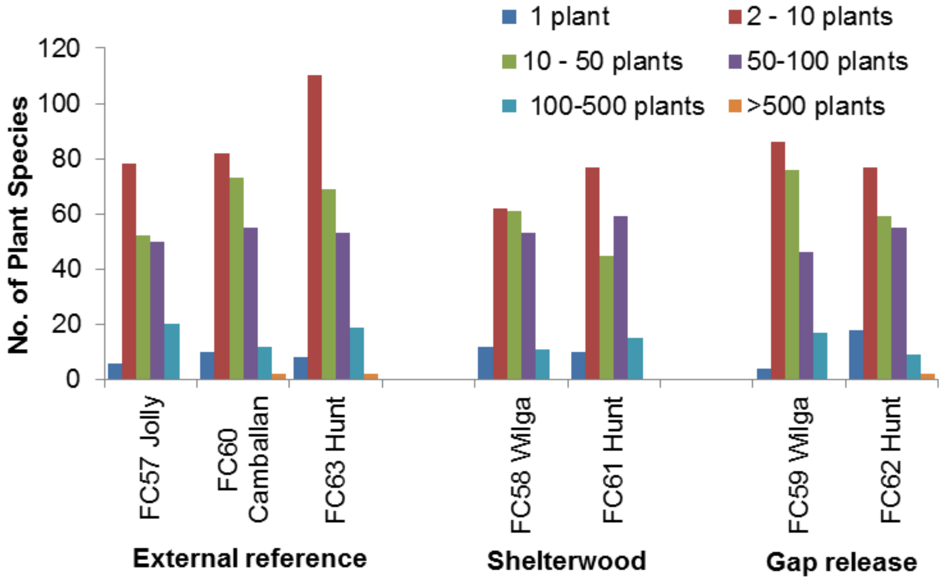


Figure 3. Number of plant species per abundance category in each Forestcheck monitoring grid in the Sandy Basins ecosystem in 2014

Plant life-forms and fire responses

In vegetation ecology, plants can be grouped into life- or growth-form categories on the basis of their similarity in structure and function—which also displays an obvious relationship to environmental influences. Here, life-form groups were analysed to determine how the different groups responded to silviculture treatments. Species richness on external reference grids was consistently higher in all life-form categories (Fig. 4). This may be due to either site characteristics or treatment effects on harvested grids; however, additional analysis may show it to be the result of an extra grid in the external reference treatment. Species richness in the gap release treatment was also consistently higher than that in the shelterwood treatment in all categories.

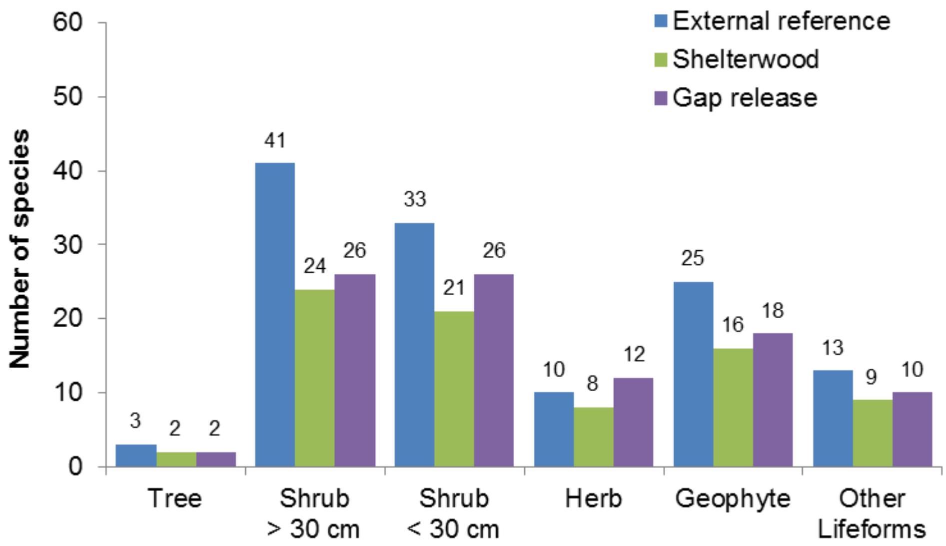


Figure 4. Number of species within each life form category in each treatment at the Sandy Basins FORESTCHECK grids in 2014

Vegetation structure

Vegetation height and structure were used to describe the vertical profile of the vegetation (Fig 5). The amount of dead contacts, determined during Levy measurements (see methods), was used to determine the level of senescence within the shrubs. Indications are that a shrub is senescent and in need of rejuvenation when 50% of the plant canopy is dead (Shedley 2007); although ongoing work in this area continues to develop the level of understanding. Structure is measured as vegetation layers on vertical planes and has value in estimating habitat condition for native animals and birds. It is also used to characterize ecosystems in order to assess changes in communities. Changes in vegetation structure between monitoring events should reflect how disturbed sites are responding and developing in terms of the functional role of the vegetation. For the Sandy Basins grids the vegetation was generally below 50cm in height with little difference between treatments. Each of the treatments contained a high component of dead material, which is understandable since most sites were at seven or more years since their last fire and therefore at an advanced successional stage.

Mean scrub heights were similar on all grids and generally quite low (<50cm) (Fig. 6). The Hunt external reference grid (FC63) had the tallest shrubs and had not been burnt for 19 years, about 10 years longer than other grids.

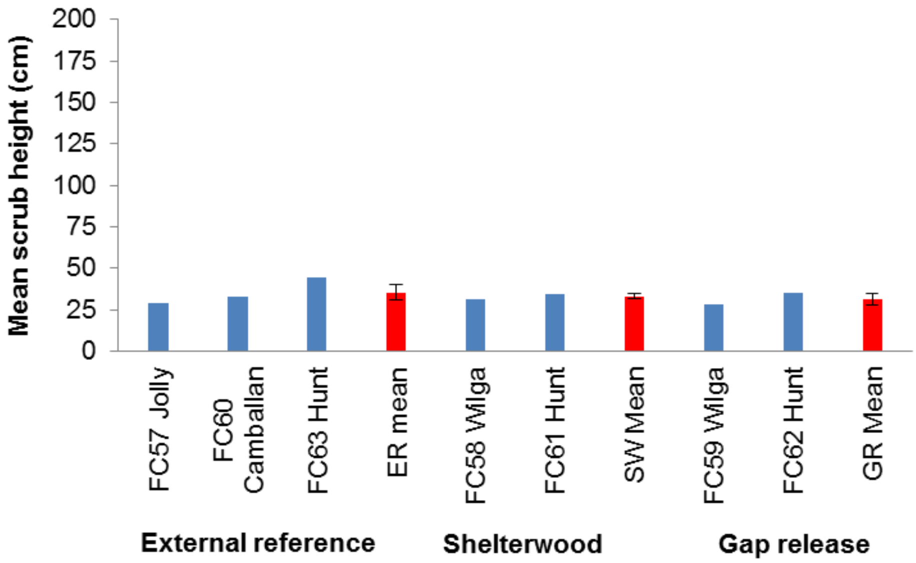


Figure 6. Mean height of understorey vegetation in each grid for the Sandy Basins ecosystems with the overall mean per treatment (±se) shown in red columns (ER = external reference, WS = shelterwood, GR = gap release)

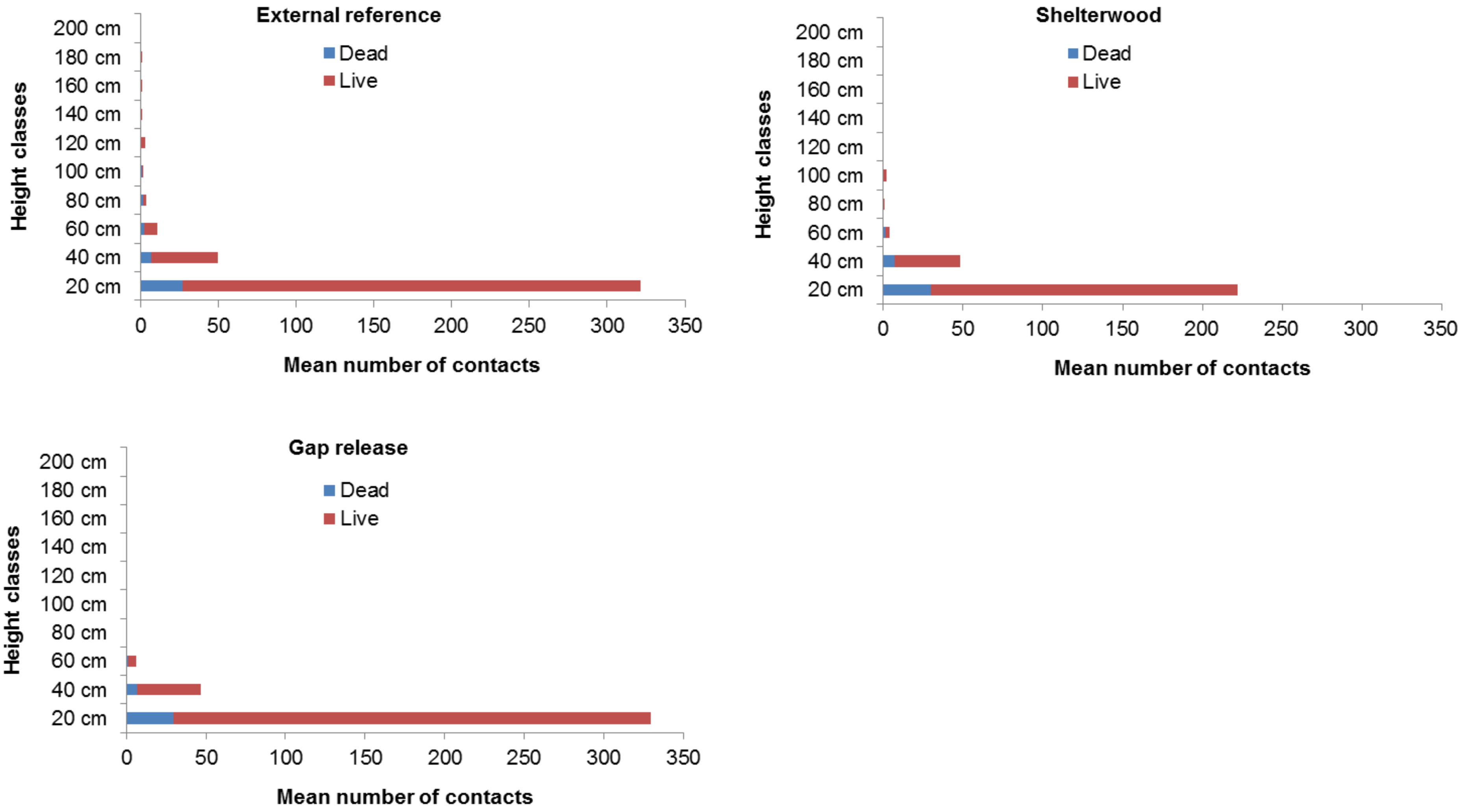


Figure 5. Vertical profile of the external reference, shelterwood/selective cut and gap release grids in the Sandy Basins ecosystem in 2014, shown by density of contacts in live and dead vegetation for 20 cm height categories up to 2 m in height.

Fire chronosequenc, Dwellingup
Species richness
A total of 91 species were recorded from the three fire chronosequence grids (Table 2, Fig. 7) near Dwellingup. Time since fire on the grids was nine (FC64, Plavins block), 39 (FC24 Edwards block) and 81 years (FC65 Amphion block). The Amphion grid (81 years since fire) had the lowest number of species with species richness being greater on the Kennedy grid (39 years since fire) and Plavins grids (6 years since fire). All three grids had low numbers of species that were unique to each, and about one-half of the species on each grid were common to all three grids.

Table 2. Total number of plant species recorded and the distribution of unique to and shared between fire chronosequence grids near Dwellingup in 2014

Number of species:	**Grid number (Years since fire)**			
	FC65 (81 yrs)	FC24 (39 yrs)	FC64 (9 yrs)	Total
Total	48	63	59	91
Unique to fire age	9	15	12	
Common to all				24
Common to 81 and 39 years since fire (not on 9)				8
Common to 81 and 9 years since fire (not on 39)				7
Common to 39 and 9 years since fire (not on 81)				16
Weeds	1	2	3	4

[1] ER = external reference, SW = shelterwood, SC = selective cut, GR = gap release).

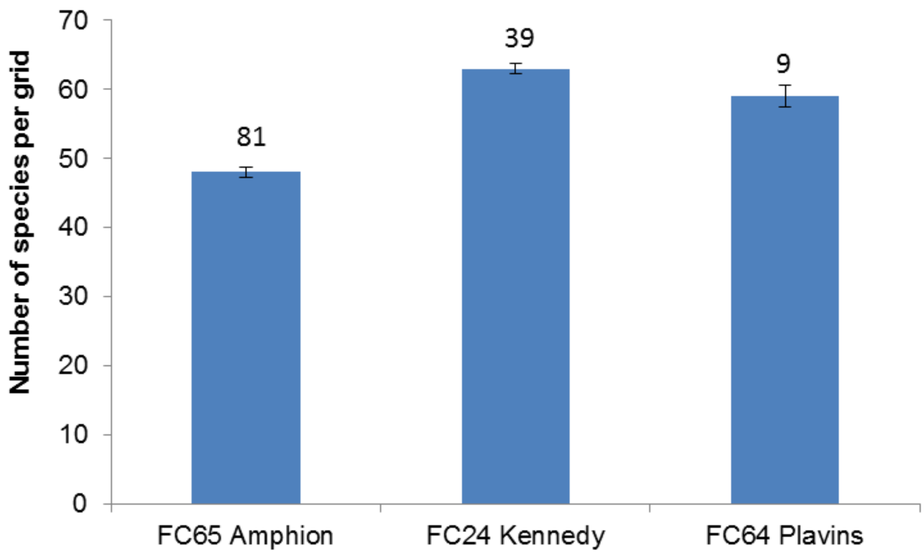


Figure 7. Species richness (±se) of plants per plot on each of the fire chronosequence grids near Dwellingup in 2014. Numbers above the columns indicate years since last fire.

Plant abundance
Amphion (FC65 with the longest time since fire) had the highest abundance of plants and Plavins (FC64 with the shortest time since fire) the lowest (Fig. 8).

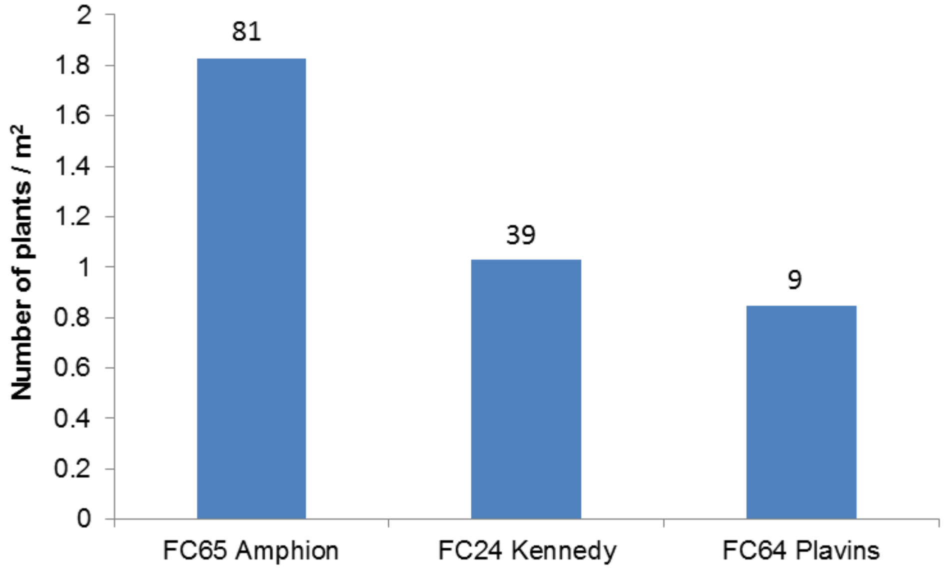


Figure 8. Total numbers of plants per square metre on each FORESTCHECK chronosequence grids near Dwellingup in 2014. Numbers above columns indicate years since fire on each grid.

The abundance of plants on the grids showed different responses. Amphion (81 years since fire) was dominated with resprouting species such as *Phylanthus calycinus, Lagenophora huegelii, Pteridium esculentum and Oxalis corniculata*, but included some seeder species such as *Clematis pubescens, Goodenia eatoniata* and *Pentapeltis silvatica,* which may not require heat treatment like many of the hard seeded legumes. The Plavins grid (the most recent burnt) was dominated by jarrah (*Eucalyptus marginata*) and marri tree (*Corymbia calophylla*) regeneration and a few long lived perennials such as *Banksia grandis, Macrozamia riedlei* with most annual species present but in very low numbers. The Kennedy grid (with an intermediate time since fire of 39 years) showed similar trends in plant numbers to that recorded at Amphion. It is interesting to note that external reference grids burnt 9 years previously in the Sandy Basins were also dominated by perennial resprouting species and some perennial seeders similar to the Plavins grid.

For plants, resource partitioning is considered important in determining species diversity in plant communities. However, this has been difficult to resolve due to problems in studying how plants compete for below ground resources (McKane *et al.* 2002). Often plant communities have only a few species that are very common (or dominant) while the majority of species occur at moderate or low abundances (subordinate or rare). Dominant species often take a disproportionate share of resources, contribute most to productivity and other ecosystem functions, and are present consistently over time. In contrast, rare and uncommon species are collectively the most diverse component of the community, but generally contribute less to ecosystem functioning and often experience high levels of species turnover.

Plant structure

All three fire chronosequence grids show high levels of dead material indicating that the plots have past their peak in productivity with vegetation cover reducing and becoming quite sparse (Fig. 9).

Conclusions

The main observations made following monitoring of vascular flora on the Sandy Basins FORESTCHECK grids in 2014 were;

- A total of 144 vascular plant species were recorded at the Sandy Basins grids.
- The overall mean species richness of plants was similar in all treatments.

- The mean abundance of plants was consistently lower in harvested grids compared to external reference grids, but may be due to fewer harvested grids than reference grids.

The main observations made following monitoring of vascular flora on the Dwellingup fire chronosequence grids in 2014 were;

- A total of 91 vascular plant species were recorded on the fire chronosequence grids.
- Time since fire appeared to have a significant effect on species richness and abundance, with species richness declining with increasing time since fire. In contrast abundance was lower on the Plavins grid but increased with time since fire.
- The structure of the understorey vegetation became sparse and contained more dead material with increasing time since fire.

Acknowledgements
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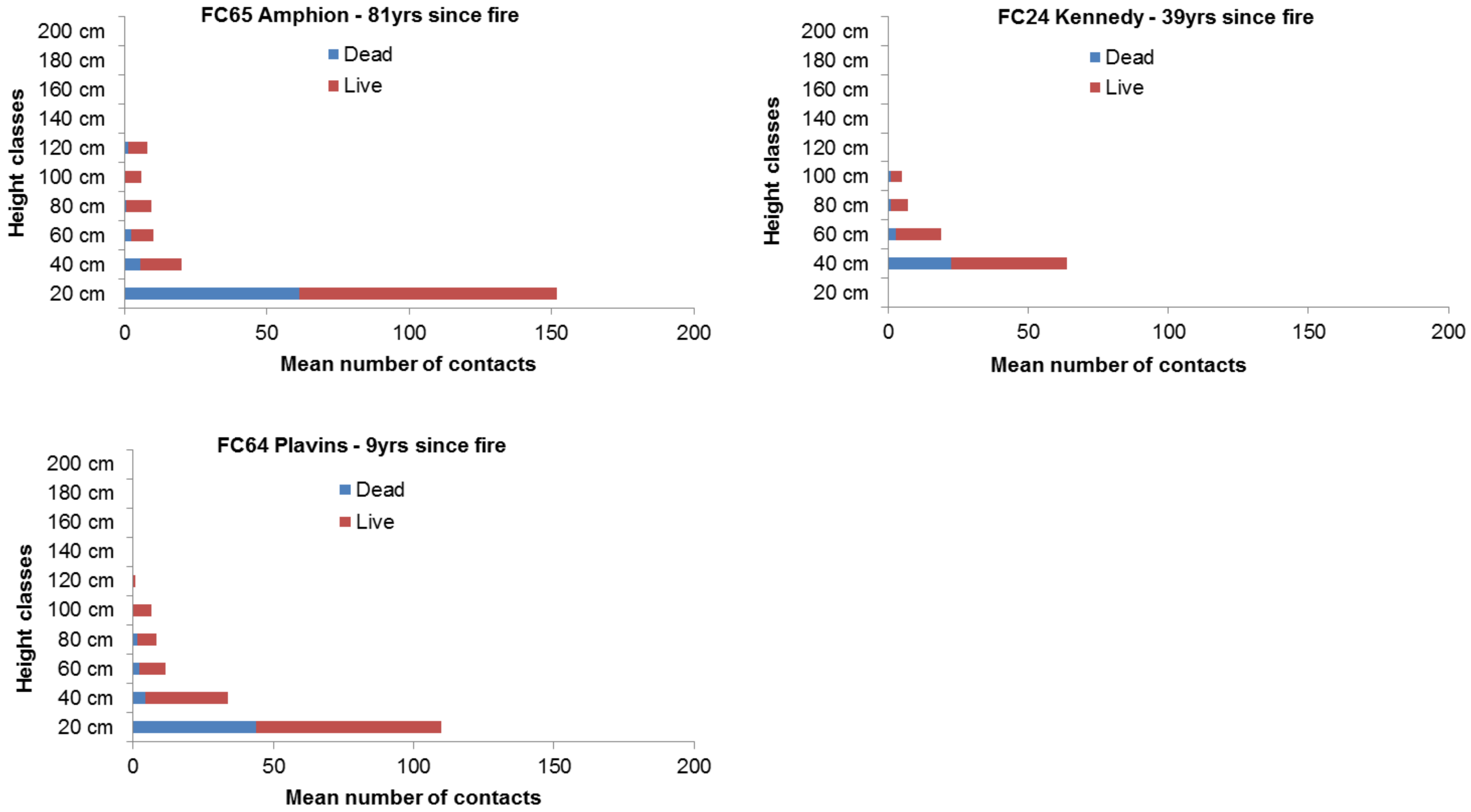


Figure 9. Vertical profile of the fire chronology grids near Dwellingup 2014, shown by density of contacts in live and dead vegetation for 20cm height categories up to 2m in height

References

Aarssen, L.W., Laird, R.A and Pither, J. (2003). Is the productivity of vegetation plots higher or lower when there are more species? Variable predictions from interaction of the 'sampling effect and 'competitive dominance effect' on the habitat templet. *Oikos* 102, 427-432.

DEC (2006) *FORESTCHECK: Monitoring biodiversity in south-west forests. Operating Plan*. Department of Environment and Conservation, Kensington, Western Australia.

Levy, E.B. and Madden, E.A. (1933). The point method of pasture analysis. *New Zealand Journal of Agriculture*, 46**,** 267-279

McKane, R.B., Johnson, L.C., Shaver, G.R., Nadelhoffer, K.J., Rastetter, E.B., Fry, B., Giblin, A.E., Kiellandk, K., Kwiatkowski, B.L., Laundre, J.A. and Murray, G. (2002). Resource-based niches provide a basis for plant species diversity and dominance in arctic tundra. *Nature* 415, 68-71

Peet, G. (1971). A study of scrub fuels in the jarrah forests of Western Australia. *Western Australian Forests Department Bulletin* 80

Penman, T.D., Binns, D.L., Shiels, R.J., Allen, R.M. and Kavanagh, R.P. (2008). Changes in understorey plant species richness following logging and prescribed burning in shrubby dry sclerophyll forest of South-eastern Australia. *Austral Ecology* 33, 197-210

Shedley, E. (2007). *Fire and biodiversity guidelines for the Avon basin*. Consultant Report to the Avon Catchment Council and the Department of Environment and Conservation. Winnijup Wildflowers, RMB 382 Bridgetown, Western Australia.

Appendix 1. Species of vascular plants and their mean abundances recorded in each treatment at the Sandy Basins FORESTCHECK grids and the fire chronosequence grids near Dwellingup in 2014 (ER = external reference, SW = shelterwood and GR = gap release treatment, bold* type indicates weed species)

Sp. No.	Species Name	Sandy Basins			Dwellingup		
		Treatment			FC65	FC24	FC64
		ER	SW	GR	burnt 1933	burnt 1979	burnt 2008
5	*Acacia celastrifolia*						1
11	*Acacia extensa*	6.5	22	16.5			
18	*Acacia pulchella*	543.5	81	571.5			
22	*Acacia urophylla*				29.5		
24	*Acaena echinata*	5.5		11			
32	***Aira cupaniana****		300.5			81	
33	*Allocasuarina fraseriana*	1					5.5
34	*Amperea ericoides*					1	
35	*Amphipogon amphipogonoides*				5.5	6.5	
46	*Anigozanthos manglesii*			5.5			
48	*Asterolasia pallida*						1
49	*Astroloma ciliatum*	1			1		
50	*Astroloma drummondii*	5.5					
51	*Astroloma pallidum*	7.5		12			
54	*Babingtonia camphorosmae*	36	5.5	29.5			
56	*Banksia bipinnatifida*	81	226.5	221			
58	*Banksia dallanneyi*	451.5	376	241.5	51.5	40.5	
60	*Banksia grandis*				186	315	223
62	*Banksia sessilis*	5.5				5.5	6.5
456	*Banksia sessilis* var. *sessilis*			29.5			
66	*Billardiera heterophylla*	1					1
67	*Billardiera variifolia*	5.5	18.5	22			
68	*Boronia crenulata*	35					
72	*Boronia spathulata*					46	177
75	*Bossiaea eriocarpa*	147.5					
76	*Bossiaea linophylla*	1					
77	*Bossiaea ornata*	1392.5	1085	888			
83	*Caladenia flava*	75.5					
87	*Caladenia reptans*	722	396	293	40.5	16.5	46
88	*Caladenia reptans* subsp. *reptans*	601					
595	*Calytrix fraseri*	302					
94	*Cassytha racemosa*	12					
97	***Centaurium erythraea****			29.5			
102	*Chamaescilla corymbosa*	1571.5	934	906	35	285.5	407
106	*Clematis pubescens*	16.5		16.5	608	75.5	140
107	*Comesperma calymega*			1		2	
113	*Conostylis aculeata*	199	76.5	199		27.5	
115	*Conostylis setigera*	75.5	27.5	140		16.5	
117	***Conyza bonariensis****				1		
118	*Corymbia calophylla*	549	536	558	46	315	118
120	*Craspedia variabilis*	650.5	691	490			
587	*Damperiea alata*	51.5		40.5			
130	*Dampiera linearis*	104	11	27.5		6.5	
135	*Daucus glochidiatus*	326	412.5	316		162	59
138	*Daviesia incrassata*		5.5				
140	*Desmocladus fasciculatus*	245	94	46			

Sp. No.	Species Name	Sandy Basins			Dwellingup		
		Treatment			FC65	FC24	FC64
		ER	SW	GR	burnt 1933	burnt 1979	burnt 2008
141	*Desmocladus flexuosus*	75.5					
142	*Dianella revoluta*	5.5	13	1		1	1
150	*Drakaea glyptodon*	1					
151	*Drosera bulbosa*	239.5	35	180.5			
152	*Drosera erythrorhiza*	480.5	57	197	11	11	57
482	*Drosera leucoblasta*	180.5		29.5			
155	*Drosera menziesii*	27.5		2			
157	*Drosera pallida*	304	150	57		33	22
161	*Drosera stolonifera*	184	35	46			
164	*Eucalyptus marginata*	3154	2706	2256	1803	1353	453
173	*Gompholobium confertum*	11					
174	*Gompholobium knightianum*					12	
175	*Gompholobium marginatum*		2				
176	*Gompholobium ovatum*	11					
178	*Gompholobium preissii*	46	2	5.5			12
179	*Gompholobium scabrum*	64.5					
184	*Goodenia eatoniana*				11		5.5
186	*Grevillea centristigma*	494					
191	*Haemodorum paniculatum*	5.5	11	5.5			
192	*Haemodorum simplex*	5.5		11			
196	*Hakea lissocarpha*	838	738.5	600.5		16.5	
205	*Hibbertia amplexicaulis*	350	346.5	335.5	16.5	11	33
206	*Hibbertia commutata*	733	622.5	768	127	269	269
207	*Hibbertia cuneiformis*			5.5		12	
490	*Hibbertia ferruginea*	245					
593	*Hibbertia hibbertioides*	263.5					
211	*Hibbertia hypericoides*	4439	2256	2481			
491	*Hibbertia inconspicua*	5.5					
214	*Hibbertia racemosa*		35				
216	*Hibbertia* spp.			5.5			
218	*Hovea chorizemifolia*						27.5
220	*Hovea trisperma*					1	
225	*Hybanthus debilissimus*				6.5		
578	*Hydrocotyle alata*	8928	451.5	3126.5			
229	*Hypocalymma angustifolium*	632	99.5	46	5.5		
231	***Hypochaeris glabra****	562	427.5	359.5		2	1
233	*Hypoxis occidentalis*		151	5.5			
237	*Isotropis cuneifolia*					5.5	
240	*Kennedia carinata*					17.5	
241	*Kennedia coccinea*		1			17.5	2
242	*Kennedia prostrata*	1					
245	*Labichea punctata*	5.5				1	
246	*Lagenophora huegelii*	1688.5	906	709	199	453	361
247	*Lasiopetalum floribundum*					291	29.5
249	*Lechenaultia biloba*	22	5.5	5.5		11	22
254	*Leptomeria cunninghamii*					5.5	6.5
256	*Leucopogon capitellatus*	1277.5	431	1803	57	134.5	16.5
258	*Leucopogon propinquus*	156.5	70	35	1	27.5	17.5
259	*Leucopogon pulchellus*	1					

Sp. No.	Species Name	Sandy Basins			Dwellingup		
		Treatment			FC65	FC24	FC64
		ER	SW	GR	burnt 1933	burnt 1979	burnt 2008
262	*Leucopogon verticillatus*				17.5	11	28.5
263	*Levenhookia pusilla*	1170.5	752	2990			
266	*Logania serpyllifolia*	16.5	29.5			5.5	11
269	*Lomandra caespitosa*	921	663	479	134.5	315	453
270	*Lomandra drummondii*			153	5.5		
271	*Lomandra hermaphrodita*	38.5	51.5	36	5.5	22	
272	*Lomandra integra*	27.5		5.5	16.5	11	75.5
502	*Lomandra micrantha* subsp. *micrantha*	5.5					59
274	*Lomandra pauciflora*				3		11
277	*Lomandra sericea*	97.5	23	46			
278	*Lomandra sonderi*				46		40.5
279	*Lomandra spartea*				199	5.5	29.5
284	*Luzula meridionalis*	5.5					
286	*Macrozamia riedlei*	149	138	52.5	269	407	239.5
290	*Millotia tenuifolia*	376		376			
299	*Opercularia hispidula*	92	105	116	40.5	27.5	
303	***Oxalis corniculata****	81	5.5	40.5	311.5	16.5	
307	*Patersonia babianoides*	52.5	51.5	46			16.5
308	*Patersonia juncea*	29.5	5.5	6.5			
310	*Patersonia pygmaea*	12	11	5.5			
311	*Patersonia umbrosa*			35			
314	*Pelargonium littorale*	5.5					
315	*Pentapeltis peltigera*					105	1
316	*Pentapeltis silvatica*				51.5		
317	*Pericalymma ellipticum* var. *ellipticum*	99.5	1	29.5			
321	*Persoonia longifolia*	64.5	62.5	93	38.5	33	57
329	*Phyllangium paradoxum*			1			
330	*Phyllanthus calycinus*	169.5			5958	453	331.5
333	*Pimelea rosea*	11					
335	*Pimelea spectabilis*	5.5					
337	*Pimelea suaveolens*	22	1	22	1	5.5	
338	*Pimelea sylvestris*	5.5					
351	*Poranthera microphylla*			5.5			
353	*Pteridium esculentum*				223	5.5	88.5
355	*Pterostylis pyramidalis*	70	153	35			64.5
356	*Pterostylis recurva*		2	18.5			
357	*Pterostylis vittata*						2
363	*Pyrorchis nigricans*	164					
365	*Ranunculus colonorum*	75.5		35	5.5		5.5
366	*Rhodanthe citrina*	16.5	330				
52	*Rytidosperma caespitosum*	82	29.5	16.5			
372	*Scaevola striata*	73.5	57	22		12	11
376	*Senecio hispidulus*	16.5	33	5.5	1	7.5	
377	*Senecio leucoglossus*						11
382	*Sowerbaea laxiflora*	94	29.5			129	5.5
386	*Stackhousia monogyna*	29.5	29.5				
388	*Stylidium amoenum*	46		16.5			75.5
389	*Stylidium brunonianum*	29.5		29.5			
391	*Stylidium ciliatum*	720.5	223	291		11	228.5

Sp. No.	Species Name	Sandy Basins			Dwellingup		
		Treatment			FC65	FC24	FC64
		ER	SW	GR	burnt 1933	burnt 1979	burnt 2008
394	*Stylidium piliferum*	5.5	35				
395	*Stylidium rhynchocarpum*		5.5				
400	*Stypandra glauca*	5.5					
401	*Styphelia tenuiflora*	33	1			17.5	81
403	*Synaphea petiolaris*	5.5	1	46			
407	*Tetraria capillaris*	233	68	308.5	123.5	97.5	129
408	*Tetraria octandra*	27.5		22			
409	*Tetrarrhena laevis*	140	246	82	51.5	81	
411	*Tetratheca hirsuta*	34	5.5	27.5		2	
414	*Thelymitra crinita*	6.5					
417	*Thomasia foliosa*	5.5			11		
527	*Thomasia grandiflora*	5.5					
418	*Thysanotus manglesianus*	1	1	1	51.5	23	1
419	*Thysanotus multiflorus*	1					
420	*Thysanotus patersonii*	5.5					
425	*Trachymene pilosa*	4776	1459.5	1188.5	29.5	223	29.5
428	*Trichocline spathulata*	232	215.5	145.5		51.5	153
429	*Tricoryne elatior*	5.5		11			
434	*Trymalium ledifolium*	361	407	407	11		5.5
433	*Trymalium odoratissimum* subsp. *odoratissimum*				1		
435	*Velleia trinervis*	129	64.5	194.5			
594	*Waitzia acuminata*	451.5		29.5			
441	*Wurmbea sinora*		6.5				
442	*Xanthorrhoea gracilis*			129	23		269
443	*Xanthorrhoea preissii*	377.5	11	11	88.5		40.5
444	*Xanthosia atkinsoniana*	5.5		1		1	
445	*Xanthosia candida*	84.5	5.5	34			
447	*Xanthosia huegelii*	16.5	12	6.5			
	Number of species in each treatment	119	80	94	48	63	59

INVERTEBRATES

Janet Farr and Allan Wills

Introduction

Invertebrates, including class Insecta, comprise over 95% of the planet's biodiversity and 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. 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 and mesic specialists. 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 and their responses to the various treatments of managed jarrah 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; and
- monitor the presence of known insect pest species.

Field survey and laboratory procedure

Seven FORESTCHECK grids in the Jarrah Sandy Basins ecosystem in the Blackwood District were sampled for invertebrates in 2014. Three grids (FC57, FC58 and FC59) were established in Wilga and Jolly forest blocks and four (FC60, FC61, FC62 and FC63) in Hunt and Camballan forest blocks. Sampling was also undertaken on three fire chronosequence grids (FC24, FC64 and FC65) in the Jarrah North West ecosystem in the Perth Hills District. These grids were all located in the Dwellingup 1 vegetation complex and time since fire was nine (FC64, Plavins block), 39 (FC 24 Kennedy block) and 81 years (Amphion block).

Sampling was conducted in March (autumn) and October (spring) 2014 using protocols outlined in the FORESTCHECK Operating Plan (DEC 2006) with minor alterations. Briefly, during autumn and spring active capture samples (hand sampling), involving sweeping, beating, and habitat searches of coarse woody debris (CWD) and litter were conducted once at each grid for a total time of one-person-hour per capture/habitat method. Light traps were run for three nights, simultaneously at each grid during each season, achieving one trap night per week for three weeks. Twenty pitfall traps, arranged in a "Z" pattern across the central grid area (see grid layout on p. 5), were opened simultaneously at each grid for 10 consecutive days. Captures were bagged and labelled with site and other capture details in the field and stored in a portable freezer. At the conclusion of a sampling period, specimens were then transported to the laboratory where they were sorted and compared to an extensive collection of voucher specimens. Vouchers for each new morphospecies were erected as necessary and labelled according to site, date of capture and capture method then preserved as either pinned or alcohol specimens. 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 12mm 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.

Results and discussion

Overall species richness and accumulation 2001–2014

Sorting, specimen identification and cataloguing was completed for the spring and autumn light trap, hand and pit fall samples for the both the grids in the Sandy Basins and the fire chronosequence grids near Dwellingup. However, these results may change slightly as taxanomic revision of morphospecies assignments continues. During the sample periods at the Sandy Basins grids there were four light trap failures out of a total of seven light trap nights comprising a total of 42 traps set. Mean minimum overnight temperature was 10.1°C and 9.3°C for autumn and spring sampling respectively. At the fire chronosequence grids there was one light trap failure out of a total of 6 light trap nights comprising a total of 18 traps set. Mean minimum overnight temperature was 14.2°C and 12.1°C for autumn and spring respectively.

The total number of morphospecies recorded for FORESTCHECK over the period 2002–14, including the three Dwellingup fire chronosequence grids, is 2522 (Fig. 1). The complete 2014 sample increased the number of morphospecies by 110, and currently a total of 102,598 individual specimens have been sorted and identified to morphospecies. Although species accumulation appeared to be approaching an asymptote in 2010–11, the new vegetation complexes surveyed in recent years resulted a higher rate of accumulation.

Morphospecies captures for previous FORESTCHECK sampling are shown in Table 1. Donnelly (2007–08) appears the most diverse sampling event with 787 morphospecies comprising an abundance of 13,581 individual specimens. Samples taken since 2013 incorporate the new pitfall trapping regime using 20 pits per grid. Thus in this report samples from the sandy Basins and Dwellingup will be compared to Donnelly 2 sampled in 2013 where the same pitfall regime was applied.

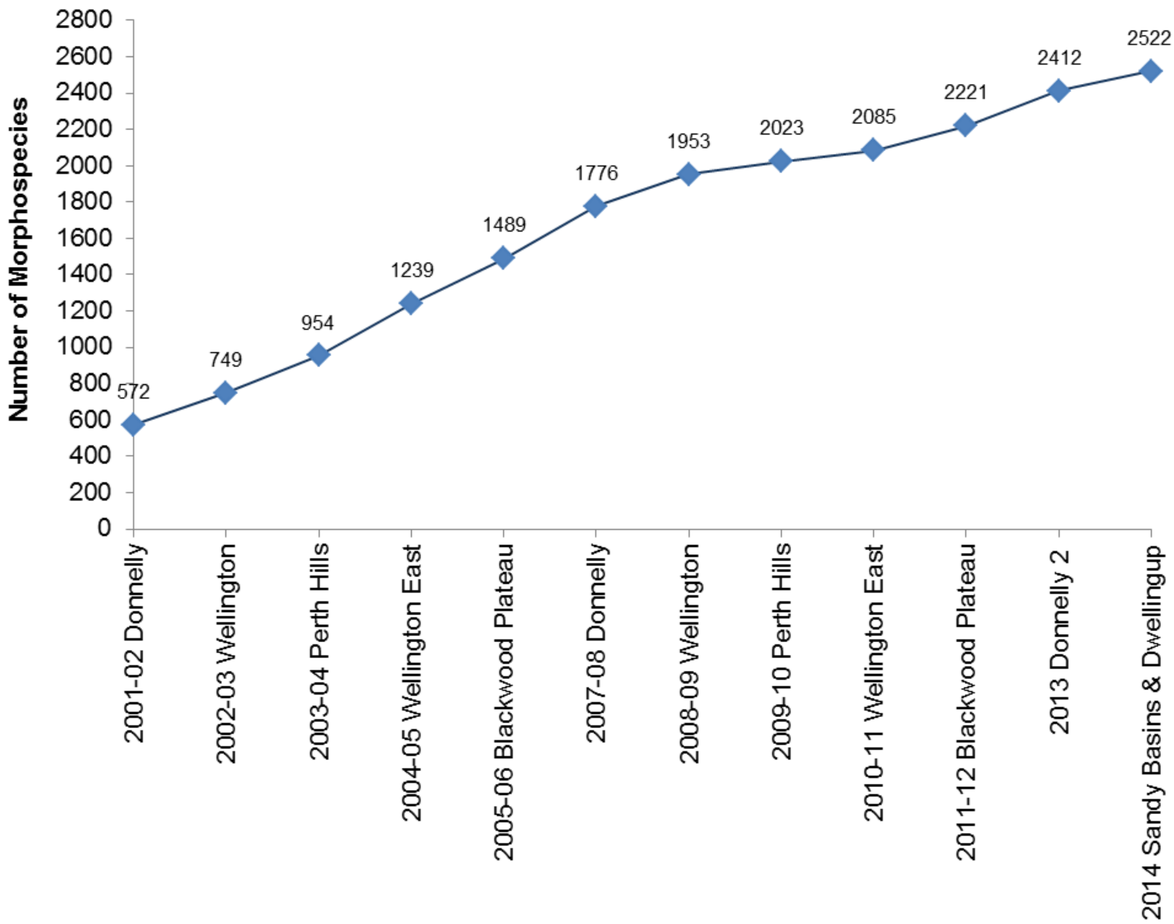


Figure 1. Accumulation of morphospecies recorded during FORESTCHECK monitoring from 2001–2014

Table 1. Number of morphospecies and abundance of invertabrates recorded on FORESTCHECK grids from 2002-2014

District	Forest ecosystem[1]	Sample period	No. of Morpho-species	No.of individuals	No of grids sampled	No. species per grid
Donnelly 1	JS	2001–02	572	NA	10	57.2
Wellington 1	JNW-C	2002–03	373	3080	9	41.4
Perth Hills	JNW-N	2003–04	428	4883	8	53.5
Wellington East	JNE	2004–05	617	28625	10	61.7
Blackwood Plateau	JB	2005–06	728	6959	11	66.2
Donnelly 1	JS	2007–08	787	13581	10	78.7
Wellington 1	JNW-C	2008–09	592	5590	9	65.8
Perth Hills	JNW-N	2009–10	529	6439	8	66.1
Wellington East	JNE	2010–11	524	8040	10	52.4
Blackwood Plateau	JB	2011–12	680	8007	11	61.8
Donnelly 2	JS	2013	797	6638	12	66.4
Sandy Basins	JSB	2014	478	3596	7	68.3
Fire chronosequence (Dwellingup)	JNW-C	2014	256	1223	3	85.3

[1] JS = Jarrah South, JNW-C = central region of the Jarrah North West, JNW-N = northern region of the Jarrah North West, JNE = jarrah North East and JB = Jarrah Blackwood Plateau, JSB = Jarrah Sandy Basins ecosystems.

In Figure 2, the numbers of morphospecies for invertebrate orders where 10 or more morphospecies have been assigned (at any of the comparative sites) are compared for Donnelly 2 sampled in 2013, and the Sandy Basins and Dwellingup in 2014. Although the Sandy Basins sample included a greater number of grids than the fire chronosequence sample, the pattern of taxa recorded at each site in 2014 was similar with relatively higher richness in the major orders Lepidoptera, Coleoptera and Hymenoptera. The invertebrate taxa Araneomorphae (modern spiders), Chilopoda (centipedes), Blattodea (cockroaches), Dermaptera (earwigs), Diplopoda (millipedes), Isopoda (slaters), Mygalamorphae (ancient spiders), Oligochaetae (worms) and Platyhelminthes (flat worms) contain species abundant in forest litter and coarse woody debris. Interception and catching these taxa is more common in hand sampling (reliant on operator experience and skill) and pitfall traps.

Most Lepidoptera species (moths and butterflies) are captured using light traps. This method is less influenced by operator experience and effort. Variation between samples can therefore be attributed to fluctuations in capture conditions including temperature, moon illumination and humidity—of which some can be corrected for, thereby attributing variation to site differences. The Sandy Basins ecosystem was more diverse for Lepidoptera species than was Donnelly 2. In addition Coleoptera (beetles), Hymenoptera (wasps) and Trichoptera (caddis flies) were also more diverse at the Sandy Basins, and contain taxa mostly caught in light traps although some were also abundant in hand capture methods such as sweeping and beating which are more dependent on operator experience. Nonetheless these orders also follow a similar pattern of relative diversity to that of the moths. Overall, in 2014 the Sandy Basins was a more diverse location for these taxa than Donnelly 2 in 2013.

Other taxa including Araneomorphae (modern spiders), Chilopoda (centipedes), Blattodea (cockroaches), Dermaptera (earwigs), Diplopoda (millipedes), Isopoda (slaters), Mygalamorphae (ancient spiders), Oligochaetae (worms) and Platyhelminthes (flat worms) contain species abundant in forest litter and coarse woody debris. Finding and catching these taxa is more common in hand sampling and pitfall traps. With the exception of Platyhelminthes, Donnelly 2 had a slightly higher richness in these taxa. In addition eight Onychophora (velvet worms) were found at Donnelly II (four from pitfalls and four from hand CWD and litter searches), two were found in the Dwellingup sample (one from a pitfall and one from hand litter searches, grids FC64 and FC65) but none were found in the Sandy

Basins sample. This tends to indicate that the Sandy Basins and Dwellingup sampling was conducted during a period of lower forest floor moisture than that at Donnelly 2 in 2013.

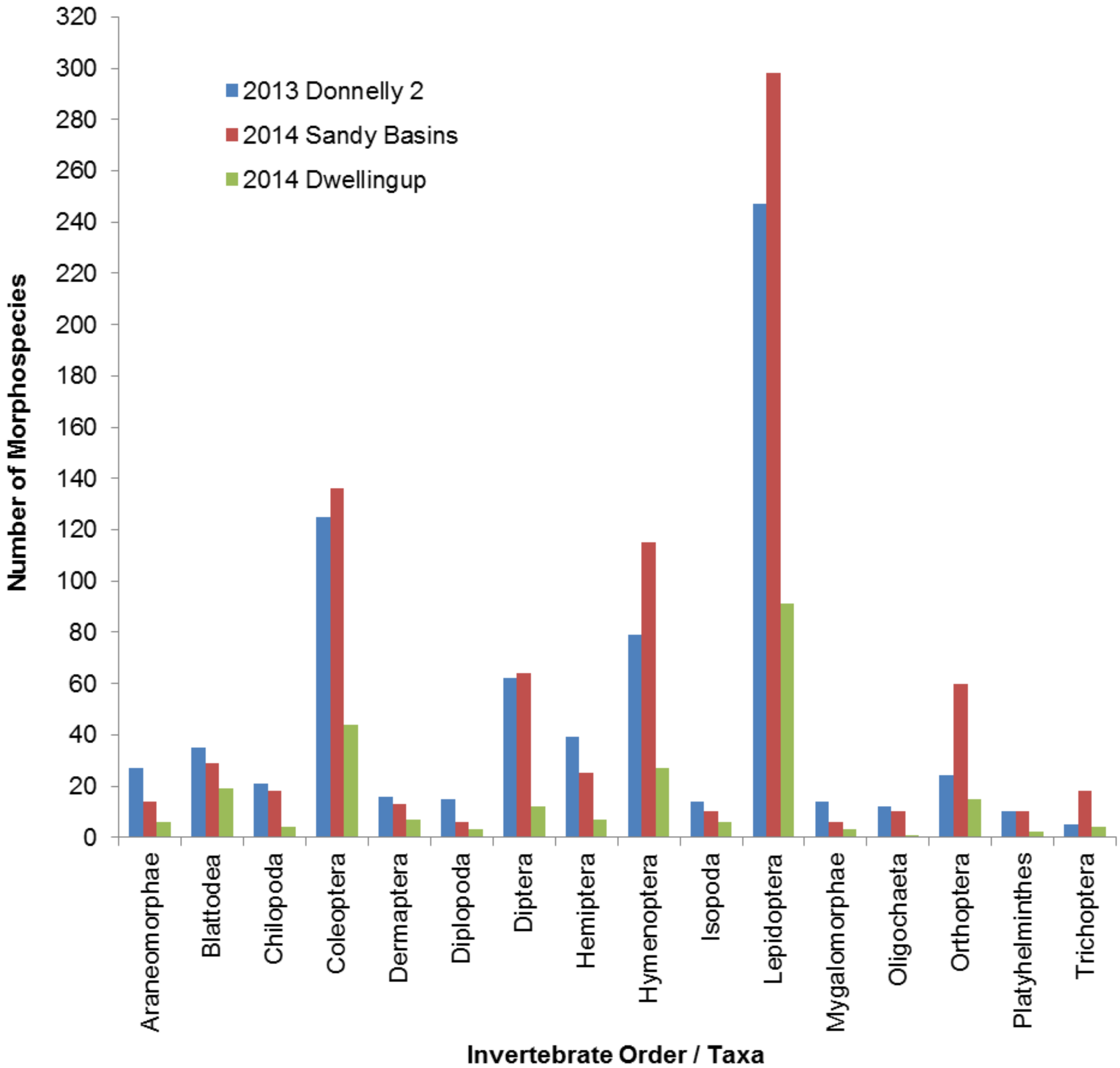


Figure 2. Numbers of morphospecies in invertebrate orders where ten or more morphospecies were recorded in FORESTCHECK grids at Donnelly 2 in 2013, and Sandy Basins in 2014 and fire chronosequence grids at Dwellingup in 2014.

Sandy Basins

Species richness and abundance

The highest species richness of 151 morphospecies was recorded at the external reference grid in Camballan (FC60), which was similar to the Jolly external reference grid (FC57) where 145 morphospecies were recorded (Figure 3). The lowest richness (91 morphospecies) occurred at the Wilga gap release grid (FC59). The highest abundances were recorded in the Hunt shelterwood (FC61) and the Jolly external reference (FC57) grids, with 677 and 656 individuals respectively. The lowest abundance of 302 individuals occurred at the Wilga shelterwood grid (FC58).

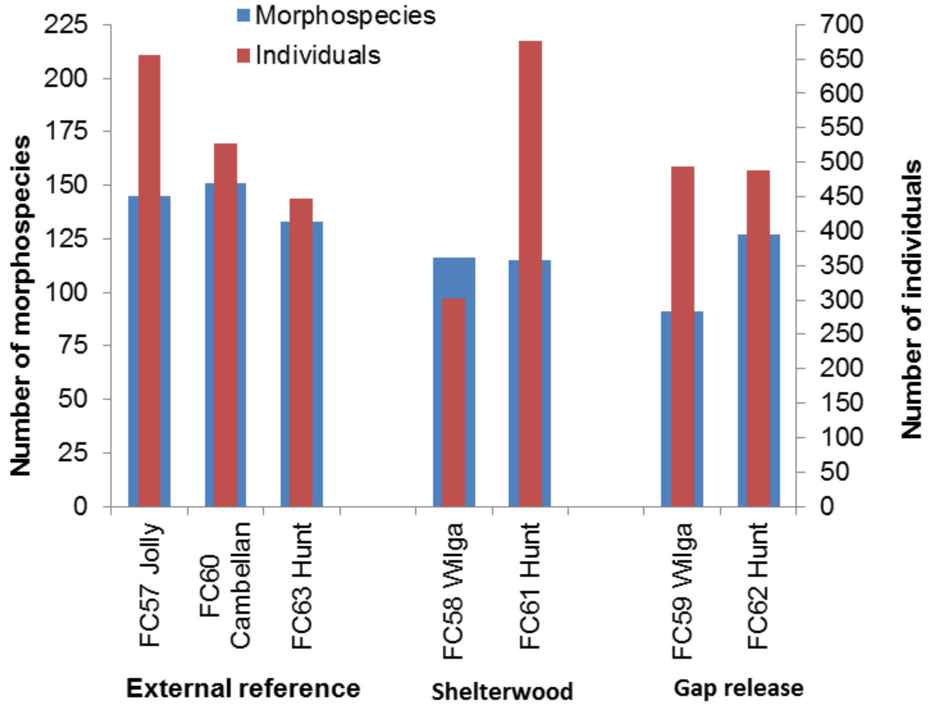


Figure 3. Number of species and individuals recorded in each FORESTCHECK monitoring grid at the Sandy Basins in 2014

Mean species richness per grid ranged from 143 to 109 (Fig. 4a) with the highest diversity occurring in the external reference treatment. Diversity in the shelterwood and gap release treatments were not significantly different. Although mean abundances were lower in the shelterwood and gap release treatments compared with the external reference, the difference was not significant (Fig. 4b). Individual species and their abundances in each silvicultural treatment are listed in Appendix 1.

The most frequent species captured was the wood ant *Camponotus* sp (sp# 423), with a frequency of 144 captures and an abundance of 323 (Fig. 5). This species is common in FORESTCHECK grids. The highest abundance, was for a Zygaenid moth *Pollanisus* sp (sp# 78 & 42) (Fig. 5) which was caught with a frequency of 110 and an abundance of 1206. It is caught in light traps as well as by hand sweeping, and its current species assignment is split between two mophospecies distinguishing males and females. The third most frequent and abundant species was a Noctuid moth *Proteuxoa* sp (sp# 39). It is very common in the jarrah forest and its capture frequency was 93 with an abundance of 441. In contrast, the arboreal canopy feeder *Opodiphthera helena* was only recorded in the Wilga external reference (FC57) and Hunt shelterwood (FC61) grids with a total abundance of five. At Donnelly 2 in 2013 it had the highest abundance (472). With the exception of the Perth Hills location, *O. helena* was generally recorded in the more northerly FORESTCHECK locations and this difference may be a reflection of the earlier spring sample period for 2014.

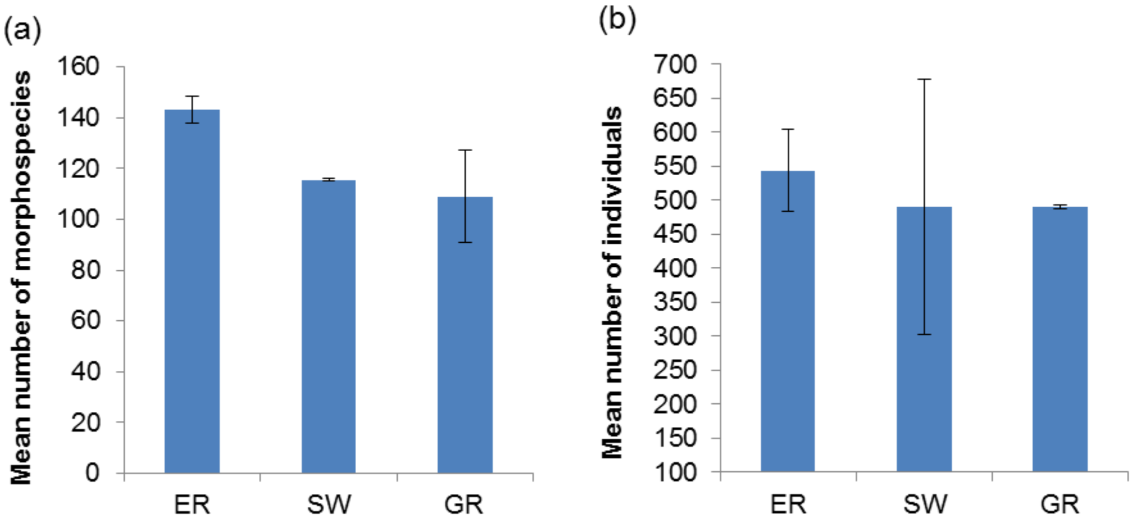


Figure 4(a) Mean number of morphospecies per grid (± SE) and (b) mean number of individuals (abundance) per grid (± SE) recorded in each treatment in the Sandy Basins in 2014. ER = external reference, SW/SC = shelterwood/selective cut and GR = gap release treatment.

Figure 5: Sp# 423 *Camponotus* (left). Sp# 78 the Zygaenid moth *Pollanisus* sp (right). Sp # 39 the Noctuid *Proteuxoa* sp.

Pest presence

Jarrah leafminer was present in all the Sandy Basins FORESTCHECK grids (Table 2). Bullseye borer (BEB) was present in all grids except the Wilga shelterwood (FC58). Gumleaf skeletoniser canopy damage (GLS, sp# 686) was not observed on any grid; however single specimens were sampled using sweeping and beating from the Jolly external reference (FC57), Wilga shelterwood (FC58) and Hunt gap release (FC62) grids indicating populations are present in this region but were low compared with the Donnelly 2 sample period in 2013. The GLS outbreak distribution was not observed to extend to this area in 2010-11.

Table 2: Pest presence and abundance assessment at each Forestcheck grid in the Sandy Basins in 2014 samples (JLM = jarrah leaf miner; GLS = gumleaf skeletonizer; BEB = bullseye borer; 0 = absent, 0.5 = found present through observations other than canopy inspection, 1 = present, 2 = abundant)

Treatment	Grid No.	Location	JLM	GLS	BEB
External reference	FC57	Jolly	1	0.5	1
External reference	FC60	Camballan	1	0	1
External reference	FC63	Hunt	1	0	1
Shelterwood	FC58	Wilga	1	0.5	0
Shelterwood	FC61	Hunt	1	0	1
Gap release	FC59	Wilga	1	0	1
Gap release	FC62	Hunt	1	0.5	1

Fire chronosequence, Dwellingup

A total of 256 species including 1223 individuals were sampled in the fire chronosequence grids near Dwellingup. The most frequent species captured was the crane fly (*Tipulidae*, sp. # 16) with a frequency of 11 captures and an abundance of 113. This species is common in FORESTCHECK grids. The second most frequent and abundant species was the Hydrophylid beetle (sp# 14). Also very common in the jarrah forest and caught in light traps, this species capture frequency was eight with an abundance of 77.

The longer unburnt grids at Kennedy (FC24) and Amphion (FC65) had lower overall species richness (110 species on each) and abundances (359 and 340 respectively) than the more recently burnt grid at Plavins (FC64, 136 morphospecies, 524 individuals) (Fig. 6). This suggests the structure of long unburnt sites does not support high diversity and that forest diversity decreases as succession advances (however this conclusion is drawn on only three monitoring grids in this report). Furthermore the presence of velvet worms (Onycophora, sp# 937—a group most likely to be disadvantaged by fire) at the long unburnt grid at Amphion and the more recently burnt grid at Plavins, suggests that diversity of some relictual mesic species may recover by nine years following prescribed fire.

Species dependent on litter and coarse woody debris are more likely to be affected by fire than the mostly more mobile understorey and canopy dwellers. Richness and abundance from pitfall captures and hand samples from coarse woody debris and litter (Figs 7 and 8) differ somewhat from the overall result shown in Figure 6. These results suggest that the long unburnt grid at Amphion (FC65) and more recently burnt grid at Plavins (FC64) have similar species richness (46), whereas the median long unburnt grid at Kennedy (39 years since fire FC24) has a lower species richness of 41. Abundance shows a similar trend with greater abundance in the long unburnt and recently burnt grids at Amphion and Plavins (82 and 88 respectively) and lower abundance at Kennedy (75).

Mesic species, including isopods, flat worms and mygalamorph spiders (Fig. 9), would be expected to prefer a long undisturbed environment with minimal fire. These species showed a peak in the median burnt grid at Kennedy (21 morphospecies and 46 individuals) compared with 14 morphospecies in both the long unburnt and recently burnt grids (abundances 17 and 21 respectively). However, the trend observed in ground dwelling predators is a slight decline in morphospecies richness and abundance (Figs 7 and 8) with time since fire.

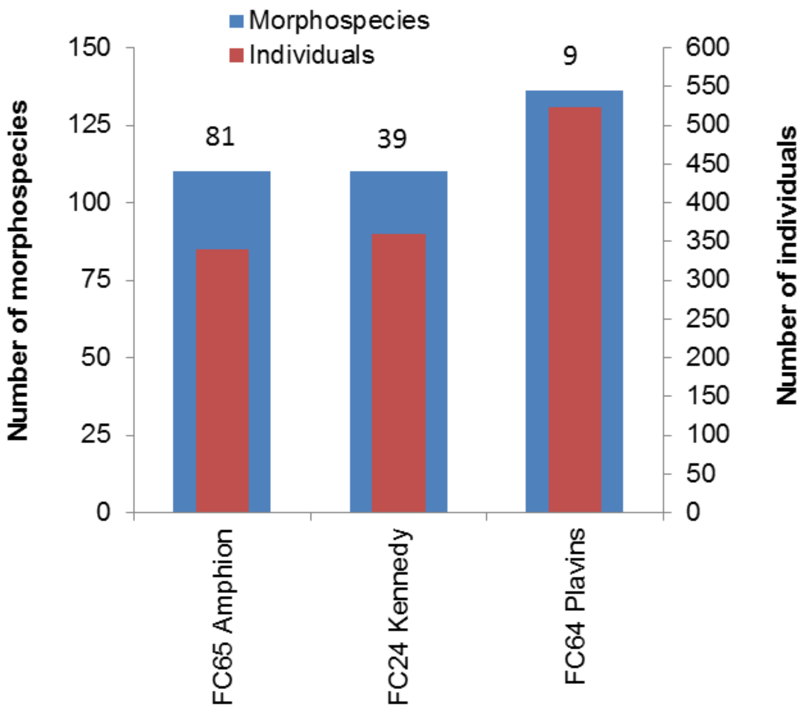


Figure 6 Total number of morphospecies and individuals sampled from each fire chronosequence grid near Dwellingup in 2014 (numbers above columns indicates the years since fire)

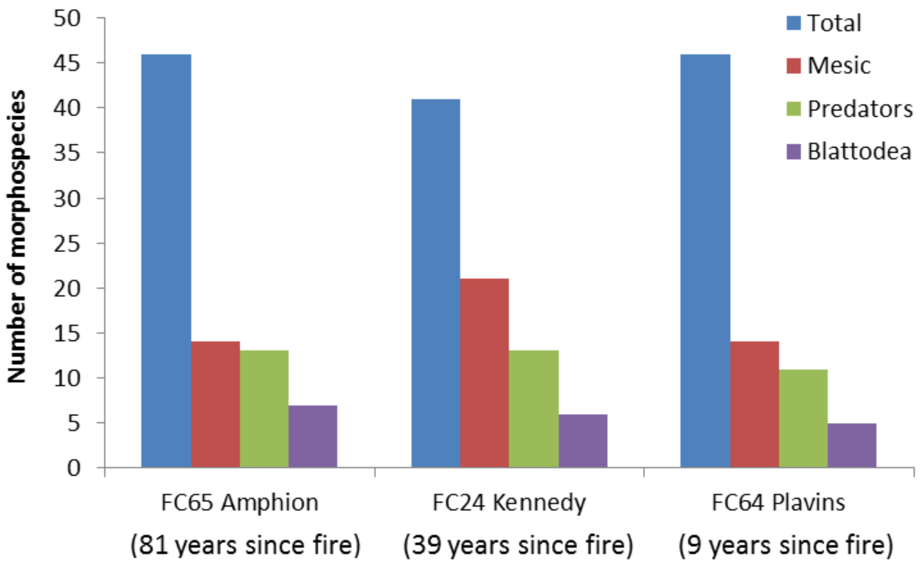


Figure 7. Total number of morphospecies sampled by pitfall trapping and hand searches of coarse woody debris and litter from fire chronosequence grids near Dwellingup in 2014.

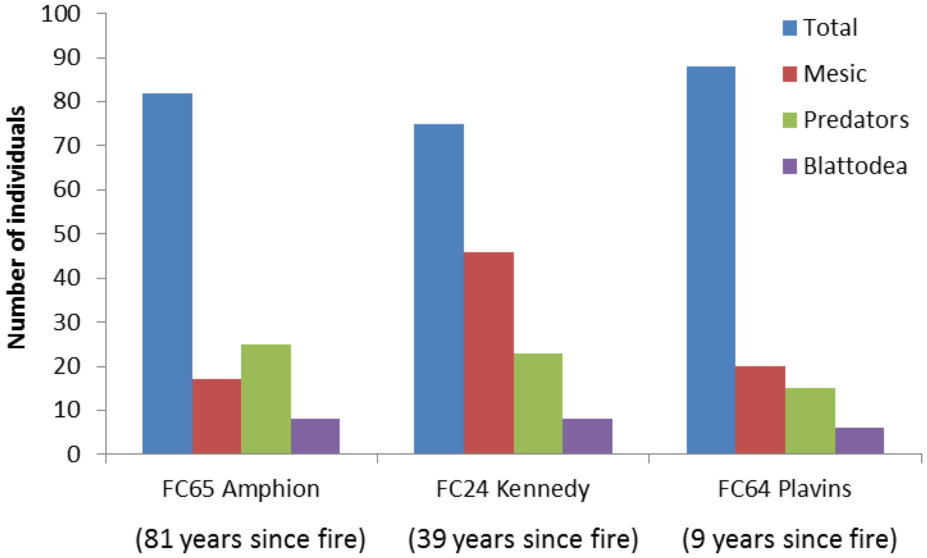


Figure 8. Total number of individuals sampled by pitfall, and hand searches of coarse woody debris and litter from fire chronosequence grids near Dwellingup in 2014.

Figure 9 A selection of mesic species captured from fire chronosequence grids near Dwellingup in 2014.

Predator and parasitoid species within this subsample include beetles, wasps, flies, centipedes and Myglamorph spiders. Some of these species (e.g. beetles wasps and flies) are mobile and easily attributed to a taxon. However, some species within the predator group, and many within the mesic species are less mobile, more likely to include localised endemism and include cryptic species within the morphospecies identity. Currently we have a reasonable understanding of taxa within Blattodea (cockroaches) and are moderately confident in isolating morphospecies. Blattodea is a good representative order of litter dwelling mesic species. Species diversity and abundance in relation to fire age for Blattodea is also shown in Figures 7 and 8, for which trends in diversity and abundance are comparable with predators, where diversity and abundance decreases with younger fire ages. However, this comparison is only looking at single grids from three time-since-fire ages and the trends observed in the Blattodea and predator subset show very small differences between species numbers. These results suggest that the influence of fire on species composition and diversity is complex and will vary between, and even within niche requirments.

Conclusions

The main observations made following monitoring of vascular flora on the Sandy Basins FORESTCHECK grids in 2014 were;

- Species previously uncollected in FORESTCHECK continue to be encountered.
- Species richness in the southern jarrah region appears to be greater than drier areas of the jarrah forest.
- Variation in richness and abundance between sample grids in the Sandy Basins ecosystem is high relative to differences between treatments indicating richness and abundance were not detectably influenced by silvicultural treatment.

The main observations made following monitoring of vascular flora on the Dwellingup fire chronosequence grids in 2014 were;

- Data suggest invertebrate species composition is affected by time since fire, but this influence is not straight forward.
- DNA barcoding will assist in identifying cryptic and less easily identified invertebrates and therefore enable a more refined examination of silvicultural influences including fire.

Acknowledgements

We thank Paul VanHeurck, Andy Young, and Leticia Povh for assistance in both the field and laboratory. Antonia Callaghan, Ian Jones and Ingrid Welles assisted in the field; Margaret Jakobson, Brooke Janitz and Robyn Bowles assisted in the laboratory.

References

DEC 2006. *FORESTCHECK: Monitoring Biodiversity in the South-West Forests. Operating Plan.* Department of Environment and Conservation, Kensington, Western Australia.

APPENDIX 1. Species list and abundance for invertebrates recorded in treatments for FORESTCHECK grids at the Sandy Basins and fire chronosequence grids near Dwellingupin in 2014. Tax 3 refers to sub family or a sub taxa relevant to the order or family, FCS = fire chronosequence, ER = external reference, SW = shelterwood/selective cut and GR = gap release treatment. (note discrepancies in abundances from previous text references are due to data anomalies yet to be addressed).

						Treatment				
Sp.#	**Order**	**Family**	**Tax 3**	**Genus**	**Species**	**FCS**	**ER**	**GR**	**SW**	**Total**
1217	Araneomorphae	Araneidae		*Eriophora*	*transmarina ?*			1		1
1213	Araneomorphae	Araneidae		*Gasteracantha*	*minax*	2	1		1	4
1551	Araneomorphae	Araneidae		*Nephila*	*edulis*		1		1	2
1471	Araneomorphae	Araneidae		*Phonographa*	*graeffei*	1	3	3	1	8
2964	Araneomorphae	Deinopidae					1			1
1558	Araneomorphae	Lycosidae						2		2
1595	Araneomorphae	Lycosidae						1		1
743	Araneomorphae	Lycosidae						1		1
4019	Araneomorphae	Miturgidae							1	1
2055	Araneomorphae	Sparassidae				1				1
1446	Araneomorphae	Sparassidae				1				1
2686	Araneomorphae	Stiphididae				1				1
3543	Araneomorphae	Stiphidiidae				1				1
3205	Blattodea					1			1	2
2511	Blattodea					3				3
3166	Blattodea						1		1	2
3972	Blattodea							1	1	2
4014	Blattodea							1	1	2
4018	Blattodea								2	2
2505	Blattodea						1			1
3902	Blattodea						2			2
3013	Blattodea					1				1
3595	Blattodea					1		2		3
2684	Blattodea					1		1		2
410	Blattodea	Blaberidae				1	5	1		7
148	Blattodea	Blaberidae					1			1
2597	Blattodea	Blaberidae	Epilamprinae	*Laxta*	sp	1				1
190	Blattodea	Blattelidae				2	1		1	4
3026	Blattodea	Blattidae				1	1	1		3
1933	Blattodea	Blattidae							1	1
1559	Blattodea	Blattidae				1				1
878	Blattodea	Blattidae						2		2
1991	Blattodea	Blattidae				1				1
2662	Blattodea	Blattidae				1		1		2
2037	Blattodea	Blattidae					1			1
490	Blattodea	Blattidae				1	1			2
1888	Blattodea	Blattidae	Polyzosteriinae	*Platyzosteria*	sp	2				2
122	Blattodea	Blattidae	Polyzosteriinae	*Platyzosteria*	sp	1				1
874	Blattodea	Blattidae	Polyzosteriinae	*Platyzosteria*	sp	1				1
2008	Blattodea	Blattidae	Polyzosteriinae	*Platyzosteria*	sp	2				2
899	Blattodea	Blattidae	Polyzosteriinae	*Platyzosteria*	sp	1	1			2
968	Blattodea	Blattidae	Polyzosteriinae	*Platyzosteria*	sp	1				1
592	Blattodea	Blattidae	Polyzosteriinae	*Polyzosteria*	sp				2	2
4022	Chilopoda						1			1
3544	Chilopoda							1		1
3441	Chilopoda					1				1
3350	Chilopoda						1		1	2
3528	Chilopoda					1	1			2
1531	Chilopoda	Geophilidae					2			2

Sp.#	Order	Family	Tax 3	Genus	Species	Treatment				Total
						FCS	ER	GR	SW	
227	Chilopoda	Geophilidae						1		1
228	Chilopoda	Lithobiidae							1	1
229	Chilopoda	Lithobiidae							5	5
1882	Chilopoda	Scolopendridae					3	2	1	6
1783	Chilopoda	Scolopendridae							1	1
277	Chilopoda	Scolopendridae							1	1
225	Chilopoda	Scolopendridae				1	2			3
223	Chilopoda	Scolopendridae	Otostigminae	*Ethmostigmus ?*		1				1
4020	Coleoptera	Buprestidae	Buprestinae	*Melobasis*			1			1
1435	Coleoptera	Buprestidae	Buprestinae	*Melobasis*	*gloriosa ?*			1	4	5
701	Coleoptera	Buprestidae	Buprestinae	*Melobasis*	sp		1		2	3
2974	Coleoptera	Cantharidae					2			2
3132	Coleoptera	Cantharidae							2	2
2993	Coleoptera	Cantharidae					8	4	8	20
795	Coleoptera	Cantharidae	Chauliognathinae	*Chauliognathus*	sp		2		6	8
198	Coleoptera	Cantharidae	Dysmorphocerinae	*Heteromastix*	sp	1				1
3419	Coleoptera	Carabidae				1				1
842	Coleoptera	Carabidae				1		1		2
1087	Coleoptera	Carabidae	Agoninae	*Notagonum*	sp		1			1
1979	Coleoptera	Carabidae	Broscinae	*Promecoderus*	sp	1				1
253	Coleoptera	Carabidae	Broscinae	*Promecoderus*	sp	2	1			3
1442	Coleoptera	Carabidae	Esydrinae			2				2
1059	Coleoptera	Carabidae	Lebiinae	*Agonocheila*	sp		1			1
566	Coleoptera	Carabidae	Pterostichinae	*Notonomus*	*mediosulcatus*	1				1
3636	Coleoptera	Carabidae	Scaritinae	*Scaraphites*	sp		3			3
2725	Coleoptera	Cerambycidae	Cerambycinae				1	1		2
654	Coleoptera	Cerambycidae	Cerambycinae	*Coptocercus*	*rubripes*				1	1
654	Coleoptera	Cerambycidae	Cerambycinae	*Coptocercus*	*rubripes*				1	1
4008	Coleoptera	Cerambycidae	Cermabycinae	*Bethelium*	*cleroides*		1			1
707	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsis*	sp			1		1
1761	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsis*	sp		1		1	2
2034	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsis*	sp		1			1
913	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsis*	sp		1	1	3	5
786	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsisterna*	sp		1			1
665	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsisterna*	sp		1			1
463	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsisterna*	sp		1			1
803	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsisterna*	sp		2			2
115	Coleoptera	Chrysomelidae	Eumolpinae	*Edusella?*			1			1
2784	Coleoptera	Curculionidae					1			1
4057	Coleoptera	Curculionidae	Amycterinae				1	2		3
970	Coleoptera	Curculionidae	Amycterinae	*Acantholophus*	sp	1				1
3000	Coleoptera	Curculionidae	Amycterinae	*Acantholophus*	sp			1		1
496	Coleoptera	Curculionidae	Amycterinae	*Acantholophus*	*suturalis*		1			1
2356	Coleoptera	Curculionidae	Amycterinae	*Cucculothorax*	sp		1			1
1571	Coleoptera	Curculionidae	Amycterinae	*Cucullothorax*	*horridus*		2		1	3
2773	Coleoptera	Curculionidae	Amycterinae	*Dialeptopus*	*macillentus?*		1			1
3539	Coleoptera	Curculionidae	Amycterinae	*Euomus*	sp		1	1		2
814	Coleoptera	Curculionidae	Amycterinae	*Neohyborrhynchus ?*				1		1
1810	Coleoptera	Curculionidae	Amycterinae	*Sclerorinus*	sp				1	1
910	Coleoptera	Curculionidae	Amycterinae	*Talaurinus*	sp	1				1
209	Coleoptera	Curculionidae	Aterpinae	*Rhinaria ?*		1				1
2088	Coleoptera	Curculionidae	Entiminae	*Mandalotus ?*			2			2
113	Coleoptera	Curculionidae	Entiminae	*Polyphrades*	*aesalon ?*		2			2

Sp.#	Order	Family	Tax 3	Genus	Species	Treatment				Total
						FCS	ER	GR	SW	
3443	Coleoptera	Curculionidae	Entiminae	*Polyphrades*	*tumidulus ?*		1			1
161	Coleoptera	Curculionidae	Gonipterinae	*Oxyops*	*fasciata*	13	1		10	24
98	Coleoptera	Curculionidae	Gonipterinae	*Oxyops*	*pictipennis*	1	7	2	8	18
1278	Coleoptera	Curculionidae	Gonipterinae	*Oxyops*	*sp*		1			1
290	Coleoptera	Curculionidae	Molytinae	*Melanotranes*	*roei*	2				2
291	Coleoptera	Curculionidae	Molytinae	*Tranes*	*vigorsii*	3				3
13	Coleoptera	Dytiscidae	Colymbetinae	*Rhantus*	*suturalis*				1	1
13	Coleoptera	Dytiscidae	Colymbetinae	*Rhantus*	*suturalis*				1	1
651	Coleoptera	Dytiscidae	Lancetinae	*Lancetes*	*lanceolatus*	2	1	1	5	9
651	Coleoptera	Dytiscidae	Lancetinae	*Lancetes*	*lanceolatus*	2	1	1	5	9
1817	Coleoptera	Elateridae				1	1	2		4
4037	Coleoptera	Elateridae				1				1
3325	Coleoptera	Elateridae	Agrypninae	*Conoderus*	sp	1		3		4
595	Coleoptera	Elateridae	Agrypninae	*Conoderus*	sp	1				1
1818	Coleoptera	Elateridae	Agrypninae	*Conoderus*	sp	4	11	11	6	32
220	Coleoptera	Elateridae	Agrypninae	*Conoderus*	sp		2	1		3
2871	Coleoptera	Elateridae	Agrypninae	*Conoderus*	sp	1				1
444	Coleoptera	Elateridae	Agrypninae	*Conoderus*	sp		7	2	3	12
1109	Coleoptera	Elateridae	Agrypninae	*Conoderus*	sp	1				1
997	Coleoptera	Elateridae	Agrypninae	*Pseudaeolus*	sp	1				1
4041	Coleoptera	Geotrupidae							1	1
2625	Coleoptera	Geotrupidae	Bolboceratinae	*Bolborhachium*	*dacoderum?*		2	1	3	6
1836	Coleoptera	Geotrupidae	Bolboceratinae	*Bolborhachium*	*hollowayi*		2		1	3
14	Coleoptera	Hydrophilidae				77	14	5	11	107
1994	Coleoptera	Lycidae						1		1
2643	Coleoptera	Lycidae	Metriorrhynchinae			1				1
802	Coleoptera	Lycidae	Metriorrhynchinae				1		1	2
2180	Coleoptera	Scarabaeidae				2				2
189	Coleoptera	Scarabaeidae	Dynastinae	*Cryptodus*	sp		5	2	2	9
1945	Coleoptera	Scarabaeidae	Dynastinae	*Metanastes*	sp				1	1
3461	Coleoptera	Scarabaeidae	Dynastinae	*Novapus*	sp	1				1
1021	Coleoptera	Scarabaeidae	Dynastinae	*Semanopterus*	sp	3				3
1838	Coleoptera	Scarabaeidae	Dynastinae	*Trissodon*	sp		1			1
1853	Coleoptera	Scarabaeidae	Melolonthinae			7				7
1847	Coleoptera	Scarabaeidae	Melolonthinae				3		3	6
3717	Coleoptera	Scarabaeidae	Melolonthinae				1			1
846	Coleoptera	Scarabaeidae	Melolonthinae	*Colpochila*	*antennalis*	20				20
353	Coleoptera	Scarabaeidae	Melolonthinae	*Colpochila*	*major*	1	27	6	27	61
2006	Coleoptera	Scarabaeidae	Melolonthinae	*Colpochila*	sp	1				1
1820	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	sp		2			2
951	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	sp	1	1			2
94	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	sp	1	1			2
347	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	sp	1	13	5		19
1133	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	sp	1				1
363	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	sp		2		1	3
1388	Coleoptera	Scarabaeidae	Melolonthinae	*Maechidius ?*			1		1	2
1846	Coleoptera	Scarabaeidae	Rutelinae	*Clilopocha*	*sp*	1			1	2
17	Coleoptera	Scarabaeidae	Scarabaeinae	*Onthophagus*	*ferox*	1	3			4
3640	Coleoptera	Scarabaeidae	Scarabaeinae	*Onthophagus*	sp	1				1
3218	Coleoptera	Scarabaeidae	Scarabaeinae	*Onthophagus*	sp	1				1
3987	Coleoptera	Scarabaeidae	Scarabaeinae	*Onthophagus ?*		1				1
628	Coleoptera	Staphylinidae				1				1
4046	Coleoptera	Tenebrionidae	Heleini	*Helea*			1			1
1012	Coleoptera	Tenebrionidae	Heleini	*Helea*	sp				1	1

Sp.#	Order	Family	Tax 3	Genus	Species	Treatment				Total
						FCS	ER	GR	SW	
904	Coleoptera	Tenebrionidae	Lagriinae	*Adelium*	sp	1		1	1	3
1117	Coleoptera	Tenebrionidae	Tenebrioninae			1				1
2706	Coleoptera	Trogidae					2			2
1538	Dermaptera					4	2	1	1	8
3550	Dermaptera					2				2
491	Dermaptera					5	2	1		8
492	Dermaptera							1		1
3529	Dermaptera	Anisolabididae				4				4
1433	Dermaptera	Anisolabididae				1	3		1	5
123	Dermaptera	Anisolabididae				1				1
258	Dermaptera	Anisolabididae				8		1		9
257	Dermaptera	Anisolabididae	Anisolabidinae						1	1
484	Dermaptera	Anisolabididae	Anisolabidinae					1		1
682	Dermaptera	Anisolabididae	Isolabelli				1			1
3536	Diplopoda						1			1
3440	Diplopoda					1				1
3020	Diplopoda						2			2
876	Diplopoda	Julida				1	1			2
260	Diplopoda	Julida				1	5	1	1	8
1811	Diptera	Asilidae					1			1
2647	Diptera	Asilidae					2			2
2709	Diptera	Asilidae						2		2
2165	Diptera	Asilidae					1		1	2
751	Diptera	Asilidae					2		2	4
541	Diptera	Asilidae				1	1	4		6
775	Diptera	Asilidae				1				1
907	Diptera	Bombyliidae					2			2
4038	Diptera	Bombyliidae				1				1
683	Diptera	Bombyliidae					1			1
745	Diptera	Bombyliidae					20	3	3	26
1634	Diptera	Calliphoridae					1			1
3254	Diptera	Calliphoridae							1	1
53	Diptera	Calliphoridae	Calliphorinae	*Calliphora*	*sp*	1		1		2
1940	Diptera	Pyrgotidae					1			1
2736	Diptera	Pyrgotidae					2	4		6
88	Diptera	Pyrgotidae						1		1
1422	Diptera	Syrphidae				2	2	1		5
1421	Diptera	Syrphidae				1		3		4
1203	Diptera	Syrphidae							1	1
206	Diptera	Syrphidae						1		1
130	Diptera	Syrphidae					2	1		3
129	Diptera	Syrphidae						1		1
3187	Diptera	Tabanidae					2		1	3
3713	Diptera	Tabanidae							1	1
2922	Diptera	Tabanidae					1			1
3947	Diptera	Tabanidae					1			1
473	Diptera	Tabanidae				3	4	2	1	10
2134	Diptera	Tabanidae					1			1
2875	Diptera	Tabanidae							1	1
2983	Diptera	Tabanidae					1			1
126	Diptera	Tabanidae				3	15	17	14	49
4059	Diptera	Tachinidae				1				1
4051	Diptera	Tachinidae							1	1
1411	Diptera	Therevidae					1			1

Sp.#	Order	Family	Tax 3	Genus	Species	Treatment				Total
						FCS	ER	GR	SW	
1802	Diptera	Therevidae					1	1		2
2646	Diptera	Therevidae						3		3
532	Diptera	Therevidae				1	1		2	4
16	Diptera	Tipulidae				113	4	1		118
792	Diptera	Tipulidae				2	1			3
1527	Gastropoda						1	2	3	6
1431	Gastropoda					1		1		2
969	Gastropoda							1		1
1302	Hemiptera	Acanthosomatidae							1	1
1934	Hemiptera	Cicadellidae	Tartessinae	*Putoniessa*	sp	1				1
787	Hemiptera	Cicadellidae	Tartessinae	*Putoniessa*	sp	1				1
2862	Hemiptera	Cicadidae					1			1
700	Hemiptera	Coreidae	Coreinae	*Amorbus*	*bispinus*		7	1	3	11
2689	Hemiptera	Gelastocoridae	Nerthrinae	*Nerthra*	sp				2	2
1611	Hemiptera	Gelastocoridae	Nerthrinae	*Nerthra*	sp				1	1
2694	Hemiptera	Gelastocoridae	Nerthrinae	*Nerthra*	sp			1		1
1567	Hemiptera	Gelastocoridae	Nerthrinae	*Nerthra*	sp		1		1	2
962	Hemiptera	Pentatomidae				1	1	1		3
1227	Hemiptera	Pentatomidae		*Ocirrhoe*	*unimaculata*	1				1
251	Hemiptera	Pentatomidae					1	2	1	4
153	Hemiptera	Pentatomidae		*Dictyotus*	sp	1	1			2
4054	Hemiptera	Reduviidae						1		1
3828	Hemiptera	Reduviidae				1	1	1		3
2492	Hemiptera	Reduviidae					2			2
311	Hemiptera	Reduviidae						1		1
714	Hemiptera	Reduviidae				2				2
2065	Hemiptera	Reduviidae	Emesinae						1	1
863	Hemiptera	Reduviidae	Harpactorinae				1			1
4055	Hymenoptera							1		1
2018	Hymenoptera	Anthophoridae				2				2
203	Hymenoptera	Anthophoridae				5	1			6
52	Hymenoptera	Apidae	Apinae	*Apis*	*mellifera*	2	1	1	3	7
3882	Hymenoptera	Braconidae						2		2
4021	Hymenoptera	Colletidae					3	1	1	5
696	Hymenoptera	Colletidae					1	2		3
3383	Hymenoptera	Colletidae	Colletinae						1	1
3157	Hymenoptera	Colletidae	Colletinae				2			2
2665	Hymenoptera	Colletidae	Hylaeinae	*Hylaeus*	sp		1			1
2069	Hymenoptera	Evaniidae						1		1
1497	Hymenoptera	Formicidae				1				1
510	Hymenoptera	Formicidae					3			3
423	Hymenoptera	Formicidae	Formicinae	*Camponotus*	sp	20	143	86	74	323
2952	Hymenoptera	Formicidae	Myrmeciinae			34				34
222	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*analis*		1			1
252	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*chasei*		8		5	13
487	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*clarki*	3	1		1	5
281	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*mandibularis*	2	2			4
2046	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*michaelseni*	2	1			3
4036	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*nigriscapa grp*	1				1
4033	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*nigrocincta sp grp*	3				3
4069	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*pavida*		1		3	4
1535	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*pavida?*		1	1		2
3362	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*rugosa*	2			1	3
1918	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	sp	17				17

Sp.#	Order	Family	Tax 3	Genus	Species	Treatment				Total
						FCS	ER	GR	SW	
945	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	sp	34				34
478	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	sp		1			1
1374	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*swalei*		2			2
712	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*vindex*		1	1	1	3
543	Hymenoptera	Formicidae	Ponerinae	*Rhytidoponera*	sp		13	13		26
3179	Hymenoptera	Halictidae					1			1
3025	Hymenoptera	Ichneumonidae	Anomaloninae	*Trichomma*	sp				1	1
1156	Hymenoptera	Ichneumonidae	Ophioninae	*Enicospilus*	sp			1	2	3
1953	Hymenoptera	Ichneumonidae	Ophioninae	*Leptophion*	sp		2		1	3
1105	Hymenoptera	Ichneumonidae	Ophioninae	*Riekophion*	*bolus*		1			1
1743	Hymenoptera	Ichneumonidae	Pimplinae	*Lissopimla*	*excelsa*	1				1
87	Hymenoptera	Ichneumonidae	Tryphoninae			1	2	4	1	8
1165	Hymenoptera	Ichneumonidae	Tryphoninae				1		4	5
1038	Hymenoptera	Ichneumonidae	Tryphoninae			1				1
4047	Hymenoptera	Mutillidae					2		1	3
4066	Hymenoptera	Mutillidae				1	11	2	1	15
2536	Hymenoptera	Mutillidae				1				1
4067	Hymenoptera	Mutillidae				2				2
4068	Hymenoptera	Mutillidae						2	1	3
580	Hymenoptera	Mutillidae							1	1
1550	Hymenoptera	Pergidae	Perginae	*Perga*	*klugii*			1		1
1601	Hymenoptera	Pompilidae				4	2		1	7
4075	Hymenoptera	Pompilidae				1				1
4061	Hymenoptera	Pompilidae					1	1	2	4
1017	Hymenoptera	Pompilidae						1		1
3344	Hymenoptera	Pompilidae					2			2
4073	Hymenoptera	Pompilidae					2	2	2	6
4074	Hymenoptera	Pompilidae					1			1
4063	Hymenoptera	Pompilidae				3				3
4064	Hymenoptera	Pompilidae					1	1		2
4065	Hymenoptera	Pompilidae				3				3
4070	Hymenoptera	Pompilidae					1	1		2
611	Hymenoptera	Pompilidae				4	9	3	8	24
612	Hymenoptera	Pompilidae				9	15	15	5	44
1781	Hymenoptera	Pompilidae	Pepsinae	*Chirodamini ?*			1			1
4062	Hymenoptera	Scoliidae ?				5	1			6
1371	Hymenoptera	Sphecidae							1	1
3666	Hymenoptera	Tiphiidae					1			1
3286	Hymenoptera	Tiphiidae					2			2
4052	Hymenoptera	Tiphiidae						1		1
3545	Hymenoptera	Tiphiidae					1			1
2060	Hymenoptera	Tiphiidae					1			1
3196	Hymenoptera	Tiphiidae	Thyninnae					1		1
4016	Hymenoptera	Tiphiidae	Thyninnae				3			3
699	Hymenoptera	Tiphiidae	Thyninnae	*Eirone*	sp		1			1
2024	Hymenoptera	Tiphiidae	Thyninnae	*Tmesothynnus*	sp		2			2
1989	Hymenoptera	Tiphiidae	Thyninnae	*Tmesothynnus*	sp		1			1
4045	Hymenoptera	Tiphiidae	Thynninae				1			1
4039	Hymenoptera	Tiphiidae	Thynninae					1		1
1982	Hymenoptera	Tiphiidae	Thynninae	*Aeolothynnus*	sp		1	1		2
3632	Hymenoptera	Tiphiidae	Thynninae	*Dimorphothynnus*	sp		1			1
2416	Isopoda							1		1
544	Isopoda					2	5	1	3	11
549	Isopoda					5				5

Sp.#	Order	Family	Tax 3	Genus	Species	Treatment				Total
						FCS	ER	GR	SW	
1305	Isopoda					1	3			4
1430	Isopoda					5			1	6
519	Isopoda		collective			1				1
539	Isopoda					2	1	1		4
3946	Lepidoptera					2	2		1	5
3954	Lepidoptera					1				1
3959	Lepidoptera							2		2
4042	Lepidoptera							3	1	4
3949	Lepidoptera							3	2	5
3953	Lepidoptera						1			1
3952	Lepidoptera						1			1
1627	Lepidoptera	Anthelidae					1	2	1	4
755	Lepidoptera	Anthelidae					1	2	1	4
381	Lepidoptera	Anthelidae	Anthelinae	*Anthela*	sp		3			3
6	Lepidoptera	Arctiidae				12		2		14
376	Lepidoptera	Arctiidae	Lithosiinae	*Castulo*	*doubledayi*		7		1	8
2924	Lepidoptera	Arctiidae	Lithosiinae	*Scoliacma*	aff. *nana*		2			2
366	Lepidoptera	Arctiidae	Lithosiinae	*Scoliacma*	sp	1				1
3426	Lepidoptera	Arctiidae	Lithosiinae	*Threnosia ?*					2	2
1	Lepidoptera	Carthaeidae		*Carthaea*	*saturnioides*	4				4
324	Lepidoptera	Depressariidae				1				1
658	Lepidoptera	Gelechiidae ?				1				1
2637	Lepidoptera	Geometridae							1	1
3494	Lepidoptera	Geometridae							2	2
2891	Lepidoptera	Geometridae					2	1		3
3116	Lepidoptera	Geometridae				1				1
2703	Lepidoptera	Geometridae					2			2
1034	Lepidoptera	Geometridae							2	2
382	Lepidoptera	Geometridae				5		1	1	7
753	Lepidoptera	Geometridae					3			3
441	Lepidoptera	Geometridae				1		4	3	8
776	Lepidoptera	Geometridae				1				1
323	Lepidoptera	Geometridae	Ennominae				2			2
387	Lepidoptera	Geometridae	Ennominae						1	1
66	Lepidoptera	Geometridae	Ennominae			2		2	1	5
1876	Lepidoptera	Geometridae	Ennominae					1		1
345	Lepidoptera	Geometridae	Ennominae			2	1			3
694	Lepidoptera	Geometridae	Ennominae					1		1
691	Lepidoptera	Geometridae	Ennominae			2		8	5	15
47	Lepidoptera	Geometridae	Ennominae			2				2
754	Lepidoptera	Geometridae	Ennominae				1			1
24	Lepidoptera	Geometridae	Ennominae				3		1	4
85	Lepidoptera	Geometridae	Ennominae				4			4
383	Lepidoptera	Geometridae	Ennominae				2			2
387	Lepidoptera	Geometridae	Ennominae						1	1
422	Lepidoptera	Geometridae	Ennominae			3		1	1	5
326	Lepidoptera	Geometridae	Ennominae			2	13	8	10	33
986	Lepidoptera	Geometridae	Ennominae	*Capusa*	sp	1				1
436	Lepidoptera	Geometridae	Ennominae	*Casbia ?*		10	1	4	2	17
50	Lepidoptera	Geometridae	Ennominae	*Euphronarcha ?*			1			1
77	Lepidoptera	Geometridae	Ennominae	*Gastrinodes*	sp	1	4	1	1	7
638	Lepidoptera	Geometridae	Ennominae	*Melanodes*	sp	1				1
403	Lepidoptera	Geometridae	Ennominae	*Melanodes*	sp	2				2
758	Lepidoptera	Geometridae	Ennominae	*Melanodes*	sp	7	96	2	6	111

Sp.#	Order	Family	Tax 3	Genus	Species	Treatment				Total
						FCS	ER	GR	SW	
858	Lepidoptera	Geometridae	Ennominae	*Stibaroma*	*melanotoxa*	5	3			8
19	Lepidoptera	Geometridae	Geometrinae	*Chlorocoma*	*dicloraria*		1	1	1	3
22	Lepidoptera	Geometridae	Geometrinae	*Chlorocoma*	*sp*	1	1		1	3
330	Lepidoptera	Geometridae	Geometrinae	*Crypsiphona*	*ocultaria*	1				1
393	Lepidoptera	Geometridae	Geometrinae	*Prasinocyma*	*sp*	1				1
41	Lepidoptera	Geometridae	Larentiinae			1				1
646	Lepidoptera	Geometridae	Larentiinae			10		1		11
652	Lepidoptera	Geometridae	Larentiinae			1		1		2
317	Lepidoptera	Geometridae	Larentiinae						1	1
83	Lepidoptera	Geometridae	Larentiinae			1		2		3
95	Lepidoptera	Geometridae	Larentiinae			2	1	2		5
42	Lepidoptera	Geometridae	Larentiinae	*Xanthorhoe*	sp	3				3
3438	Lepidoptera	Geometridae	Oenochrominae				1			1
957	Lepidoptera	Geometridae	Oenochrominae			1				1
1516	Lepidoptera	Geometridae	Oenochrominae				1			1
411	Lepidoptera	Geometridae	Oenochrominae			1	12	7	1	21
631	Lepidoptera	Geometridae	Oenochrominae	*Arcina*	*fulgorigera*	28	2	1		31
2	Lepidoptera	Geometridae	Oenochrominae	*Arhodia*	*lasiocamparia*		2			2
837	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*ioneura*		6	1	1	8
661	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*orthotis*	1				1
1031	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	sp		3			3
67	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	sp	2	7	4	3	16
1659	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	sp		2			2
2639	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	sp	1				1
1155	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	sp			1	2	3
48	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	sp	2	1	5	2	10
425	Lepidoptera	Geometridae	Oenochrominae	*Epidesmia ?*			1			1
392	Lepidoptera	Geometridae	Oenochrominae	*Epidesmia ?*		3	6		2	11
1171	Lepidoptera	Geometridae	Oenochrominae	*Hypographa*	*aristarcha*		1	1	1	3
2119	Lepidoptera	Geometridae	Oenochrominae	*Nearcha ?*			1			1
861	Lepidoptera	Geometridae	Oenochrominae	*Nearcha ?*		5	4	1		10
31	Lepidoptera	Geometridae	Oenochrominae	*Oenochroma*	sp	1	2			3
72	Lepidoptera	Geometridae	Oenochrominae	*Oenochroma*	sp	2				2
377	Lepidoptera	Geometridae	Oenochrominae	*Phallaria*	*ophiusaria*	1	3		1	5
3948	Lepidoptera	Hepialidae							1	1
373	Lepidoptera	Hepialidae		*Abantiades*	*ocellatus*		5			5
761	Lepidoptera	Hepialidae		*Abantiades*	sp		1			1
3998	Lepidoptera	Hesperiidae				1	1			2
1832	Lepidoptera	Lasiocampidae				1	1			2
380	Lepidoptera	Lasiocampidae					1		2	3
1625	Lepidoptera	Limacodidae		*Doratifera*	sp		1			1
332	Lepidoptera	Limacodidae		*Doratifera*	sp	1				1
398	Lepidoptera	Limacodidae		*Doratifera*	sp	1	1			2
81	Lepidoptera	Limacodidae		*Doratifera*	sp	2	1			3
80	Lepidoptera	Lymantriidae				3	1			4
556	Lepidoptera	Noctuidae				1				1
3951	Lepidoptera	Noctuidae				1				1
38	Lepidoptera	Noctuidae							1	1
140	Lepidoptera	Noctuidae					1			1
407	Lepidoptera	Noctuidae					2			2
379	Lepidoptera	Noctuidae	Acronictinae	*Peripyra*	*sanguinipucta*		1			1
996	Lepidoptera	Noctuidae	Amphipyrinae				1			1
2917	Lepidoptera	Noctuidae	Amphipyrinae			1				1
394	Lepidoptera	Noctuidae	Amphipyrinae				1			1

Sp.#	Order	Family	Tax 3	Genus	Species	Treatment FCS	ER	GR	SW	Total
452	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*epiplecta*	1				1
770	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*melanographa ?*	14				14
3457	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*oxygona ?*			1		1
39	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*pissonephra*	62	45	23	17	147
388	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*poliocrossa*	1	7	1	6	15
1899	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	sp	5	16	2	3	26
523	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	sp		13	6	1	20
3220	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	sp		5		15	20
1898	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	sp		1			1
414	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	sp			5		5
859	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	sp		1			1
799	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	sp	1	9	3		13
833	Lepidoptera	Noctuidae	Catocalinae				1			1
5	Lepidoptera	Noctuidae	Catocalinae	*Pantydia*	sp	2				2
329	Lepidoptera	Noctuidae	Catocalinae	*Pantydia*	*sparsa*	2			1	3
344	Lepidoptera	Noctuidae	Catocalinae	*Praxis*	sp			2		2
25	Lepidoptera	Noctuidae	Hadeninae				1			1
766	Lepidoptera	Noctuidae	Hadeninae	*Leucania*	sp			1		1
139	Lepidoptera	Noctuidae	Heliothinae	*Helicoverpa*	sp		1		1	2
642	Lepidoptera	Noctuidae	Heliothinae	*Helicoverpa*	sp		1			1
336	Lepidoptera	Noctuidae	Heliothinae	*Helicoverpa*	sp		1	2		3
43	Lepidoptera	Noctuidae	Hypeninae	*Sandava*	*scitisigna*	1	6	6	4	17
419	Lepidoptera	Noctuidae	Noctuinae				1			1
18	Lepidoptera	Noctuidae	Noctuinae	*Agrotis*	*infusa*	2		1		3
18	Lepidoptera	Noctuidae	Noctuinae	*Agrotis*	*infusa*	2		1		3
649	Lepidoptera	Noctuidae	Noctuinae	*Agrotis*	*munda ?*		2			2
686	Lepidoptera	Nolidae	Nolinae	*Uraba*	*lugens*		1	1	1	3
656	Lepidoptera	Notodontidae		*Antimima*	sp		4			4
4	Lepidoptera	Notodontidae		*Destolmia*	sp		1		1	2
76	Lepidoptera	Notodontidae		*Gallaba*	sp				1	1
1081	Lepidoptera	Notodontidae		*Gallaba*	sp		1			1
2893	Lepidoptera	Notodontidae		*Gallaba*	sp			1		1
750	Lepidoptera	Notodontidae						1	1	2
3	Lepidoptera	Notodontidae	Thaumetopoeinae	*Epicoma*	sp		4		1	5
594	Lepidoptera	Nymphalidae	Nymphalinae	*Vanessa*	*kershawi*	13	4	1	1	19
1840	Lepidoptera	Oecophoridae					3	6	2	11
64	Lepidoptera	Oecophoridae				1				1
62	Lepidoptera	Oecophoridae				13				13
92	Lepidoptera	Oecophoridae	Oecophorinae			44	5	9	6	64
374	Lepidoptera	Oenosandridae				8	48	3	4	63
864	Lepidoptera	Psychidae?				2	10	8	11	31
333	Lepidoptera	Pyralidae				5	6	4	1	16
63	Lepidoptera	Pyralidae				34				34
1134	Lepidoptera	Pyralidae					9		3	12
1489	Lepidoptera	Pyralidae						1		1
1051	Lepidoptera	Pyralidae				43	2	1		46
1491	Lepidoptera	Pyralidae							3	3
3108	Lepidoptera	Pyralidae					1			1
1815	Lepidoptera	Pyralidae				1				1
3491	Lepidoptera	Pyralidae				1				1
356	Lepidoptera	Pyralidae					1			1
342	Lepidoptera	Pyralidae				16			2	18
397	Lepidoptera	Pyralidae	Crambidae				4		1	5
2884	Lepidoptera	Pyralidae	Crambinae	*Hednota*	sp				2	2

Sp.#	Order	Family	Tax 3	Genus	Species	Treatment				Total
						FCS	ER	GR	SW	
460	Lepidoptera	Pyralidae	Epipaschiinae			1	1	4		6
1126	Lepidoptera	Pyralidae	Epipaschiinae			1	1			2
73	Lepidoptera	Pyralidae	Epipaschiinae ?			7				7
322	Lepidoptera	Pyralidae	Nymphulinae	*Nymphula*	*nitens*	26	16	3	6	51
1628	Lepidoptera	Pyralidae	Pyraustinae				1			1
84	Lepidoptera	Pyralidae	Pyraustinae	*Uresiphita*	*ornithopteralis*	5	1	1		7
1910	Lepidoptera	Pyralidae ?					1			1
2446	Lepidoptera	Pyralidae ?					2			2
3221	Lepidoptera	Pyralidae ?						1		1
12	Lepidoptera	Pyralidae ?				2		1		3
3415	Lepidoptera	Pyralidae ?				1	1			2
328	Lepidoptera	Saturniidae		*Opodiphthera*	*helena*		3		2	5
319	Lepidoptera	Tineidae	Myrmecozelinae	*Moerarchis*	*clathrella*	7	1			8
943	Lepidoptera	Tortricidae					1			1
1814	Lepidoptera	Tortricidae ?					1			1
1172	Lepidoptera			*unidentifiable*	*unidentifiable*	17	25	5	19	66
2719	Lepidoptera	Xyloryctidae	Xyloryctinae			2	1			3
316	Lepidoptera	Xyloryctidae ?				21	12	8	5	46
45	Lepidoptera	Zygaenidae		*Pollanisus*	*cupreus*	1	60	36	26	123
78	Lepidoptera	Zygaenidae		*Pollanisus*	*sp*	12	343	372	356	1083
1459	Mantodea	Mantidae					1		1	2
3813	Mantodea	Mantidae					3	2		5
3833	Mantodea	Mantidae					1			1
718	Mantodea	Mantidae					1			1
1463	Mecoptera	Bittacidae		*Harpobittacus*	*quasisimilis*		5	3	6	14
89	Mecoptera	Meropeidae		*Austromerope*	*poultoni*	1				1
3381	Mygalomorphae						1			1
3339	Mygalomorphae							1		1
4071	Mygalomorphae	Barychelidae							1	1
4058	Mygalomorphae	Idiopidae						1		1
3162	Mygalomorphae	Nemesiidae				4				4
1792	Mygalomorphae	Nemesiidae					1			1
887	Mygalomorphae	Nemesiidae				1				1
581	Mygalomorphae	Nemesiidae		*Chenistonia*	sp	5				5
585	Mygalomorphae	Nemesiidae					1			1
2054	Neuroptera	Chrysopidae							1	1
2715	Neuroptera	Chrysopidae					1			1
822	Neuroptera	Chrysopidae		*Chrysopa*	sp	5	2		1	8
360	Neuroptera	Hemerobiidae				15	1			16
400	Neuroptera	Osmylidae					1			1
237	Odonata	Lestidae	Lestoidea	*Austrolestes*	*analis*	1				1
4053	Oligochaeta	Megascolecidae						2		2
4056	Oligochaeta	Megascolecidae						1		1
4060	Oligochaeta	Megascolecidae				1				1
4049	Oligochaeta	Megascolecidae							1	1
4050	Oligochaeta	Megascolecidae							1	1
4048	Oligochaeta	Megascolecidae					1			1
4035	Oligochaeta	Megascolecidae					2			2
4015	Oligochaeta	Megascolecidae							2	2
4044	Oligochaeta	Megascolecidae							1	1
4043	Oligochaeta	Megascolecidae					4			4
4017	Oligochaeta	Megascolecidae					4			4
937	Onychophora					2				2
1619	Orthoptera	Acrididae					1			1

Sp.#	Order	Family	Tax 3	Genus	Species	Treatment				Total
						FCS	ER	GR	SW	
1976	Orthoptera	Acrididae						2		2
2031	Orthoptera	Acrididae					2		1	3
2191	Orthoptera	Acrididae					1			1
2133	Orthoptera	Acrididae					1			1
174	Orthoptera	Acrididae				1	1		1	3
782	Orthoptera	Acrididae					3	2	2	7
738	Orthoptera	Acrididae				1	1		1	3
868	Orthoptera	Acrididae	Catantopinae	*Adreppus*	sp		1			1
1323	Orthoptera	Acrididae	Catantopinae	*Adreppus*	sp			1	1	2
890	Orthoptera	Acrididae	Catantopinae	*Cedarinia*	sp	6	4		2	12
231	Orthoptera	Acrididae	Catantopinae	*Coryphistes*	sp		4	1	1	6
235	Orthoptera	Acrididae	Catantopinae	*Goniaea*	sp	1	3	1		5
872	Orthoptera	Acrididae	Catantopinae	*Goniaea*	sp	1	3			4
871	Orthoptera	Acrididae	Catantopinae	*Goniaea*	sp		2			2
1547	Orthoptera	Acrididae	Catantopinae	*Goniaea*	sp			1		1
1984	Orthoptera	Acrididae	Catantopinae	*Goniaea*	sp		6	1	4	11
1470	Orthoptera	Acrididae	Catantopinae	*Goniaea*	sp		1		1	2
2682	Orthoptera	Acrididae	Catantopinae	*Goniaea*	sp		1			1
1441	Orthoptera	Acrididae	Catantopinae	*Goniaea*	sp	1		1		2
232	Orthoptera	Acrididae	Catantopinae	*Goniaea*	*vocans?*		2	3	2	7
293	Orthoptera	Acrididae	Catantopinae	*Phaulacridium*	*crassum*		1			1
3436	Orthoptera	Acrididae	Catantopinae	*Phaulacridium*	*vittatum*				1	1
1762	Orthoptera	Acrididae	Catantopinae	*Phaulacridium*	*vittatum ?*				1	1
3805	Orthoptera	Gryllidae				1		9		10
2587	Orthoptera	Gryllidae					1			1
4072	Orthoptera	Gryllidae							1	1
3780	Orthoptera	Gryllidae				4	5	6	10	25
3585	Orthoptera	Gryllidae							1	1
1916	Orthoptera	Gryllidae		*Teleogryllus*	*commodus*	25				25
609	Orthoptera	Gryllidae							1	1
809	Orthoptera	Gryllidae					2			2
180	Orthoptera	Gryllidae					1		2	3
608	Orthoptera	Gryllidae					1			1
524	Orthoptera	Stenopelmatidae				6				6
1582	Orthoptera	Stenopelmatidae				18				18
3530	Orthoptera	Stenopelmatidae							1	1
672	Orthoptera	Stenopelmatidae				12				12
526	Orthoptera	Stenopelmatidae	Henicinae	*Onosandrus*	sp	6		3		9
3809	Orthoptera	Tettigoniidae						1	1	2
4034	Orthoptera	Tettigoniidae				4				4
2936	Orthoptera	Tettigoniidae					1			1
688	Orthoptera	Tettigoniidae		*Pachysaga*	sp		1			1
485	Orthoptera	Tettigoniidae	Phaneropterinae	*Caedicia*	sp	1				1
303	Phasmatodea	Phasmatidae							1	1
3869	Platyhelminthes						1			1
3164	Platyhelminthes					1				1
1568	Platyhelminthes	Tricladida					1	18		19
1404	Platyhelminthes	Tricladida				3	27	4	27	61
521	Platyhelminthes	Tricladida					21			21
3840	Scorpionida							3	1	4
1451	Scorpionida								1	1
2693	Scorpionida					1				1
568	Scorpionida					2			2	4
469	Scorpionida						2	2		4

Sp.#	Order	Family	Tax 3	Genus	Species	Treatment				Total
						FCS	ER	GR	SW	
4040	Trichoptera					3	2	10	5	20
2904	Trichoptera	Hydropsychidae				1				1
1852	Trichoptera	Hydropsychidae					1	3		4
145	Trichoptera	Hydropsychidae				4	3	2	2	11
144	Trichoptera	Hydropsychidae				8	13	8	8	37
752	Trichoptera	Polycentropodidae					1			1

DIURNAL AND NOCTURNAL BIRDS

Graeme Liddelow 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.* 1988). 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; and .
- analysing trends within species between treatments.

Field survey

Bird surveys were conducted on seven FORESTCHECK monitoring grids in the Wilga vegetation complex in the Sandy Basins ecosystem in Blackwood District and three in the Dwellingup 1 vegetation complex in the Jarrah North West ecosystem in the Perth Hills District. The grids included three external reference (FC57, FC60, FC63), two shelterwood (FC58, FC61) and two gap release grids (FC59, FC62) in the in the Sandy Basins ecosystem and three fire chronosequence grids (FC24, FC64 and FC65) in uncut forest near Dwellingup in the Jarrah North West ecosystem. Time since fire on the Dwellingup grids was nine (FC64 Plavins block), 39 (FC24 Kennedy block) and 81 years (FC65 Amphion block).

Birds were identified by both sight and sound and census techniques are detailed in the FORESTCHECK Operating Plan (DEC 2006). Briefly, for diurnal birds each grid was monitored five times during the spring of 2014, with at least seven days between each census. Monitoring commenced at sunrise and continued for four hours after sunrise in fine still weather. The central one hectare area at each grid is monitored for 20 minutes before moving on to the next grid.

Preliminary results and discussion

Sandy Basins

Diurnal birds

A total of 36 species of birds comprising 679 individuals were recorded. Seventeen species were recorded 10 or more times (Table 2). Similar numbers of species were recorded in each treatment, but the shelterwood treatment recorded the highest number of individuals and gap release the lowest. Twenty seven species (232 individuals) were recorded in the external reference, 25 (272 individuals) in the shelterwood and 22 (175 individuals) in the gap release treatment.

Eleven species were recorded in only one treatment (either external reference, shelterwood or gap release) (Table 1). However, none would be expected to be restricted to that particular treatment. Although there appeared to be adequate nesting and feeding sites at or in close proximity to each monitored area, the forest red-tailed black cockatoo was only recorded in the gap release grid at Hunt block (FC62).

Table 1. Species list and the number of records of each species in each treatment in the Sandy Basins FORESTCHECK grids in 2014

RAOU No.	Name	Common Name	Treatment[1] ER	SW	GR	Total
35	*Phaps elegans*	Brush bronzewing	1			1
259	*Parvipsitta porphyrocephala*	Purple-crowned lorikeet		3		3
264	*Calyptorhynchus banksii naso*	Forest red-tailed black cockatoo			4	4
266	*Calyptorhynchus baudinii*	Baudins cockatoo	2		3	5
289	*Platycercus icterotis*	Western rosella		6		6
290	*Platycercus spurius*	Red-capped parrot	5	8	9	22
294	*Platycerus zonarius*	Australian ringneck	16		5	21
307	*Neophema elegans*	Elegant parrot	2			2
322	*Dacelo novaeguineae*	Laughing kookaburra	3		1	4
337	*Cacomantis pallidus*	Pallid cuckoo	1		1	2
338	*Cacomantis flabelliformis*	Fan-tailed cuckoo	4	8	2	14
342	*Chrysococcyx basalis*	Horsfield's bronze cuckoo			1	1
344	*Chrysococcyx lucidus*	Shining bronze cuckoo	2	5	5	12
361	*Rhipidura albiscapa*	Grey fantail	7	10	15	32
380	*Petroica boodang*	Scarlet robin	9	3	4	16
394	*Eopsaltria austrakis griseogularis*	Western yellow robin	9	4	5	18
398	*Pachycephala occidentalis*	Western golden whistler	11	19	12	42
408	*Colluricincla harmonica*	Grey shrike-thrush	12	11	15	38
424	*Coracina novaehollandiae*	Black-faced cuckoo-shrike			2	2
463	*Gerygone fusca*	Western gerygone	22	16	12	50
472	*Acanthiza inornata*	Western thornbill		4		4
476	*Acanthiza apicalis*	Broad-tailed (Inland) thornbill	35	28	26	89
486	*Acanthiza chrysorrhoa*	Yellow-rumped thornbill	1			1
488	*Sericornis frontalis*	White-browed scrubwren	2	7	4	13
532	*Malurus splendens*	Splendid Fairy-wren	3	5	5	13
538	*Malurus elegans*	Red-winged fairy-wren		2		2
549	*Daphoenositta chrysoptera*	Varied sittella		6		6
556	*Climacteris rufus*	Rufous treecreeper	3	3		6
565	*Pardalotus punctatus*	Spotted Pardalote	14	8	7	29
574	*Zosterops lateralis*	Grey-breasted white-eye /.Silvereye	3	2		5
578	*Melithreptus chloropsis*	Western white-naped honeyeater	17	32	2	51
592	*Acanthorhynchus superciliosus*	Western spinebill	1	1		2
638	*Anthochaera carunculata*	Red wattlebird				0
705	*Cracticus tibicen*	Australian magpie	8	9		17
930	*Corvus coronoides*	Australian raven	3	4		7
976	*Pardalotus striatus*	Striated pardalote	36	68	35	139
	Total number of species		27	25	22	36
	Total number of individuals		232	272	175	679

[1] ER = external reference, SW = shelterwood, GR = gap release.

Four species of bird were recorded 50 times or more. The most common was the striated pardalote (*Pardalotus striatus*) with 139 individuals; with almost twice as many individuals recorded in the shelterwood than both the external reference and gap release treatments. Others were the broad-tailed thornbill (*Acanthiza* apicalis) with 89 individuals; the western white-naped honeyeater (*Melithreptus chlorospsis*) with 51 and the western gerygone (*Gerygone fusca*) with 50. Six other species were recorded 20 times or more; the western golden whistler (*Pachycephala occidentalis*) 42, the grey shrike-thrush (*Colluricincla* *harmonica*) 38, the grey fantail (*Rhipidura albiscapa*) 32, spotted pardalote (*Pardalotus punctatus*) 29, red capped parrot (*Platycerus spurius*) 22, and the Australian ringneck (*Platycerus zonarius*) 21. Overall these 10 species accounted for over 75% of the total individuals recorded (513 of 679).

Although low in numbers, both the scarlet robin (*Petroica boodang*) and the western yellow robin (*Eopsaltria australis griseogularis*) were more common in external reference grids. Both birds generally prefer the more open understory found on reference grids than the denser shrub structure found on harvested grids.

Six different leaf gleaning and trunk and branch feeding species were recorded; the western gerygone, broad-tailed thornbill, varied sittella (*Daphoenositta chrysoptera*), rufous treecreeper (*Climacteris rufa*) and the spotted and striated pardalotes. Five species of scrub bird were recorded including the scarlet and western yellow robins, white-browed scrubwren (*Sericornis frontalis*) and both splendid (*Malurus splendens*) and red-winged fairy-wrens (*Malurus elegans*). Four species of mid canopy birds; the grey fantail, golden whistler, grey shrike-thrush and grey-breasted white-eye (*Zosterops lateralis*), recorded a total of 117 individuals. Only two species of honeyeater were recorded; the western white-naped honeyeater with 51 individuals and the western spinebill (*Acanthorhynchus superciliosus*) with 2 individuals. Six species of parrots were recorded. The most common were the red-capped parrot with 22 individual records and the Australian ringneck with 21.

The mean density of birds across all grids was 19.4 birds ha^{-1} with densities of 15.5 in the external reference, 27.2 in the shelterwood and 17.5 in the gap release treatments (Fig. 1).

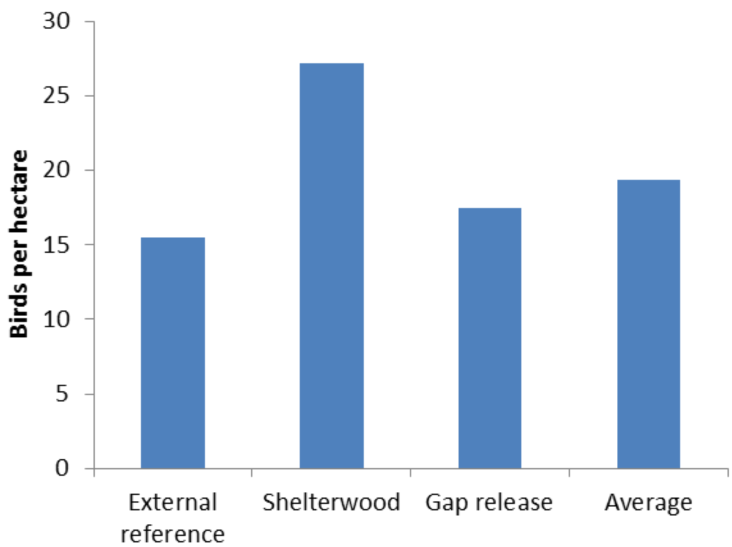


Figure 1. Bird densities recorded in each treatment and the overall average in the Sandy Basins FORESTCHECK monitoring grids in 2014

The average density of birds in the Sandy Basins grids is higher than that found in the southern jarrah forest region where the yearly average recorded in the long-term Kingston Study (see Abbott *et al.* 2003, 2009) is 10.4 birds ha^{-1} (Liddelow, unpublished). Three species account for the high density in the shelterwood treatment; the striated pardalote, the western white-naped honeyeater, and the western golden whistler which collectively had twice as many records in the shelterwoood than in both the external reference and gap release treatments (Table 1).

Nocturnal birds
Due to constraints on time and personnel, no systematic survey of nocturnal birds was undertaken in 2014. However, studies by Liddelow *et al.* (2002) would suggest that most species of nocturnal birds should be encountered in the Sandy Basins ecosystem.
Three tawny frogmouths (*Podargus strigoides*) were seen during the day whilst carrying out mammal trapping activities; one at Hunt shelterwood grid, one at Jolly external reference grid and one in the Wilga shelterwood grid. Two southern boobook owls (*Ninox boobook boobook)* were also seen during mammal trapping; one in the Wilga gap release grid and one in the Hunt external reference grid.

Fire cronosequence grids, Dwellingup
Diurnal birds
A total of 32 species of birds comprising 275 individuals were recorded at the Dwellingup fire chronosequence grids. Time since fire did not appear to influence the number of birds in each grid. Overall, there were 19 species (88 individuals) in FC65 Amphion block (81 years since fire), 22 species (108 individuals) in FC24 Kennedy block (39 years since fire) and 20 species (79 individuals) in FC64 Plavins block (9 years since fire). There was a slightly higher number of individuals recorded in FC24 Kennedy block.

Eleven species of birds were recorded in only one treatment (Table 1). However, none would be expected to be restricted to that particular treatment. Four species of birds were recorded 20 times or more; the broad-tailed thornbill (*Acanthiza* apicalis) with 33 individuals, the striated pardalote (*Pardalotus striatus*) 26, the western spinebill (*Acanthorhynchus superciliosus*) 22 and the western gerygone (*Gerygone fusca*) 20. Eight species were recorded 10 times or more; the scarlet robin (*Petroica boodang*) with 11 individuals, the western yellow robin (*Eopsaltria australis griseogularis*) 15, the western golden whistler (*Pachycephala occidentalis*), the grey shrike-thrush (*Colluricincla harmonica*) 10, the western thornbill (*Acanthiza* inornata) 19, the white-browed scrub-wren (*Sericornis frontalis*) 10, the varied sittella (*Daphoenositta chrysoptera*) 13, the grey breasted white-eye (*Melithreptus chloropsis*)19 and the red wattlebird (*Anthochaera carunculata*) with 16 individuals. Overall these 13 species accounted for almost 84% of the total individuals recorded (230 of 275).

Seven different leaf gleaning and trunk and branch feeding species were recorded; the western gerygone, western and broad-tailed thornbill, varied sittella, rufous treecreeper (*Climacteris rufa*) and the striated and spotted pardalote (*Pardalotus punctatus*). Five species of scrub birds; the scarlet and western yellow robins, the white-browed scrubwren, and the splendid (*Malurus splendens*) and red-winged fairy-wrens (*Malurus elegans*) and four species of mid canopy birds: the grey fantail (*Rhipidura albiscapa*), western golden whistler, grey shrike-thrush and the grey-breasted white-eye were also recorded. There were 38 individual records, but only two species of honeyeater recorded, the western spinebill and the red wattlebird. Four species of parrots, but only 11 individuals were recorded; none of which were recorded more than five times.

Table 2. Species list and the number of birds in each treatment at Dwellingup in 2014

RAO U No.	Name	Common Name	FC65 Ampion	FC24 Kennedy	FC64 Plavins	Total
35	*Phaps elegans*	Brush Bronzewing	1			1
264	*Calyptorhynchus banksii naso*	Forest red-tailed black cockatoo		4		4
289	*Platycercus icterotis*	Western rosella		2		2
290	*Platycercus spurius*	Red-capped parrot		3		3
294	*Platycerus zonarius*	Australian ringneck			2	2
322	*Dacelo novaeguineae*	Laughing kookaburra	2	1		3
329	*Merops ornatus*	Rainbow bee-eater			4	4
337	*Cacomantis pallidus*	Pallid cuckoo		1		1
338	*Cacomantis flabelliformis*	Fan-tailed cuckoo		1		1
342	*Chrysococcyx basalis*	Horsfield's bronze cuckoo			2	2
344	*Chrysococcyx lucidus*	Shining bronze cuckoo		1	1	2
361	*Rhipidura fuliginosa*	Grey fantail	1	2	2	5
380	*Petroica boodang*	Scarlet robin		6	5	11
394	*Eopsaltria australis griseogularis*	Western yellow robin	5	6	4	15
398	*Pachycephala occidentalis*	Western golden whistler	7	6	3	16
408	*Colluricincla harmonica*	Grey shrike-thrush	3	4	3	10
424	*Coracina novaehollandiae*	Black-faced cuckoo-shrike		1		1
463	*Gerygone fusca*	Western gerygone	7	8	5	20
472	*Acanthiza inornata*	Western thornbill	5	10	4	19
476	*Acanthiza apicalis*	Broad-tailed (Inland) thornbill	8	13	12	33
488	*Sericornis frontalis*	White-browed scrubwren	8		2	10
532	*Malurus splendens*	Splendid fairy-wren	4	3		7
538	*Malurus elegans*	Red-winged fairy-wren	1			1
549	*Daphoenositta chrysoptera*	Varied sitella	12	1		13
556	*Climacteris rufus*	Rufous treecreeper	1		1	2
565	*Pardalotus punctatus*	Spotted pardalote	2		1	3
578	*Melithreptus chloropsis*	Grey-breasted white-eye Silvereye	2	10	7	19
592	*Acanthorhynchus superciliosus*	Western spinebill	6	8	8	22
638	*Anthochaera carunculata*	Red wattlebird	4	9	3	16
930	*Corvus coronoides*	Australian raven			1	1
976	*Pardalotus striatus*	Striated pardalote	9	8	9	26
						0
		Total number of species	19	22	20	32
		Total number of individuals	88	108	79	275

As with the total number of species and individuals, there was little difference in the density of birds between grids (Fig. 2). The average density of birds within the treatments was 18.3 birds ha^{-1}, which is almost twice the average yearly long-term density of 10.4 recorded in the southern jarrah forest region (Liddelow, unpublished) from the Kingston Study (see Abbott *et al.* 2003, 2009).

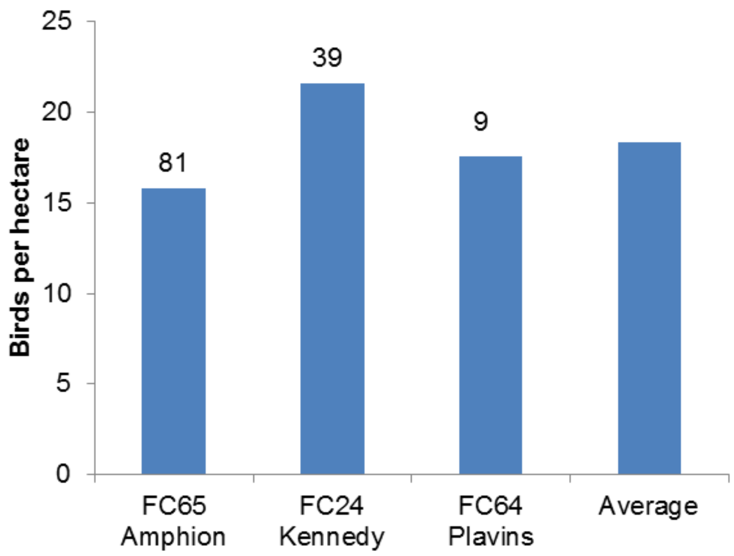


Figure 2. Bird densities recorded in each grid at Dwellingup in 2014

Nocturnal birds

Due to constraints on time and personnel, no systematic survey of nocturnal birds was undertaken in 2014. However, studies by Liddelow *et al.* (2002) would suggest that most species of nocturnal birds should be encountered at these Dwellingup locations.

Conclusions

Bird species composition and abundances change continuously as the understory density and fuel ages vary. These changes occur in harvested forest as the structure of understory vegetation and tree crown development changes over time; and in uncut forest as structural and successional changes occur in understory plants with time since fire. The composition of bird populations also change as a result of variation in plant flowering cycles.

Observations from monitoring bird populations in the Sandy Basins in 2014 include:

- Leaf gleaning, and branch and trunk feeding species made up the majority of individuals recorded during the survey period.
- Leaf gleaning species were similar across all treatments, likely due to the healthy crowns of trees in all treatments.
- Only two species of honeyeater were recorded during the survey period, which was likely due to the lack of plant species flowering, especially the banksias.
- Scarlet and western yellow robins were mostly recorded in the external reference grids, which have a more open understorey and less dense scrub layer than harvested grids.
- Although no nocturnal bird surveys were conducted, tawny frogmouths and boobook owls were sighted during other monitoring activities.

Observations from monitoring bird populations in the fire chronosequence grids near Dwellingup in 2014 are:

- Leaf gleaning, and branch and trunk feeding species made up the majority of individuals recorded during the survey period.
- Leaf gleaning species were generally similar over the three burn ages, likely due to the healthy crowns of the overstorey trees.

- The only species with 10 or more individuals recorded on each grid included; the varied sitella on the long unburnt (81 years) Amphion grid, three species, the western thornbill, broad-tailed thornbill and the grey-breasted white-eye on the intermediate (39 years) Kennedy grid, and the broad-tailed thornbill on the more recently burn (8 years) Plavins grid.
- Only two species of honeyeater were recorded during the survey period, which was likely due to the lack of plant species flowering, especially banksias.

References

Abbott, I. 1999. The avifauna of the forests of south-west Western Australia: changes in species composition, distribution, and abundance following anthropogenic disturbance. *CALMScience* Supplement 5, 1-175.

Abbott, I. Mellican, A., Craig, M.D., Williams, M., Liddelow, G. and Wheeler, I. 2003. Short-term logging and burning impacts on species richness, abundance and community structure of birds in open eucalypt forest in Western Australia. *Wildlife Research* 30, 321-329.

Abbott, I., Liddelow, G., Vellios, C., Mellican, A. and Williams, M. 2009. Monitoring bird populations after logging in forests of south-west Western Australia: an update from two long-term experimental research case studies. *Conservation Science Western Australia* 7, 301-347.

Catterall, C.P., Kingston, M.B., Park, K. and Sewell, S. 1998. Deforestation, urbanization and seasonality: Interacting effects on a regional bird assemblage. *Biological Conservation* 84, 65-81.

DEC 2006. *Monitoring Biodiversity in south-west forests: FORESTCHECK Operating Plan*. Department of Environment and Conservation, Kensington, WA.

Liddelow, G.L., Wheeler, I.B. and Kavanagh, R.P. 2002. Owls in the southwest forests of Western Australia. *In*: Newton, I., Kavanagh, R., Olsen, J. and Taylor, I. (eds.) *Ecology and Conservation of Owls*. CSIRO Publishing, Collingwood, Victoria, pp. 233-241.

Simpson, K and Day, N. 1993. *Field Guide to the Birds of Australia*, 4th Edition. Viking O'Neill, Ringwood, Victoria.

Western Australian Museum, 2015. *Checklist of the terrestrial vertebrate fauna of Western Australia*. http://museum.wa.gov.au/research/departments/terrestrial-zoology/checklist-terrestrial-vertebrate-fauna-western-australia.

MAMMALS AND HERPETOFAUNA

Graeme Liddelow 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 ratio and trap percentages between grids and treatments at each location and between FORESTCHECK locations;
- recording the presence of larger mammals along set transects that cover all treatments of the FORESTCHECK location on a landscape basis; and
- recording the presence of nocturnal mammals by spotlighting along set transects that cover all treatments of the FORESTCHECK location.

Field survey

Trapping of terrestrial vertebrates was conducted on seven FORESTCHECK monitoring grids in the Wilga vegetation complex in the Sandy Basins ecosystem in Blackwood District and three in the Dwellingup 1 vegetation complex in the Jarrah North West ecosystem in the Perth Hills District. The grids included three external reference (FC57, FC60, FC63), two shelterwood (FC58, FC61) and two gap release grids (FC59, FC62) in the in the Sandy Basins ecosystem and three fire chronosequence grids (FC24, FC64 and FC65) in forest near Dwellingup in the Jarrah North West ecosystem. Time since fire on the Dwellingup grids was nine (FC64 Plavins block), 39 (FC24 Kennedy block) and 81 years (FC65 Amphion block).

Trapping was conducted twice over four consecutive nights separated by one month in both autumn and spring. Protocols are outlined in the FORESTCHECK Operations Plan (DEC 2006). Briefly on each 2ha grid, 15 wire cage traps (20cm x 20cm x 45cm) were set-up in a 50m x 50m grid pattern and 15 20-litre pit fall traps (25cm dia. x 40cm deep) were installed in a 50m x 20m grid pattern (see grid layout on p. 5). In 2014 trapping sessions were conducted from 25–28 March and 6–9 May in autumn and 23–26 September and 4–7 November in spring. The external reference grid in Hunt block (FC63) was not trapped in spring due to it being prescribe burnt immediately prior to the trapping session.

Results and discussion

Sandy Basins

Trapping

Trapping sessions consisted of 3240 trap nights. This included 1620 trap nights for pit fall traps and 1620 trap nights for wire cages. The overall capture rate was 18.7 animals per night (cpn); 16.6 in autumn and 20.7 in spring (Fig. 1).

A total of 291 captures were recorded over the two sessions, 133 in autumn and 158 in spring. Seven species of mammals, 13 species of reptiles and five species of amphibians (all frogs) were recorded with total captures of 148, 85 and 58 respectively (Fig. 2).

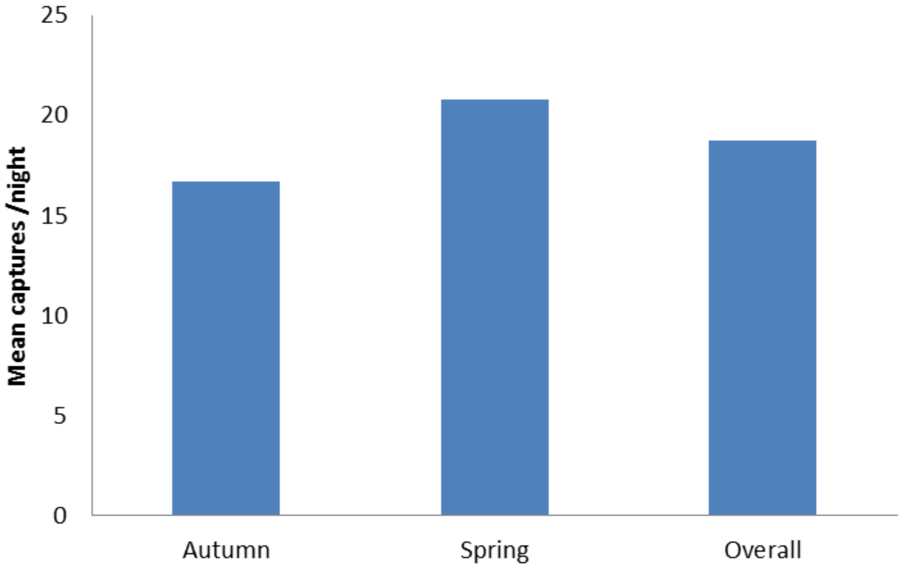


Figure 1. Mean number of animals captured per night on the Sandy Basins FORESTCHECK grids in 2014

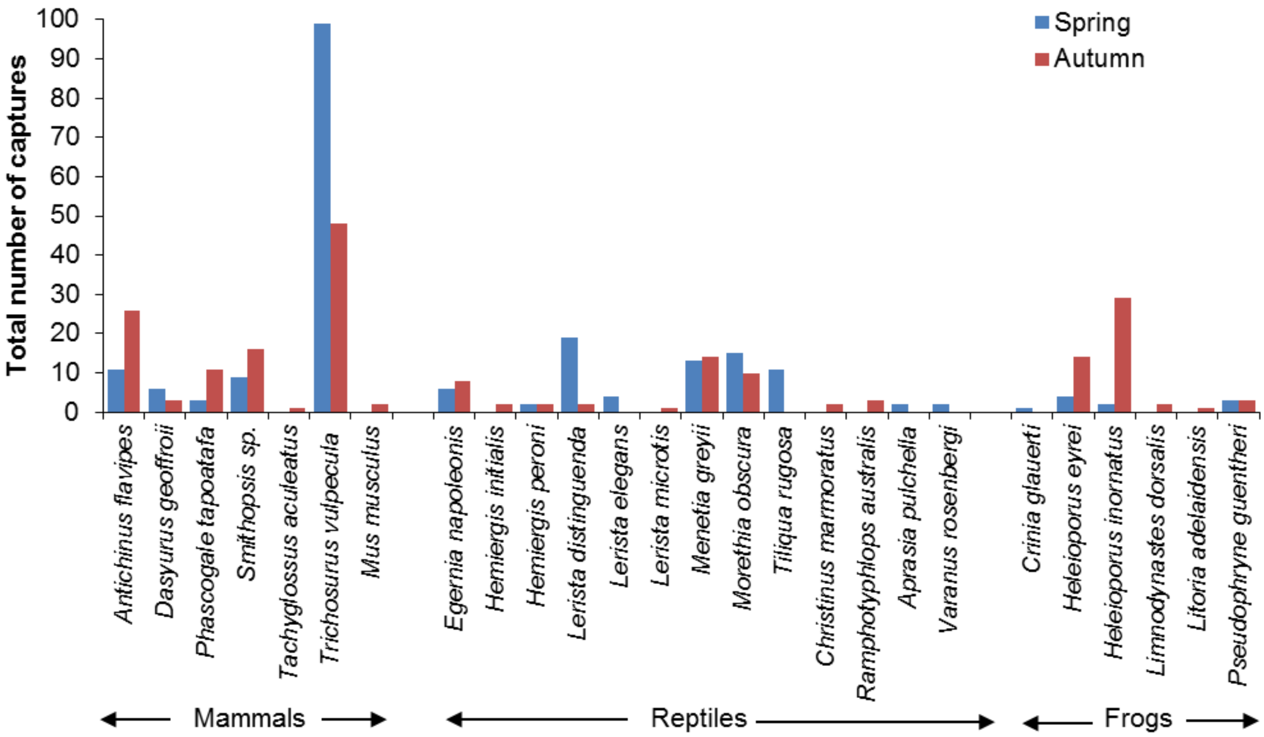


Figure 2. Total number of animals captured on the Sandy Basins FORESTCHECK grids in 2014

More mammals and reptiles captures were recorded in spring than autumn and more amphibian captures were recorded in autumn. Generally, more mammal and amphibian captures were recorded in external reference than in shelterwood and gap release treatments and more reptiles were recorded in the shelterwood and gap treatments in spring (Fig. 3).

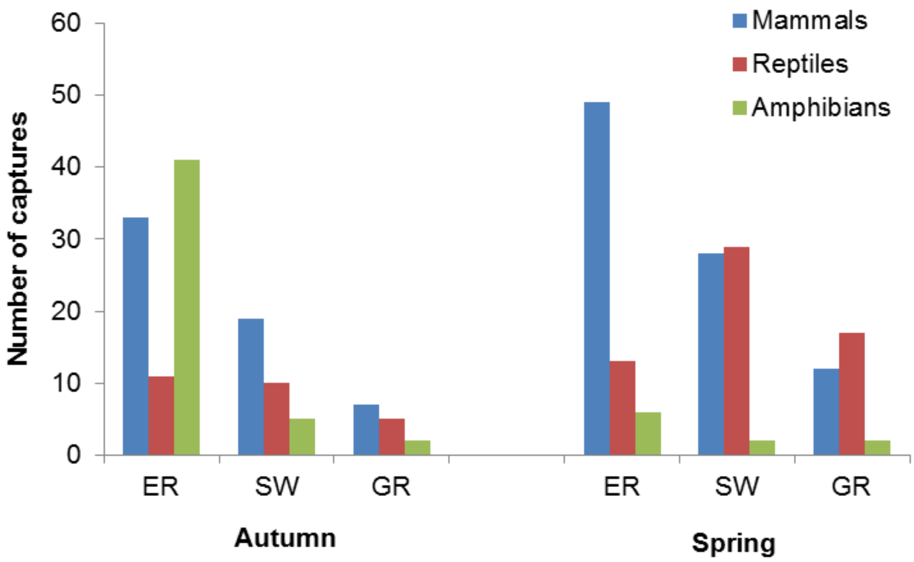


Figure 3. Total number of captures for mammals, reptiles and amphibians recorded in autumn and spring on Sandy Basins FORESTCHECK grids in 2014

The most captured mammal was the common brushtail possum (*Trichosurus vulpecula vulpecula*) with 20 individuals and 102 total captures; 27 of these captures were in autumn (13 individuals) and 75 in spring (15 individuals). The dunnart (*Sminthopsis sp.*) recorded 19 individuals and 25 captures, and the brush-tailed phascogale (*Phascogale tapoatafa tapoatafa*) recorded nine individuals and 11 captures (Table 1).

Sixty one possum captures were recorded in the external reference grids (10 individuals) and 41 in the silvicultural treatment areas including 6 in gap release (3 individuals) and 35 in shelterwood (7 individuals). Nine Sminthopsis (all individuals) captures were recorded in both external reference and gap release grids, and five (four individuals) in shelterwood grids. Eight Phascogale captures (6 individuals) were recorded in external reference grids and three captures (all individuals) in shelterwood grids. Eight chuditch (*Dasyurus geoffroii*) captures (five individuals) were also recorded, two in the external reference, three in shelterwood and three in the gap release grids. Two mice (*Mus musculus*) were captured in Jolly external reference grid.

A total of 13 species of reptiles were captured in spring, nine skinks, one each of gecko, snake, legless lizard and goanna (Table 1). All were caught in pit traps, except the heath goanna (*Varanus rosenbergi*) (3 captures) and bobtail skink (11 captures) which were trapped in wire cages. As expected, most reptile captures occurred in spring (59 from a total of 85). The most common species recorded were the southern pale flecked morethia (*Morethia obscura*) with 23 captures (13 in spring and 10 in autumn), the south western orange-tailed slider (*Lerista distinguenda*) with 17 captures (15 in spring and two in autumn), the common dwarf skink (*Menetia greyii*) with 12 captures (eight in spring and four in autumn), and the bobtail (*Tiliqua rugosa*) with 11 captures. No individual reptiles were captured more than once, except one bobtail that was captured twice on the Hunt shelterwood in spring.

Table 1. Total number of animal captures recorded on each grid and in each treatment on the Sandy Basins FORESTCHECK grids in 2014

Scientific Name	Common Name	External reference				Shelterwood			Gap release			Overall Total
		FC57	FC60	FC63	Total	FC58	FC61	Total	FC59	FC62	Total	
Mammals												
Dasyurus geoffroii	Chuditch		1	1	2	3		3	3		3	8
Phascogale tapoatafa	Southern brush-tailed phascogale, Wambenger	8			8	3		3				11
Smithopsis sp.	Dunnart	1	3	5	9	5	1	6	7	3	10	25
Trichosurus vulpecula vulpecula	Common brushtail possum / Koomal	45	16		61	35		35	6		6	102
Mus musculus	House mouse	2			2							2
Reptiles												
Egernia napoleonis	Smith's skink	1	1	1	3				1	2	3	6
Hemiergis peroni	Peron's (Lowland) earless skink	1			1	2		2	1		1	4
Lerista distinguenda	South western orange-tailed slider	2			2	1	9	10	2	4	6	18
Lerista elegans	Elegant slider	1			1	2		2				3
Lerista microtis	South-western slider			1	1							1
Menetia greyii	Common dwarf skink	1	3		4	2	4	6		2	2	12
Morethia obscura	Southern pale flecked morethia		6	1	7		13	13		3	3	23
Tiliqua rugosa	Bobtail / Shingleback		1	1	2		3	3	2	4	6	11
Christinus marmoratus	Marbled gecko		1		1							1
Anilios australis	Southern blind snake					1		1		1	1	2
Aprasia pulchella	Western granite worm lizard						2	2				2
Varanus rosenbergi	Heath monitor	1	1		2							2
Amphibians												
Crinia glauerti	Glauert's frog / Clicking froglet	1			1							1
Heleioporus eyrei	Moaning frog	1		16	17					2	2	19
Heleioporus inornatus	Whooping frog		2	23	25		4	4		1	1	30
Limnodynastes dorsalis	Pobblebonk / Western banjo frog / Bullfrog	1			1	1		1				2
Pseudophryne guentheri	Crawling toadlet / Güther's toadlet		1	2	3		2	2		1	1	6
	Total number of captures	66	36	51	153	55	38	93	22	23	45	291

Five species of amphibians, all frogs, were recorded over the two trapping sessions (Table 1). The total number of captures was 58, with 48 occurring in autumn and 10 in spring. The whooping frog (*Heleioporus inornatus*) recorded 31 captures, 29 in autumn and two in spring, the moaning frog (*Heleioporus eyrei*) recorded 18 captures,14 in autumn and four in spring, and Günther's toadlet (*Pseudophryne guentheri*) recorded six captures, three in both autumn and spring. The other two species Glauert's frog *(Crinia glauerti*) and the western banjo frog (*Limnodynastes dorsalis*) recorded only one and two captures respectively.

Wire Cage Traps

Total captures recorded from wire cage traps over the two sessions was 133 (8.3cpn) which was made up of 42 captures (2.6 cpn) in autumn and 91 (5.7 cpn) in spring (Fig. 4 and 5).

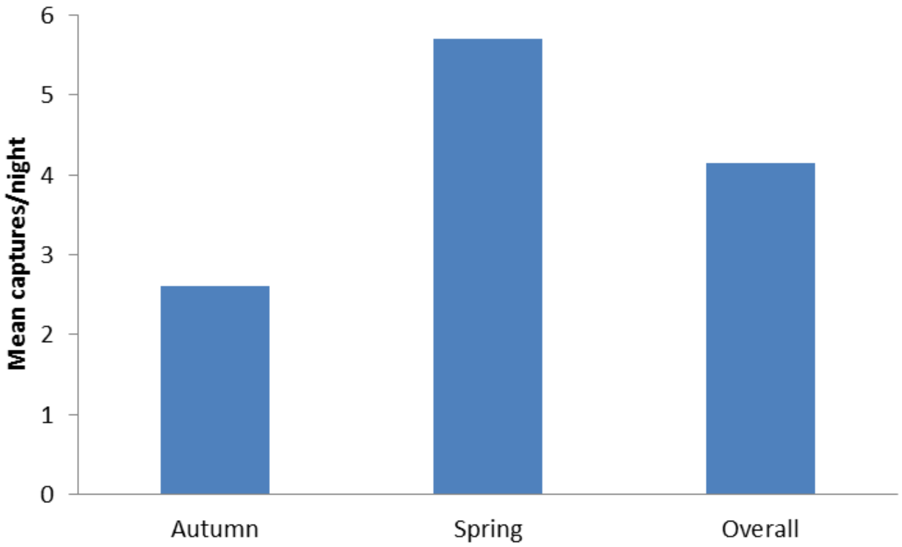


Figure 4. Mean number of animal captures recorded in wire cage traps on the Sandy Basins FORESTCHECK grids in 2014

Mammals were the most common group of vertebrates captured in wire cage traps. All 42 captures in autumn were mammals and 79 of the 91 captures in spring were mammals. The seven other captures in spring were reptiles made up of 11 bobtail and three heath monitors. The most common animal caught in wire cage traps was the common brushtail possum, with 27 captures in autumn and 75 in spring. The phascogale had 11 captures, all in autumn, and the chuditch had three in autumn and five in spring. The heath goanna had one capture in autumn and two in spring and bobtails were all caught in spring.

There were noticeably more mammal captures on the Wilga/Jolly grids than on the Hunt/Camballan set of grids in both autumn and spring (Fig. 5). The highest number of captures occurred on external reference grids, and the lowest on gap release grids. It is not clear why the captures were higher on the Wilga/Jolly grids. This needs to be investigated further, but it may be related to the more open habitat associated with sandier soils on the Hunt/Camballan grids.

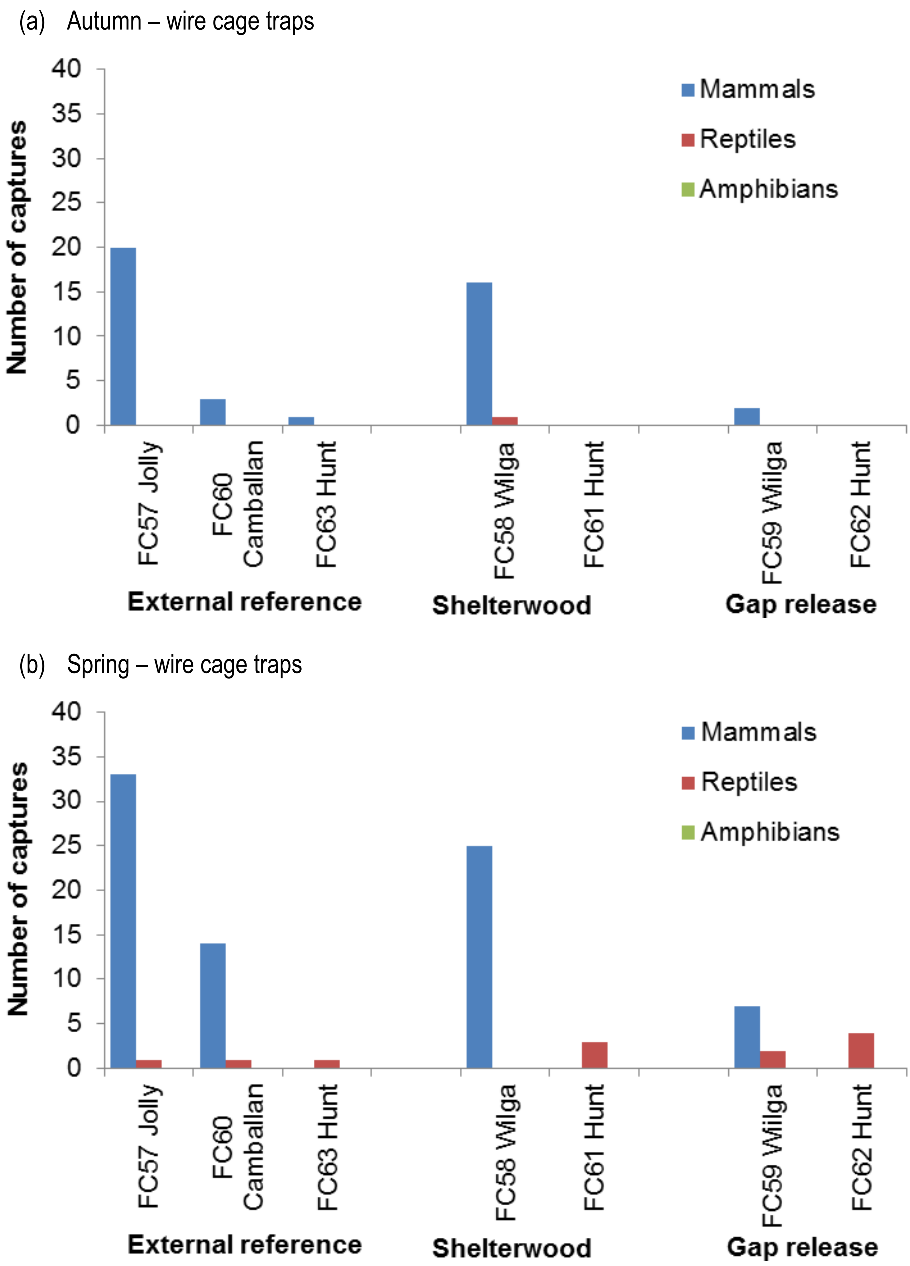


Figure 5. Total captures of mammals, reptiles and amphibians recorded in wire cage traps in (a) autumn and (b) spring on the Sandy Basins FORESTCHECK grids in 2014

Pit fall traps

One hundred and fifty eight (9.8 cpn) of the 291 total captures were in pit fall traps. Ninety one in autumn (5.7cpn) and 67 in spring (4.1cpn) (Fig.6)

Of the 158 captures in pit fall traps 26 (17.2%) were mammals; they included 24 dunnart captures, and two for the house mouse. Nine of the dunnart captures were in external reference, six in shelterwood and 9 in gap release grids.

Seventy one of the 85 reptile captures were recorded in pit fall traps (all bobtail and heath goanna captures were recorded in wire cage traps). The southern pale flecked morethia was the most common skink trapped with 23 captures; seven captures in reference, 13 in shelterwood and three in gap release grids. The south west orange-tailed slider had 17 captures; two in reference, 10 in shelterwood and five in gap release grids. The common dwarf skink had 12 captures, four in reference, six in shelterwood and two in gap release grids.

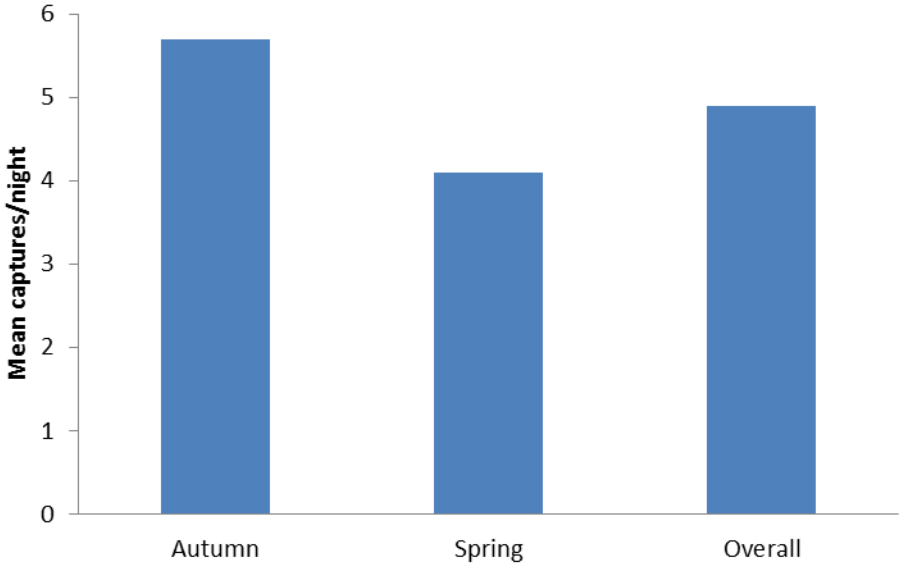
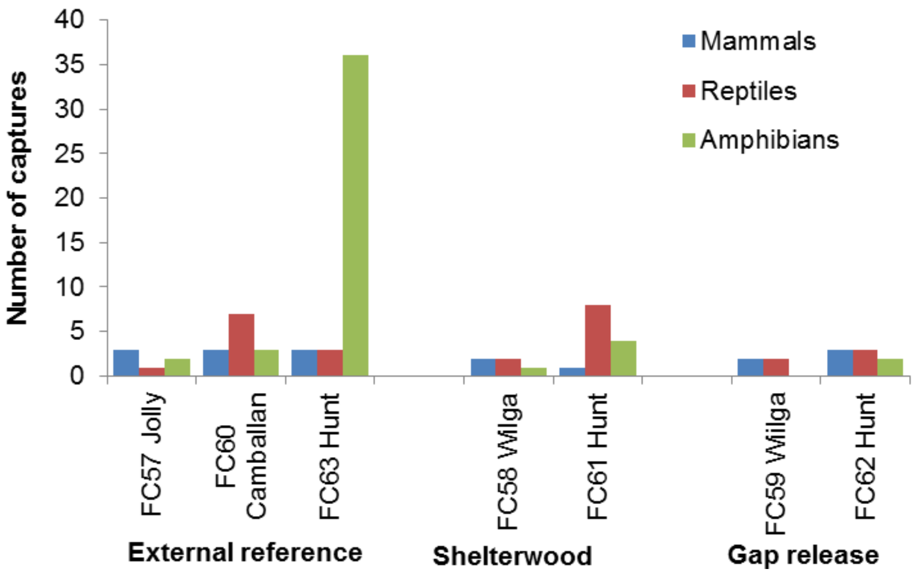


Figure 6. Mean number of animal captures per night in pit fall traps on the Sandy Basins FORESTCHECK grids in 2014

All 58 amphibian captures were recorded in pit fall traps of which 48 occurred in autumn and 10 in spring. Overall, 47 captures occurred in the external reference (41 autumn, six spring), seven in the shelterwood (five autumn, two spring) and four in the gap release grids (two autumn, two spring). Forty nine (84.4%) of the captures were from two species; the moaning frog (*Heleioporus eyrie)* with 19 captures and the whooping frog (*Heleioporus inornatus*) with 30 captures.

The majority of the frog captures (63.8%) were recorded on the Hunt external reference grid in autumn (Fig. 7). The remainder were spread more-or-less evenly across all other grids in autumn but captures in spring were sporadic across the grids.

(a) Autumn – pit fall traps



(b) Spring – pit fall traps

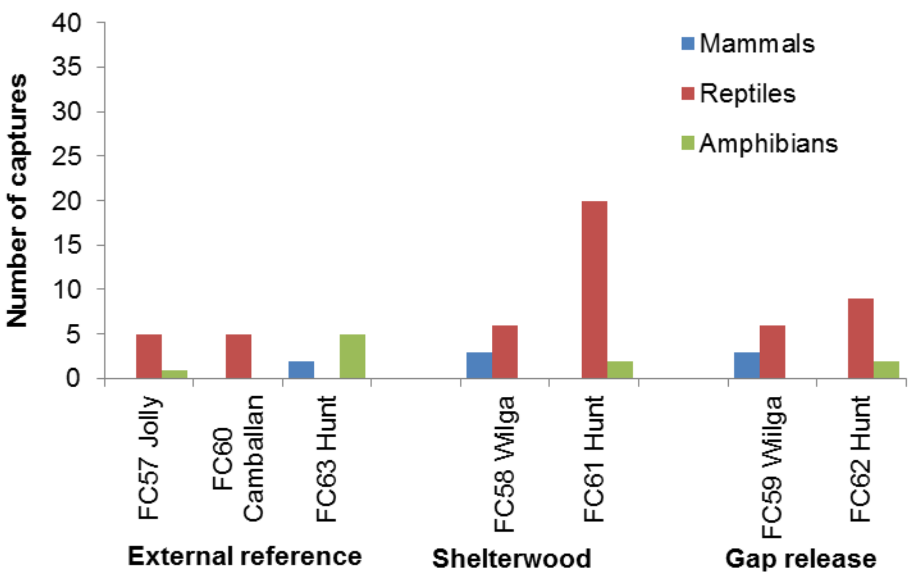


Figure 7. Total numbers of mammals, reptiles and amphibians recorded in pit fall traps in (a) autumn and (b) on the Sandy Basins FORESTCHECK grids in 2014

Fire chronosequence grids, Dwellingup

Trapping

Trapping on the three Dwellingup fire chronosequence grids consisted of 720 trap nights. This included 360 trap nights for pit fall traps and 360 trap nights for wire cage traps. The overall capture rate was 7.7 animals per night (cpn); 8.4 in autumn and 7.1 in spring (Fig. 8). Total captures recorded from wire cages over the two seasons was 86 (5.4 cpn) comprising 44 captures (5.5 cpn) in autumn and 42 (5.3 cpn) in spring (Fig. 8). Total captures recorded in pit fall traps over the two seasons was 37 (2.3 cpn) comprising 23 in autumn (2.9 cpn) and 14 in spring (1.8 cpn) (Fig.8).

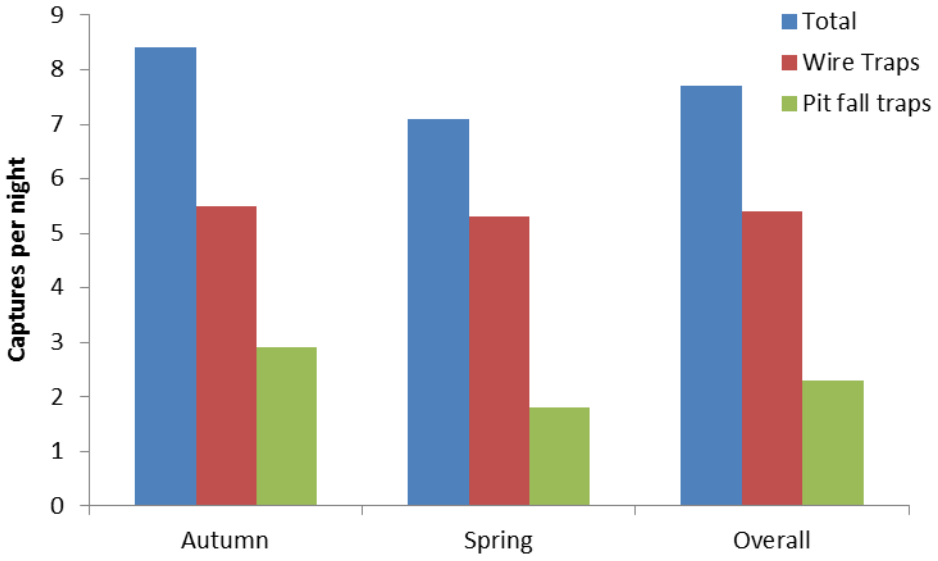


Figure 8. Mean number of animals captured per night on the Dwellingup fire chronosequence grids in 2014

A total of 123 captures were recorded; 67 in autumn and 57 in spring. Overall, five species of mammals were recorded with a total of 87 captures. Eight species of reptiles were recorded, 6 skinks, one gecko and one snake, with 33 captures. Only one amphibian, a slender tree frog (*Litoria adelaidensis*) was recorded once on the long unburnt Amphion grid (FC65, 81 years since fire). One species of bird, the Australian raven (*Corvus coronoides*) recorded two captures; both on the Amphion grid in spring (Fig. 9 and Table 2).

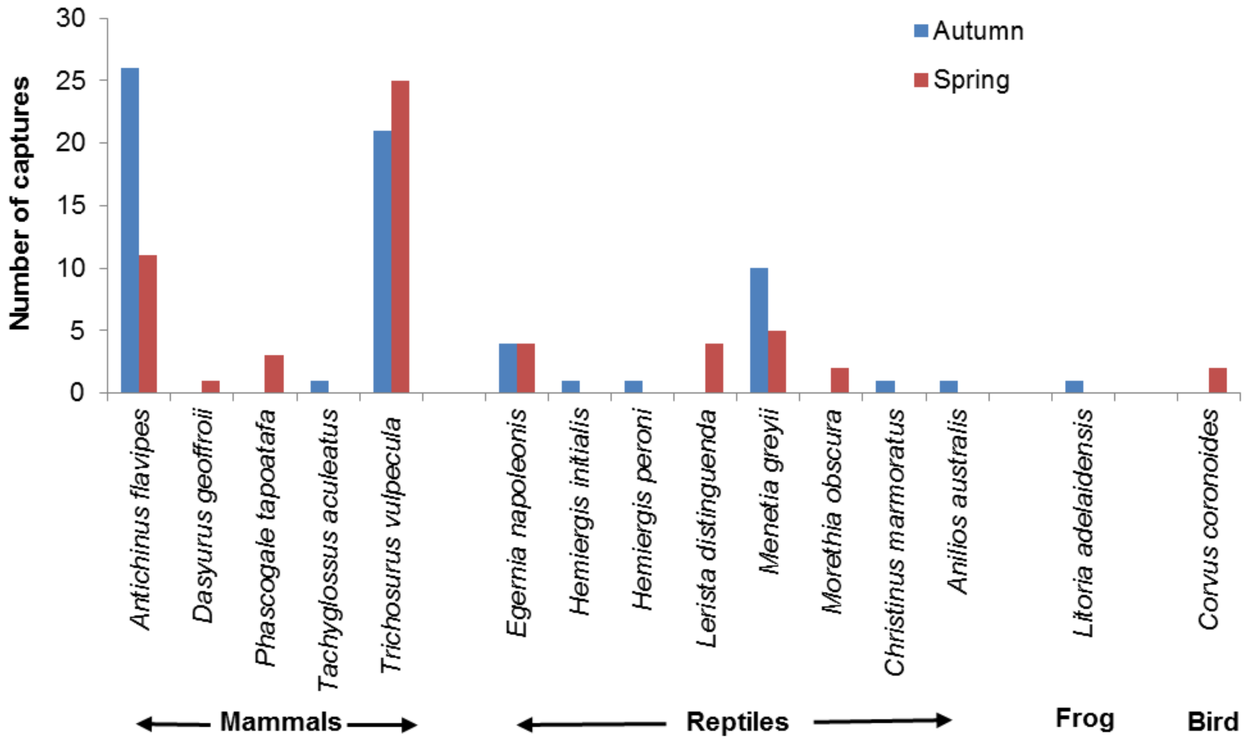


Figure 9. Total number of animal captures in autumn and spring on the Dwellingup fire chronosequence grids in 2014

Table 2. Total number of animal captures in each trap type in autumn and spring on the Dwellingup fire chronosequence grids in 2014 (numbers in brackets indicate the years since fire on each grid)

Scientific Name	Common Name	FC65 Ampion (81)				FC24 Kennedy (39)				FC64 Plavins (9)				Overall Total
		Autumn		Spring		Autumn		Spring		Autumn		Spring		
		Pit	Wire	Pit	Wire	Pit	Wire	Pit	Wire	Pit	Wire	Pit	Wire	
Mammals														
Antichinus flavipes	Mardo / Yellow-footed antichinus	1	13		6	1	3		3	3	5		2	37
Dasyurus geoffroii	Chuditch								1					1
Phascogale tapoatafa	Southern brush-tailed phascogale / Wambenger								3					3
Tachyglossus aculeatus	Short-beaked echidna										1			1
Trichosurus vulpecula	Common brushtail possum / Koomal		1		1		18		19		2		4	45
Reptiles														
Egernia napoleonis	South west crevice skink / Smith's skink	2	1	4						1				8
Hemiergis initialis	Southern five-toed slider									1				1
Hemiergis peroni	Peron's (Lowland) earless skink					1								1
Lerista distinguenda	South western orange-tailed slider							1				3		4
Menetia greyii	Common dwarf skink	3		2		1		1		6		2		15
Morethia obscura	Southern pale flecked morethia											1	1	2
Christinus marmoratus	Marbled gecko									1				1
Anilios australis	Southern blind snake					1								1
Frog														
Litoria adelaidensis	Slender tree frog	1												1
Bird														
Corvus coronoides	Australian raven				2									2
	Total captures per trap type	7	15	6	9	4	21	2	26	12	8	6	7	
	Overall total captures				37				53				33	123

The highest number of mammal captures was recorded on the Kennedy grid (FC24), which had the intermediate fire age (39 years since fire) (Fig. 10). In contrast the Kennedy grid recorded the lowest reptile captures. The long unburnt Amphion grid and the more recently burnt Plavins grid (FC64, 9 years since fire) had similar numbers of captures for both mammals and reptiles.

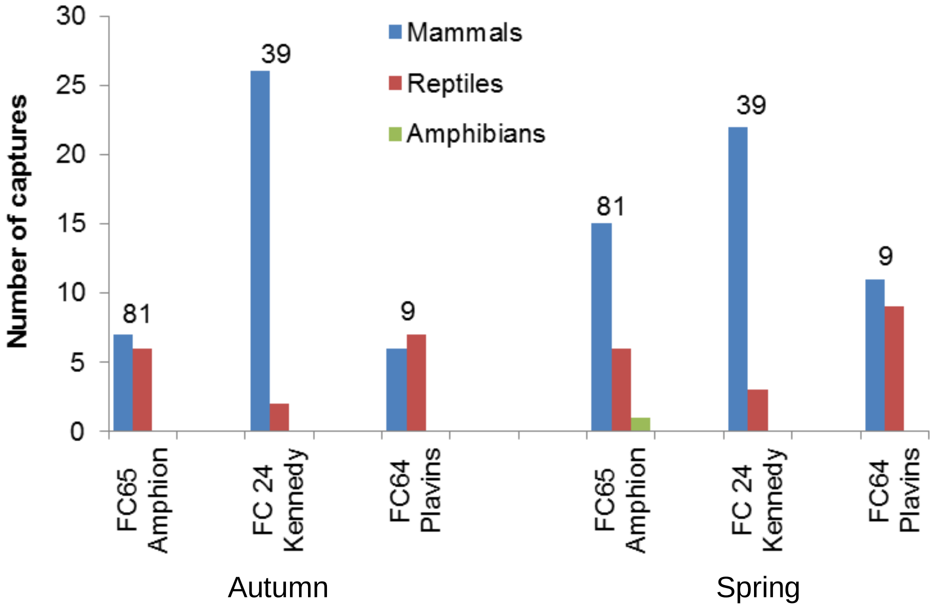


Figure 10. Total numbers of mammals, reptiles and amphibians captured in traps in autumn (left) and spring (right) on the Dwellingup fire chronosequence grids in 2014. Numbers above columns refer to the number of years since fire on the grids.

The most common mammal captured was the brushtail possum (*Trichosurus vulpecula vulpecula*) with 20 individuals and 45 total captures; 21 captures in autumn (13 individuals) and 24 in spring (15 individuals). Thirty seven captures were recorded on the Kennedy grid (39 years since fire) and six on the Plavins (9 years since fire) and only one capture on Amphion (81 years since fire). Nineteen individual mardos (*Antechinus flavipes*) were recorded with 37 total captures; 26 in autumn and 11 in spring. Twenty mardo captures were recorded on Amphion, 10 on Plavins and seven on Kennedy. Three individual brush-tailed phascogales (*Phascogale tapoatafa*) were recorded once each; all in spring on the Kennedy grid. Other species trapped included a single chuditch (*Dasyurus geoffroii*) on Kennedy in spring and one short-beaked echidna (*Tachyglossus aculeatus*) on Plavins in autumn.

All five species of mammals were captured in wire cage traps. However, five of the 35 mardo captures were recorded in pit fall traps.

Of the 33 reptile captures, 18 were recorded in autumn and 15 in spring. Sixteen captures were recorded on Plavins, 12 on Amphion and five on Kennedy. The most trapped species were skinks. The common dwarf skink (*Menetia greyii*) recorded 15 total captures; 10 in autumn and 5 in spring. The south west crevice skink (*Egernia napoleonis*) recorded eight captures; 4 in autumn and 4 in spring. Only one marbled gecko (*Christinus marmoratus*) and one southern blind snake (*Anilios australis*) were captured over both trapping seasons.

All eight species or reptile were recorded in pit fall traps. Two species, the south west crevice skink and the southern pale flecked morethia were also recorded once each in wire cage traps. The presence of the southern pale flecked morethia in the wire cage on the

Plavins grid in spring may have been a misidentification of a south west crevice skink or it was a coincidental capture.

Other survey techniques

Due to constraints on time and personnel no spotlight surveys or road transect surveys were carried out apart from incidental sightings and the use of remote cameras. The cameras were RECONYX HyperFire model HC600. Cameras were installed at two sites in each grid 1.5 m above ground at an angle of 45° and operated for two weeks between each of the two autumn and spring trap sessions.

At the Sandy Basins grids a total of seven species were recorded which included five native mammals and two birds. Four different western grey kangaroo, 13 western brush wallaby, three common brushtail possum, one dunnart and one western brush-tailed phascogale can be seen on the images. There are also two birds, the Australian raven and the western golden whistler (*Pachycephala occidentalis*).

At the Fire chronosequence grids, a total of nine species were recorded which included six mammals, one reptile and two birds. Mammals included western grey kangaroo, western brush wallaby, brush-tailed possum, southern brush-tailed phascogale, mardo and the short-beaked echidna. The only reptile was the southern heath monitor and the two birds were the rufous tree-creeper (*Climacteris rufa*).

Conclusions

Observations made following monitoring of terrestrial vertebrates in the Sandy Basins FORESTCHECK grids in 2014 were:

- Changing the trap sessions to a week trapping, a month break and then another weeks trapping has reduced the strain on animal handles and assistants.
- Eighty five of the 102 brushtail captures possums were trapped in spring.
- Sixty one (60%) of the common brush tail possums captures were trapped in the external reference grids with 34% from shelterwood/selective cut grids and the remaining 6% from the gap release grids.
- Sixteen (64%) of the 25 dunnart captures were either in the shelterwood or gap release treatment grids.

Observations made following monitoring of terrestrial vertebrates in the Jarrah North West fire chronosequence grids in 2014 were:

- Overall there were higher captures per night in autumn than in spring.
- The most captures were in the FC24 grid, which was last burnt in 1975 where 53 of 123 captures occurred. FC65 (1933 burn) and FC64 (2008 burn) had 37 and 33 captures respectively.
- Although there were suitable habitat trees with hollows on all three grids, 37 of the 45 brush-tailed possums captures were on the intermediate (39 years) fire aged grid at Kennedy block.
- Twenty of the 22 mardo captures occurred on the longest unburnt (81 years) grid at Amphion block—likely due to a deep litter layer favoured by mardos.

At both locations remote sensor cameras proved effective in detecting mammals and larger birds and should be considered as a supplementary technique for future monitoring.

Acknowledgements
We would like to thank Neil Burrows, Bruce Ward, Chris Vellios, Colin Ward, Marika Maxwell Lachie McCaw, Richard Robinson, Renee Ettridge and Dave Pickett for their assistance with the animal trapping program in 2014.

References

DEC 2006. *FORESTCHECK: Monitoring Biodiversity in the South-West Forests. Operating Plan.* Department of Environment and Conservation, Kensington, Western Australia.

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 is 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

Sampling data are saved and backed up as individual files on the network drive. Data are saved and secured when the 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 at present lodged at PERTH and housed at the Tony Annels Herbarium in Manjimup, to enable work on descriptions and identification to be completed. It is in preparation to be transferred to PERTH in the near future. 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 PERTH for incorporation into the herbarium database. Max was developed by Simon Woodman and Paul Gioia as an in-house software product 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 minimize 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:

Parastitic 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		

INVERTEBRATES (2013 Report update)

Janet Farr, Allan Wills and Paul Van Heurck

Introduction

Invertebrates, including class Insecta, comprise over 95% of the planet's biodiversity and 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. 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 and mesic specialists. 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 and their responses to the various treatments of managed jarrah forest;
- analyse trends in species composition, richness and abundance;
- to monitor the presence of Gondwanan relic and affinity invertebrate species with respect to the above treatments; and
- to monitor the presence of known insect pest species.

Field survey and laboratory procedure

Sampling of 12 FORESTCHECK grids in the Jarrah South ecosystem in Donnelly District was carried out in March (autumn) 2013 and November (spring) 2013, using protocols outlined in the revised FORESTCHECK Operating Plan (DEC 2006) with minor alterations. Grids FC1–FC3 and FC10 (Donnelly 1) had been previously sampled in 2001–02 and 2007–08 while grids FC49–FC56 (Donnelly 2) were newly established and monitored for the first time in 2013 (Table 1). To briefly summarise sampling protocol: active capture samples (hand sampling), involving sweeping, beating, and habitat searches of coarse woody debris (CWD) and litter were conducted once at each grid for a total time of one-person-hour per capture/habitat method. Light traps were run for three nights, simultaneously at each grid achieving one trap night per week for three weeks. In 2013, pit fall trap numbers were increased to 20 traps per grid arranged in a "Z" pattern across the central grid area (see grid layout on p. 5) and opened for 10 consecutive days simultaneously at each grid. Increasing pit fall trap numbers from from 10 to 20 has been shown to be more effective in capturing a wider diversity of the ground invertebrate fauna (van Heurck, unpublished data). Captures were bagged and labelled with site and other capture details in the field and stored in a portable freezer. At the conclusion of a sampling period, specimens were then transported to the laboratory where they were sorted and compared to an extensive collection of voucher specimens. Vouchers for each new morphospecies were erected as necessary and labelled according to site, date of capture and capture method then preserved as either pinned or alcohol specimens. To constrain sample processing times only macro-invertebrates are recorded, that is, invertebrates with a body length 10mm or greater and Lepidoptera with a wing length of 12mm 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.

This is a full report for the invertebrate sample collected in 2013 published as a supplement to the FORESTCHECK Report of Progress 2013.

Table 1. Characteristics of FORESTCHECK grids monitored in Donnelly district in 2013. Years since silvicultural treatment are relative to the 2013 sample period. See FORESTCHECK Report 2013 for detailed descriptions of grids and llocations.

Treatment/ grid number	Forest block	Years since fire	Years since harvest
External reference			
FC01	Kingston	27	Uncut
FC10	Easter	18	Uncut
FC49	Boyndaminup	4	Uncut
FC54	Carter	6	Uncut
Shelterwood/selective cut*			
FC03	Kingston	18	18
FC51	Boyndaminup*	5	6
FC53	Carter	6	6
FC56	Barlee	9	7
Gap release			
FC02	Kingston	17	17
FC50	Gobblecannup	5	7
FC52	Carter	7	7
FC55	Lewin	9	9

Results

Sorting, specimen identification and cataloguing for the spring and autumn light trap, hand and pit fall samples was completed in May 2015. Morphospecies assignment may change as taxonomic expertise is gained and/or updates are incorporated into the database. During the sample periods in 2013, there were six light trap failures out of a total of 15 light trap nights comprising a total of 75 traps set. Pitfall traps were set at all 12 grids comprising 240 pits (20 pits per grid) which was double the pitfall traping rate conducted on previous samples. The mean minimum overnight temperature was 11.3°C and 12 5°C for spring and autumn repectively.

Following the 2013 monitoring the number of morphospecies recorded for FORESTCHECK is presently 2,412 (Fig. 1) an increase of 191 morphospecies, with a total of 97,778 individual specimens. Thus although species accumulation appeared to be starting to approach an asymtote in 2010–11, current data suggests otherwise. Figure 1 indicates sampling in southern, moister jarrah is less complete than the drier Perth Hills and Wellington East locations.

Morphospecies capture for past sampling districts and periods are shown in Table 2. Donnelly 2 appears the most diverse location with 798 morphospecies comprising an abundance of 6,639 individual specimens, followed by Donnelly 1 (2007–08) and Blackwood Plateau.

The numbers of morphospecies for invertebrate orders where 10 or more morphospecies have been assigned are compared for Donnelly 2 in 2013 and Donnelly 1 in 2007–08 and 2001–02 in Figure 2. Most Lepidoptera species (moths and butterflies) are captured using light traps. This method is less influenced by operator experience and effort, variation between samples can be attributed to fluctuations in capture conditions including temperature, moon illumination, humidity and some of these can be corrected for, thus variation can be mostly attributed to site differences. Donnelly 1 in 2007–08 was the most diverse sample for moths and in 2001–02 the least diverse for moths. Coleoptera (beetles), Orthoptera (crickets and grasshoppers) and Neuroptera (lace wings) also contain taxa mostly caught in light traps although these can also be abundant in hand capture methods such as sweeping and beating which are more dependant on operator experience.

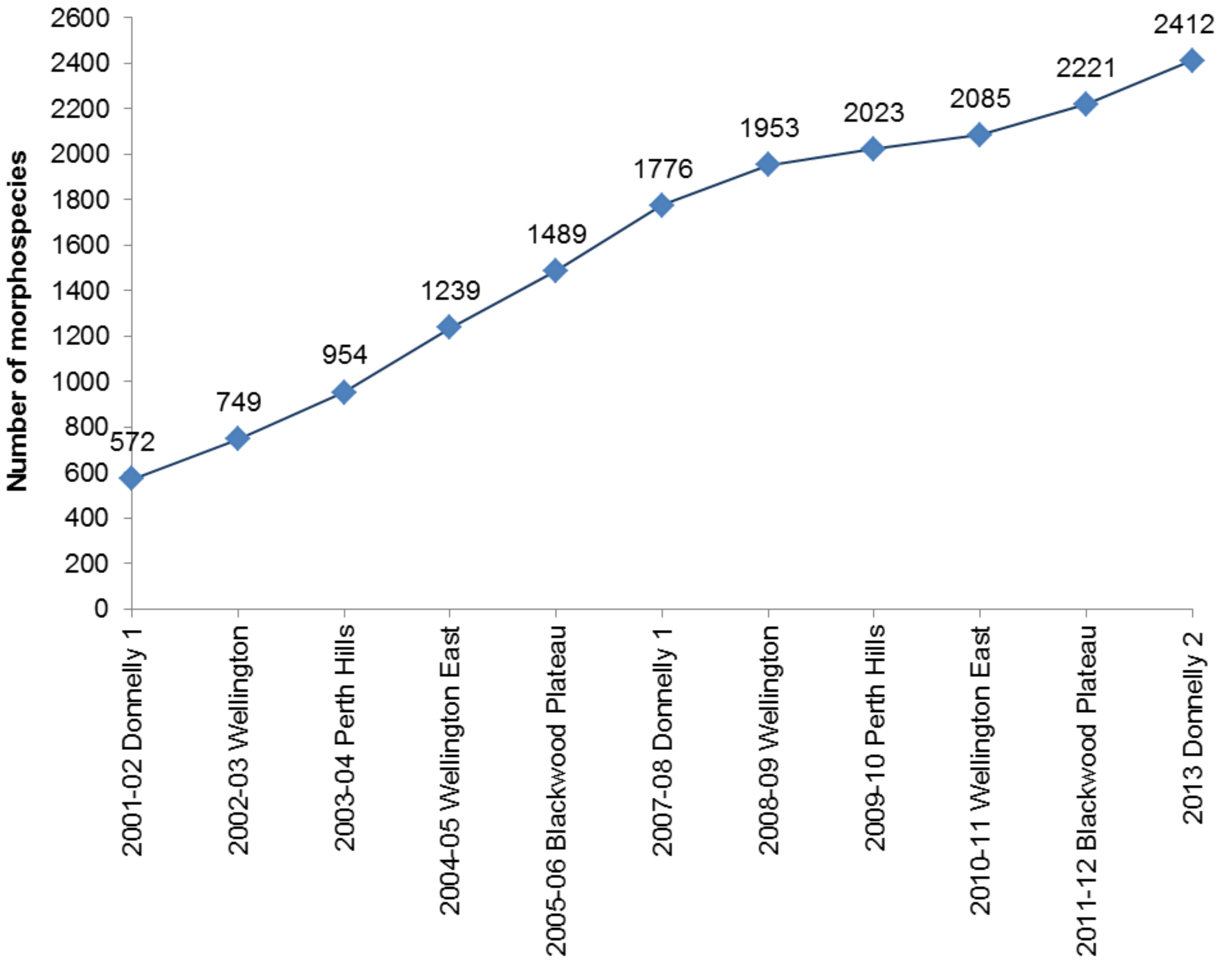


Figure 1. Cumulative morphospecies for 2001–13.

Table 2. Morphospecies and abundance comparisons between FORESTCHECK sample locations, 2001–2013.

FORESTCHECK location	Sample date	Number of morphospecies	Number of individuals
Donnelly 1	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	6959
Donnelly 1	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	680	8007
Donnelly 2	2013	798	6639

Nonetheless the data shows these orders also follow a similar pattern of relative diversity to that of moths. Thus 2007–08 was a more diverse year for these taxa than 2001–02. The invertebrate taxa Araneomorphae (modern spiders), Chilopoda (centipedes), Blattodea (cockroaches), Dermaptera (earwigs), Diplopoda (millipedes), Isopoda (slaters), Mygalamorphae (ancient spiders), Oligochaetae (worms) and Platyhelminthes (flat worms) contain species abundant in forest litter and coarse woody debris. Interception and catching these taxa is more common with hand sampling (reliant on operator experience and skill) and pitfall traps. Donnelly 2 in 2013 had the highest richness of these taxa (Fig. 2) — in fact no flatworms were caught in any of the other Donnelly samples. In addition eight Onychophora (velvet worms) were found in Donnelly 2 in 2013 (4 from pitfalls, 4 from hand CWD and litter searches), three in the 2007–08 sample (1 from a pitfall and 2 from hand CWD and litter searches) but none in 2001–02.

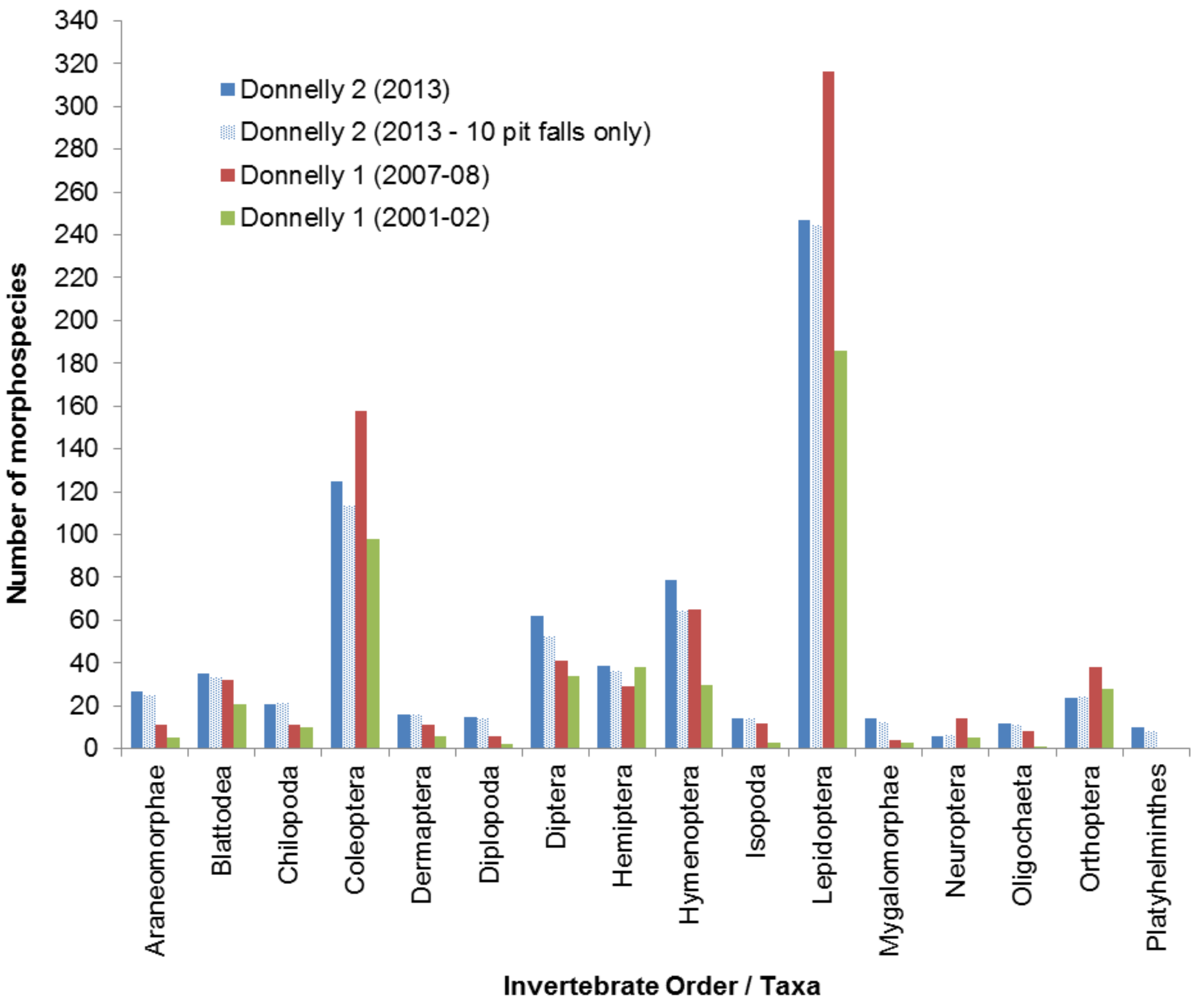


Figure 2. Comparison of captures of morphospecies numbers for invertebrate orders where ten or more morphospecies were assigned at Donnelly 2 in 2013, Donnelly 1 in 2007–08 and 2001–02

These findings indicate three possibilities; (1) the Donnelly 2 sample was undertaken during a period of higher moisture levels for the forest floor; (2) the additional pitfall traps have contributed to this increase in diversity; (3) operator skill has improved since 2001–02. Pitfall capture data was partitioned according to the original (pits 1-10) and the new pitfall regime (pits 1-20): 170 morphospecies were captured from the first 10 pitfalls compared with 246 morphospecies in all 20 traps (abundance 889 and 1717 respectively). Although greater total individuals would be expected with increased trap numbers, a 45% increase in morphospecies indicates pitfall trapping may still be under-representing ground foraging species. Table 3 shows those orders where species diversity displayed a distict difference between the current and past pitfall regime. Particular families of Coleoptera (beetles) are commonly found foraging on the forest floor thus their appearance would be expected in pitfalls. However, the other two orders with discrepancies are Diptera (flies) and Hymenoptera (wasps and ants), which are non-targeted taxa for pitfall traping. Most of these 42 taxa comprise species attracted to flowers and are positively phototactic in ultraviolet so they may be responding to the colour of the traps. Therefore although more pitfall traps have increased the diversity of capture most of this increase is due to the incidental capture of species less likely to forage on the forest floor and the essential diversity pattern between sample periods remains consistent.

Table 3. Invertebrate orders/families with distinctive differences in species diversity related to pitfall trap numbers. Number of morphospecies and their abundance occurring in new pitfall regime (pits 1-20) but absent from original pitfall regime (pits 1-10).

Order	Family	Sub Family	No. of morpho-species	Abundance
Coleoptera	Carabidae		3	11
Coleoptera	Chrysomelidae	Chrysomelinae	1	1
Coleoptera	Curculionidae		4	4
Coleoptera	Elateridae	Pityobiinae	1	1
Coleoptera	Lucanidae		1	1
Coleoptera	Lycidae	Metriorrhynchinae	1	1
Coleoptera	Scarabaeidae	Melolonthinae	2	2
Diptera	Anthomyiidae		1	1
Diptera	Asilidae		3	4
Diptera	Bombyliidae		2	2
Diptera	Syrphidae		4	9
Diptera	Tachinidae		3	3
Diptera	Tipulidae		1	1
Hymenoptera	Braconidae		1	1
Hymenoptera	Colletidae		4	10
Hymenoptera	Formicidae		2	2
Hymenoptera	Megachilidae		1	1
Hymenoptera	Mutillidae		4	6
Hymenoptera	Pompilidae		3	3

Comparing sample grids

The greatest species richness was found at the shelterwood in Carter (FC53) with 201 morphospecies. However this did not differ greatly from the external reference grid at Boyndaminup (FC49) and the Carter gap release (FC52) for which species richness was 177 morphospecies (Fig. 3). The lowest richness of 136 morphospecies occurred at the Barlee shelterwood grid. Abundance peaked in the external reference grid at Boyndaminup (FC49) with 892 individuals, and was lowest at the external reference grid at Carter (FC54) with 367 individuals. Mean species richness ranged from 160 to 165 (Fig. 4a) and varied little between treatments. Although mean abundances were lower in the shelterwood/select cut and gap release grids, this difference was not significant (Fig. 4b). Individual species and their abundances in each silvicultural treatment are listed in Appendix 1.

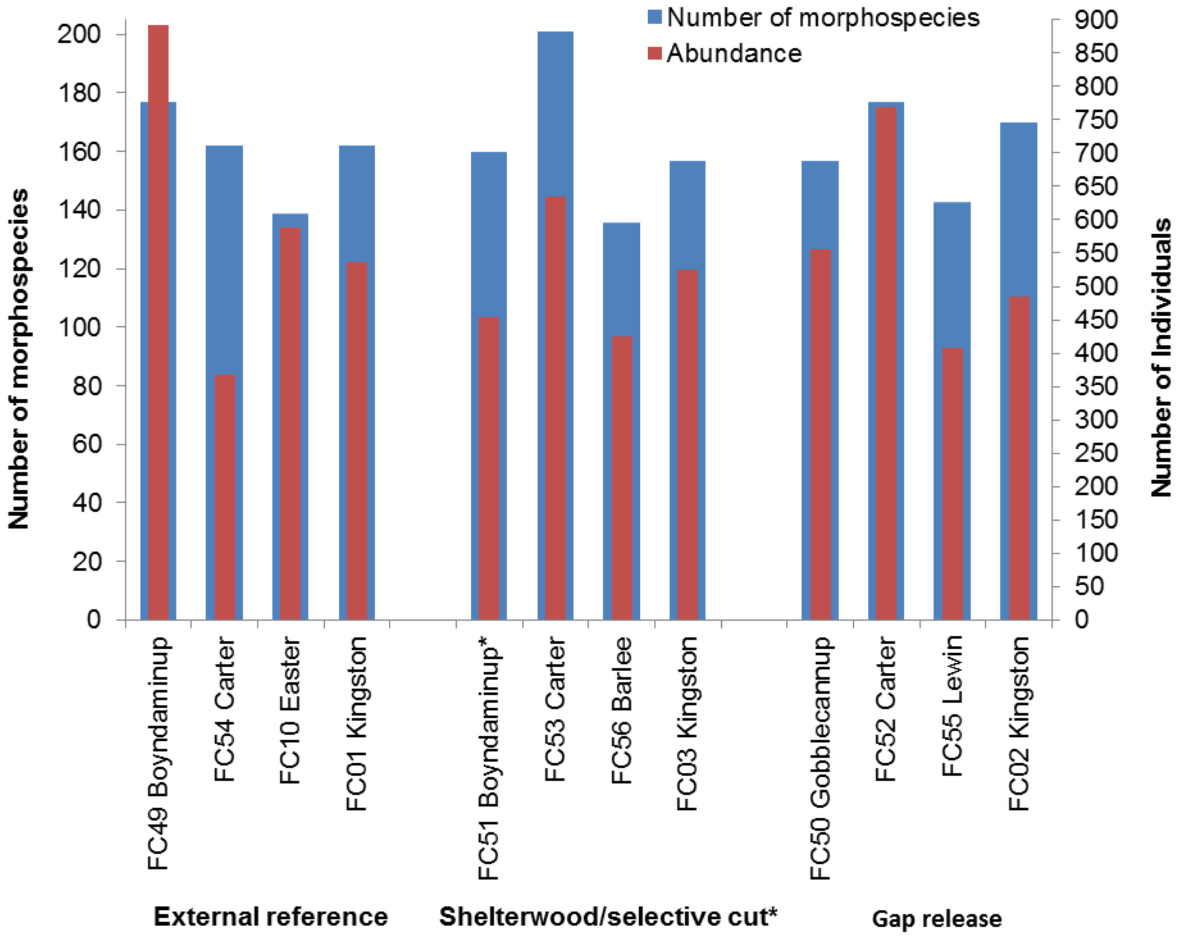


Figure 3. Total number of morphospecies and individuals (abundance) sampled at each FORESTCHECK monitoring grid at Donnelly 2 in 2013

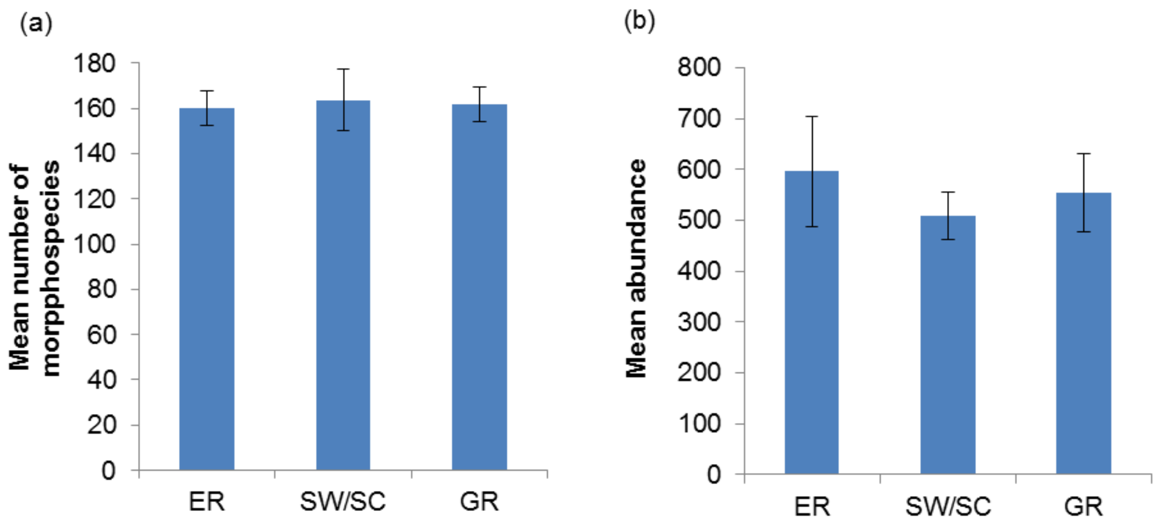


Figure 4 (a) Mean number of morphospecies per grid (± se) and (b) mean number of individuals (abundance) per grid (± se) recorded in each treatment at Donnelly 2 FORESTCHECK grids in 2013. ER = external reference, SW/SC = shelterwood/selective cut and GR = gap release treatment.

The most frequent species captured was a Tipulid fly known as sp# 16, with an abundance of 296. This species is common in FORESTCHECK grids. The highest abundance of 472 was for the Lepidopteran *Opodiphthera helena* (sp# 328). This species (Fig. 5), which is caught in light traps, has progresively increased in abundance since the first FORESTCHECK sample in 2001–02. Since this species is an arboreal leaf feeder, its increase reflects an increasing herbivory demand on the upper forest canopy together with the persistant high population of gumleaf skeletonizer since 2009 (Fig. 5; Farr 2012, Farr and Wills 2012a,b).

A selection of species recorded for the first time in FORESTCHECK, and captured at the Donnelly 2 location in 2013 are shown in Figure 6.

Figure 5. *Opodiphthera helena* (Sp# 328) attracted to a light trap in a Donnelly 2 sample grid (left) and skeletonised leaf damage caused by gumleaf skeletonizer on FC10 in 2013.

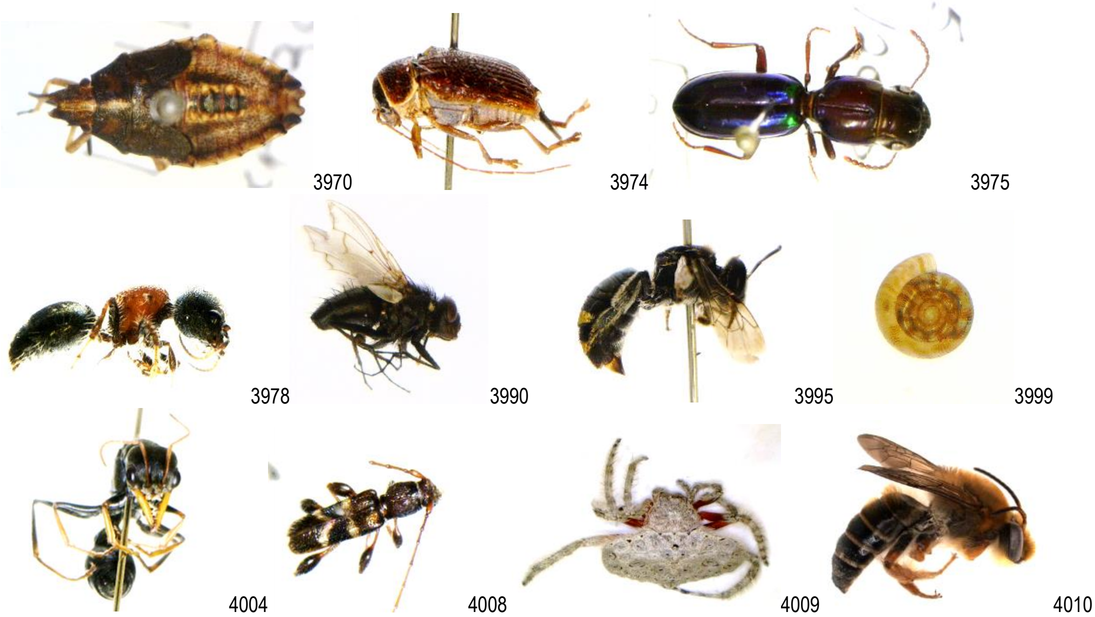


Figure 6 A selection of new species captured from Donnelly 2 FORESTCHECK monitoring grids in 2013. Morphospecies designation is the number to the right of each picture.

Pest presence

All recognised invertebrate pests of the jarrah forest were present at Donnelly 2 and across all treatments (Table 5). Gumleaf skeletoniser (GLS) levels are still relatively high across the forest compared with the earlier observations on Donnelly 2001 and 2007. However, GLS was also observed in the Easter site FC10 in 2007 at a lower abundance than in 2013 (but not in 2001). JLM was present on six sites but not abundant on any.

Table 5: Pest presence and abundance assessment at each Donnelly 2 FORESTCHECK grid in 2013 (JLM = jarrah leaf miner; GLS = gumleaf skeletonizer; BEB = bullseye borer, 0 = absent, 1 = present, 2 = abundant. Note JLM is assessed on presence only).

Treatment/grid number	Location	JLM	GLS	BEB
External reference				
FC49	Boyndaminup	1	1	1
FC54	Carter	0	0	1
FC10	Easter	1	2	1
Shelterwood/selective cut*				
FC01	Kingston	1	0	2
FC51*	Boyndaminup	1	1	0
FC53	Carter	0	1	0
FC56	Barlee	0	0	0
FC03	Kingston	1	0	1
Gap release				
FC50	Gobblecannup	1	1	1
FC52	Carter	0	1	1
FC55	Lewin	0	0	0
FC02	Kingston	1	0	1

Conclusions

- The ordinal composition signature for trapping in Donnelly did not appear to be different from previous trapping by similar methodogy in the same district. Doubling pitfall traps increased pitfall species richness by 45%, but ordinal patterns remained the same.
- Increasing the number of pitfall traps also increased the diversity of capture although this was largely attributable to incidental capture of species less likely to forage on the forest floor. The diversity pattern remained broadly consistent between sample periods. The costs in additional processing time and the ethical considerations of extra bycatch versus the benefit of richer, more representative invertebrate samples resulting from increasing number of pitfall traps need further investigation. Species previously uncollected in FORESTCHECK continue to be encountered and richness of the southern jarrah appears to be greater than the drier parts of the jarrah forest, as indicated by unsaturated species accumulation.
- Variation in richness and abundance between sample grids is high relative to differences between treatments indicating richness and abundance were not detectably influenced by silvicultural treatment.

Acknowledgements
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References
DEC 2006. *Monitoring Biodiversity in south-west forests: FORESTCHECK Operating Plan*. Department of Environment and Conservation, Kensington, WA.

Farr J (2012). Gumleaf skeletonizer: a defoliator of jarrah. Landscope 28(2)**,** pp. 50–53

Farr J, Wills A (2012a). *Gumleaf skeletonizer (*Uraba lugens*) outbreak, February 2010: preliminary survey of the extent and severity of gumleaf skeletonizer outbreak in Warren region.* Department of Environment and Conservation, Kensington, WA.

Farr JD, Wills AJ (2012b). Field testing DesireÂ® Delta trap and GLS sex pheromone lure system for measuring outbreak and basal populations of Uraba lugens Walker (Lepidotera: Nolidae). Australian Journal of Forestry **75**: 175–179

APPENDIX 1. Species list for Donnelly 2 FORESTCHECK grids in 2013, including abundances at different silvicultural tratments. ER = external reference, SW/SC = shelterwood/selective cut and GR = gap release treatment. (note discrepancies in abundances from previous text references are due to data anomalies yet to be addressed)

						Treatment			
Spec #	Order	Family	Sub Taxa	Genus	Species	ER	SW/SC	GR	Total
1303	Amphipoda					92	48	15	155
4009	Araneomorphae	Araneidae						1	1
1217	Araneomorphae	Araneidae		*Eriophora*	*transmarina*	1			1
1680	Araneomorphae	Araneidae		*Eriophora*	*sp*	1			1
1671	Araneomorphae	Araneidae		*Phonographa*	*graeffei*		2	3	5
536	Araneomorphae	Corinnidae		*Supunna*	*albopunctata*	2	2	1	5
2964	Araneomorphae	Deinopidae					1		1
620	Araneomorphae	Gnaphosidae		*Rebilus*	*sp*		1	1	2
561	Araneomorphae	Lycosidae				2	5	1	8
1589	Araneomorphae	Lycosidae					1	10	11
733	Araneomorphae	Lycosidae						1	1
1448	Araneomorphae	Miturgidae					3		3
1449	Araneomorphae	Miturgidae				1			1
3379	Araneomorphae	Miturgidae					2	1	3
4006	Araneomorphae	Miturgidae						1	1
597	Araneomorphae	Miturgidae					1		1
3364	Araneomorphae	Miturgidae				1		1	2
2495	Araneomorphae	Sparassidae				2			2
2606	Araneomorphae	Sparassidae				1			1
2976	Araneomorphae	Sparassidae						1	1
3140	Araneomorphae	Sparassidae				1			1
2686	Araneomorphae	Stiphididae				1			1
2692	Araneomorphae	Stiphidiidae				1			1
732	Araneomorphae	Stiphidiidae		*Baiami*	*sp*		3	1	4
725	Araneomorphae	Stiphidiidae		*Baiami*	*volucripes*		1		1
1007	Araneomorphae	Zodariidae				1			1
3875	Araneomorphae	Zodariidae				1			1
468	Araneomorphae	Zodariidae		*Storena*	*sp*	1	1	1	3
3264	Araneomorphae	Zodariidae					1		1
2511	Blattodea							1	1
2673	Blattodea					1			1
2684	Blattodea					1			1
2699	Blattodea					1		1	2
3173	Blattodea					1	1	2	4
3201	Blattodea					2			2
3348	Blattodea					1			1
3595	Blattodea						1		1
3972	Blattodea						1		1
3210	Blattodea							1	1
148	Blattodea	Blaberidae				3	1	3	7
410	Blattodea	Blaberidae				1	3		4
147	Blattodea	Blaberidae	Diplopterinae	*Calolampra*	*sp*		2	2	4
27	Blattodea	Blaberidae	Epilamprinae	*Laxta*	*sp*	2		2	4
119	Blattodea	Blaberidae	Epilamprinae	*Laxta*	*sp*	4	1	4	9
2597	Blattodea	Blaberidae	Epilamprinae	*Laxta*	*sp*		2	1	3
2857	Blattodea	Blaberidae	Epilamprinae	*Laxta*	*sp*			1	1
190	Blattodea	Blattelidae				3	1	2	6
120	Blattodea	Blattellidae	Parcoblattini	*Neotemnopteryx*	*sp*		1	1	2

Spec #	Order	Family	Sub Taxa	Genus	Species	Treatment			Total
						ER	SW/SC	GR	
591	Blattodea	Blattellidae	Parcoblattini	*Neotemnopteryx*	*sp*	1			1
891	Blattodea	Blattidae					1		1
1555	Blattodea	Blattidae					1		1
1780	Blattodea	Blattidae					1		1
2037	Blattodea	Blattidae						1	1
2662	Blattodea	Blattidae				1		1	2
2978	Blattodea	Blattidae					1		1
2979	Blattodea	Blattidae					2		2
490	Blattodea	Blattidae				1			1
483	Blattodea	Blattidae	Polyzosteriinae	*Platyzosteria*	*sp*	1	2	1	4
706	Blattodea	Blattidae	Polyzosteriinae	*Platyzosteria*	*sp*			1	1
899	Blattodea	Blattidae	Polyzosteriinae	*Platyzosteria*	*sp*		1	2	3
971	Blattodea	Blattidae	Polyzosteriinae	*Platyzosteria*	*sp*			1	1
1474	Blattodea	Blattidae	Polyzosteriinae	*Platyzosteria*	*sp*	2			2
1888	Blattodea	Blattidae	Polyzosteriinae	*Platyzosteria*	*sp*		2	1	3
777	Blattodea	Blattidae	Polyzosteriinae	*Polyzosteria*	*sp*		1		1
2222	Chilopoda					1	3	1	5
2224	Chilopoda						1		1
3350	Chilopoda					1			1
3385	Chilopoda					4	1	2	7
3441	Chilopoda						1	1	2
3879	Chilopoda						1		1
227	Chilopoda	Geophilidae					1	1	2
1429	Chilopoda	Lithobiidae					1		1
228	Chilopoda	Lithobiidae					1	5	6
229	Chilopoda	Lithobiidae				1	4	7	12
586	Chilopoda	Scolopendridae					1	1	2
1767	Chilopoda	Scolopendridae				2	2	1	5
1783	Chilopoda	Scolopendridae					1		1
1882	Chilopoda	Scolopendridae				1	1		2
2050	Chilopoda	Scolopendridae				2			2
225	Chilopoda	Scolopendridae					1	2	3
267	Chilopoda	Scolopendridae				1			1
2421	Chilopoda	Scolopendridae	Otostigminae	*Ethmostigmus*	*sp*	3		4	7
223	Chilopoda	Scolopendridae	Otostigminae	*Ethmostigmus ?*	*sp*		3	3	6
224	Chilopoda	Scolopendridae	Otostigminae	*Ethmostigmus ?*	*sp*		1	4	5
1200	Chilopoda	Scolopendridae						1	1
100	Coleoptera	Belidae		*Araiobelus*	*sp*	2			2
168	Coleoptera	Belidae		*Rhinotia*	*sp*	1		3	4
198	Coleoptera	Cantharidae	Dysmorphocerinae	*Heteromastix*	*sp*	3			3
1366	Coleoptera	Carabidae						3	3
3075	Coleoptera	Carabidae					1		1
3975	Coleoptera	Carabidae						1	1
3991	Coleoptera	Carabidae						2	2
4000	Coleoptera	Carabidae						2	2
566	Coleoptera	Carabidae		*Notonomus*	*mediosulcatus*			2	2
529	Coleoptera	Carabidae					2		2
2612	Coleoptera	Carabidae	Broscinae	*Cerotalis*	*substriata*			2	2
253	Coleoptera	Carabidae	Broscinae	*Promecoderus*	*sp*		1		1
280	Coleoptera	Carabidae	Carabinae	*Carenum*	*sp*			6	6
1442	Coleoptera	Carabidae	Esydrinae				6	4	10
264	Coleoptera	Carabidae	Harpalinae	*Cenogmus*	*sp*		4	1	5
914	Coleoptera	Carabidae	Licininae	*Dicrochile*	*sp*	6	1	5	12
654	Coleoptera	Cerambycidae	Cerambycinae	*Coptocercus*	*rubripes*			1	1

						Treatment			
Spec #	**Order**	**Family**	**Sub Taxa**	**Genus**	**Species**	**ER**	**SW/SC**	**GR**	**Total**
673	Coleoptera	Cerambycidae	Cerambycinae	*Stenoderus*	*suturalis*		1		1
4008	Coleoptera	Cerambycidae	Cermabycinae	*Bethelium*	*cleroides*	1			1
476	Coleoptera	Cerambycidae	Lamiinae	*Ancita*	*sp*		4	2	6
1082	Coleoptera	Cerambycidae	Prioninae	*Sceleocantha*	*pilosicollis*			1	1
667	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsis*	*sp*	1	1	1	3
913	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsis*	*sp*	1	2	1	4
112	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsisterna*	*sp*			1	1
308	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsisterna*	*sp*	1		3	4
463	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsisterna*	*sp*		2	1	3
665	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsisterna*	*sp*		1	1	2
677	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsisterna*	*sp*	8	1		9
786	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsisterna*	*sp*	2	5	1	8
803	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsisterna*	*sp*		1		1
1065	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsisterna*	*sp*		1	1	2
1205	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsisterna*	*sp*	1			1
1263	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsisterna*	*sp*	2			2
1752	Coleoptera	Chrysomelidae	Chrysomelinae	*Paropsisterna*	*sp*			1	1
1444	Coleoptera	Chrysomelidae	Chrysomelinae	*Trachymela*	*sp*	1			1
2651	Coleoptera	Chrysomelidae	Chrysomelinae	*Trachymela*	*sp*	1			1
3974	Coleoptera	Chrysomelidae	Cryptocephalinae					1	1
4012	Coleoptera	Cleridae		*Eleale*	*sp*		8		8
911	Coleoptera	Curculionidae					1		1
2973	Coleoptera	Curculionidae					1	1	2
3874	Coleoptera	Curculionidae						1	1
244	Coleoptera	Curculionidae				1	2	1	4
1183	Coleoptera	Curculionidae	Adelognatha	*Psapharus*	*inconspicuus*			1	1
3988	Coleoptera	Curculionidae	Amycterinae			1			1
496	Coleoptera	Curculionidae	Amycterinae	*Acantholophus*	*suturalis*	1			1
1523	Coleoptera	Curculionidae	Amycterinae	*Acantholophus*	*suturalis*		1		1
2356	Coleoptera	Curculionidae	Amycterinae	*Cucculothorax*	*sp*			1	1
1110	Coleoptera	Curculionidae	Aterpinae	*Pelororhinus*	*sulcirostris*			1	1
1182	Coleoptera	Curculionidae	Aterpinae	*Pelororhinus*	*sp*		1	2	3
209	Coleoptera	Curculionidae	Aterpinae	*Rhinaria*	*sp*	2	5	4	11
1225	Coleoptera	Curculionidae	Entiminae	*Leptopius*	*maleficus*	5			5
2088	Coleoptera	Curculionidae	Entiminae	*Mandalotus*	*sp*			1	1
113	Coleoptera	Curculionidae	Entiminae	*Polyphrades*	*aesalon*	1	3	1	5
3598	Coleoptera	Curculionidae	Erihininae	*Aonychus*	*sp*	1			1
488	Coleoptera	Curculionidae	Gonipterinae	*Gonipterus*	*sp*		3		3
1304	Coleoptera	Curculionidae	Gonipterinae	*Ipterogonus*	*sp*			4	4
98	Coleoptera	Curculionidae	Gonipterinae	*Oxyops*	*pictipennis*		2	2	4
161	Coleoptera	Curculionidae	Gonipterinae	*Oxyops*	*fasciata*		1		1
1278	Coleoptera	Curculionidae	Gonipterinae	*Oxyops*	*sp*	2	1		3
157	Coleoptera	Curculionidae	Rhadinosominae	*Rhadinosomus*	*lacordairei*	5	5	1	11
3935	Coleoptera	Dytiscidae						1	1
13	Coleoptera	Dytiscidae	Colymbetinae	*Rhantus*	*suturalis*	4	5	9	18
651	Coleoptera	Dytiscidae	Lancetinae	*Lancetes*	*lanceolatus*	8	17	26	51
1083	Coleoptera	Elateridae				1			1
1817	Coleoptera	Elateridae					1	1	2
3782	Coleoptera	Elateridae				1			1
4002	Coleoptera	Elateridae				1			1
621	Coleoptera	Elateridae						4	4
2186	Coleoptera	Elateridae	Agrypninae	*Chrostus*	*sp*			1	1
220	Coleoptera	Elateridae	Agrypninae	*Conoderus*	*sp*	5	1	4	10
444	Coleoptera	Elateridae	Agrypninae	*Conoderus*	*sp*			1	1

Spec #	Order	Family	Sub Taxa	Genus	Species	Treatment			Total
						ER	SW/SC	GR	
1109	Coleoptera	Elateridae	Agrypninae	*Conoderus*	*sp*		3	1	4
1818	Coleoptera	Elateridae	Agrypninae	*Conoderus*	*sp*	6	6	5	17
2871	Coleoptera	Elateridae	Agrypninae	*Conoderus*	*sp*	1	6		7
997	Coleoptera	Elateridae	Agrypninae	*Pseudaeolus*	*sp*			1	1
2674	Coleoptera	Elateridae	Agrypninae	*Pseudotetralobus*	*sp*	1			1
2408	Coleoptera	Elateridae	Pityobiinae	*Parablax*	*sp*	1			1
2625	Coleoptera	Geotrupidae		*Bolborhachium*	*dacoderum*	1			1
3943	Coleoptera	Geotrupidae	Bolboceratinae			1			1
14	Coleoptera	Hydrophilidae				116	43	157	316
1245	Coleoptera	Lucanidae		*Figulus*	*sp*		1		1
1994	Coleoptera	Lycidae					1		1
99	Coleoptera	Lycidae	Metriorrhynchinae			8	7	8	23
208	Coleoptera	Lycidae	Metriorrhynchinae				1		1
1992	Coleoptera	Lycidae	Metriorrhynchinae				2	1	3
2000	Coleoptera	Lycidae	Metriorrhynchinae			6			6
2412	Coleoptera	Lycidae	Metriorrhynchinae			1			1
189	Coleoptera	Scarabaeidae	Dynastinae	*Cryptodus*	*sp*	2	1	1	4
1160	Coleoptera	Scarabaeidae	Dynastinae	*Cryptodus*	*sp*			1	1
1945	Coleoptera	Scarabaeidae	Dynastinae	*Metanastes*	*sp*		6	1	7
1562	Coleoptera	Scarabaeidae	Dynastinae	*Trissodon*	*sp*			1	1
1853	Coleoptera	Scarabaeidae	Melolonthinae				1		1
1926	Coleoptera	Scarabaeidae	Melolonthinae			1			1
2652	Coleoptera	Scarabaeidae	Melolonthinae			1	5		6
353	Coleoptera	Scarabaeidae	Melolonthinae	*Colpochila*	*major*	4	9	1	14
1138	Coleoptera	Scarabaeidae	Melolonthinae	*Colpochila*	*andersoni*			2	2
2006	Coleoptera	Scarabaeidae	Melolonthinae	*Colpochila*	*sp*		2	2	4
55	Coleoptera	Scarabaeidae	Melolonthinae	*Colymbomorpha*	*vittata*	5	1	3	9
1985	Coleoptera	Scarabaeidae	Melolonthinae	*Diphucephala*	*sp*	3	3	1	7
3171	Coleoptera	Scarabaeidae	Melolonthinae	*Diphucephala*	*sp*	6	1		7
347	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	*sp*		3	1	4
359	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	*sp*		1		1
363	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	*sp*		5	8	13
1660	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	*sp*		1		1
1856	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	*sp*	1	5		6
1863	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	*sp*		1	1	2
1923	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	*sp*		1		1
1843	Coleoptera	Scarabaeidae	Melolonthinae	*Maechidius*	*sp*	1			1
668	Coleoptera	Scarabaeidae	Melolonthinae	*Phyllotocus*	*ustulatus*		1		1
3717	Coleoptera	Scarabaeidae	Melononthinae				11		11
17	Coleoptera	Scarabaeidae	Scarabaeinae	*Onthophagus*	*ferox*		2	1	3
3987	Coleoptera	Scarabaeidae	Scarabaeinae	*Onthophagus*	*sp*	7			7
924	Coleoptera	Silphidae	Silphinae	*Ptomaphila*	*lacrymosa*	1			1
1656	Coleoptera	Silphidae	Silphinae	*Ptomaphila*	*sp*		5		5
2815	Coleoptera	Staphylinidae					2	2	4
3989	Coleoptera	Staphylinidae						1	1
628	Coleoptera	Staphylinidae				1	2	2	5
1187	Coleoptera	Tenebrionidae						1	1
904	Coleoptera	Tenebrionidae	Lagriinae	*Adelium*	*sp*			1	1
1536	Coleoptera	Tenebrionidae	Lagriinae	*Adelium*	*sp*		2		2
192	Coleoptera	Tenebrionidae	Lagriinae	*Metriolagria*	*sp*	6		11	17
711	Coleoptera	Tenebrionidae	Stenochiinae	*Oectosis*	*sp*		4	1	5
778	Coleoptera	Tenebrionidae	Stenochiinae	*Oectosis*	*sp*		3	1	4
1307	Coleoptera	Tenebrionidae	Stenochiinae	*Oectosis*	*sp*	1		1	2
1721	Coleoptera	Tenebrionidae	Stenochiinae	*Oectosis*	*sp*			1	1

Spec #	Order	Family	Sub Taxa	Genus	Species	Treatment ER	SW/SC	GR	Total
1538	Dermaptera					2	4	8	14
1790	Dermaptera					1		6	7
3550	Dermaptera					2	2	4	8
4013	Dermaptera						1		1
491	Dermaptera					3	19	12	34
492	Dermaptera					4	5	5	14
734	Dermaptera						2	3	5
1433	Dermaptera	Anisolabididae				2	2		4
1678	Dermaptera	Anisolabididae					8	2	10
1723	Dermaptera	Anisolabididae				4	1	18	23
3529	Dermaptera	Anisolabididae				1		1	2
123	Dermaptera	Anisolabididae				2	1	3	6
258	Dermaptera	Anisolabididae					9	13	22
257	Dermaptera	Anisolabididae	Anisolabidinae				1	6	7
484	Dermaptera	Anisolabididae	Anisolabidinae				3	3	6
682	Dermaptera	Anisolabididae	Isolabelli				2		2
2528	Diplopoda						1	2	3
3378	Diplopoda					50	35	11	96
3401	Diplopoda						2		2
3536	Diplopoda							1	1
3557	Diplopoda						1	1	2
3611	Diplopoda							1	1
3857	Diplopoda							2	2
2070	Diplopoda	Craspedosomatida					1	1	2
876	Diplopoda	Julida				2	3	6	11
1526	Diplopoda	Julida						1	1
1546	Diplopoda	Julida						1	1
259	Diplopoda	Julida				6	11	5	22
260	Diplopoda	Julida				3		3	6
717	Diplopoda	Julida				1		2	3
2074	Diplopoda	Siphonophorida				1	1		2
127	Diptera	Anthomyiidae					1		1
1255	Diptera	Asilidae				3		1	4
1273	Diptera	Asilidae				1	1		2
1869	Diptera	Asilidae					1		1
2647	Diptera	Asilidae					1		1
2648	Diptera	Asilidae				1			1
2878	Diptera	Asilidae					1		1
3276	Diptera	Asilidae					2		2
313	Diptera	Asilidae					3	2	5
751	Diptera	Asilidae				2		1	3
775	Diptera	Asilidae						1	1
2670	Diptera	Athericidae					1		1
907	Diptera	Bombyliidae				1			1
3143	Diptera	Bombyliidae						1	1
719	Diptera	Bombyliidae					1		1
745	Diptera	Bombyliidae				14	10	5	29
929	Diptera	Calliphoridae				1	3	3	7
1634	Diptera	Calliphoridae						1	1
53	Diptera	Calliphoridae	Calliphorinae	*Calliphora*	*sp*	1	4	2	7
1419	Diptera	Calliphoridae	poor specimen					1	1
3866	Diptera	Conopidae				1			1
1725	Diptera	Lauxaniidae					1		1
1961	Diptera	Muscidae				2			2

						Treatment			
Spec #	**Order**	**Family**	**Sub Taxa**	**Genus**	**Species**	**ER**	**SW/SC**	**GR**	**Total**
3985	Diptera	Muscidae				1			1
624	Diptera	Pyrgotidae						1	1
3103	Diptera	Pyrgotidae					2		2
579	Diptera	Sarcophagidae					1	4	5
2044	Diptera	Stratiomyidae		*Exaireta*	*sp*		2		2
54	Diptera	Syrphidae				2	2	2	6
130	Diptera	Syrphidae				6	2	8	16
206	Diptera	Syrphidae				4	3	1	8
1203	Diptera	Syrphidae					2	4	6
1421	Diptera	Syrphidae				1	1		2
1422	Diptera	Syrphidae				1		1	2
1425	Diptera	Syrphidae				3			3
1983	Diptera	Syrphidae					1		1
2128	Diptera	Syrphidae					5		5
2220	Diptera	Syrphidae						3	3
129	Diptera	Syrphidae				6	1		7
473	Diptera	Tabanidae					1		1
901	Diptera	Tabanidae				1			1
1321	Diptera	Tabanidae				1			1
2875	Diptera	Tabanidae				1			1
2876	Diptera	Tabanidae						2	2
3523	Diptera	Tabanidae					1		1
126	Diptera	Tabanidae				6		4	10
178	Diptera	Tabanidae					3		3
495	Diptera	Tabanidae						1	1
1151	Diptera	Tachinidae				4			4
2035	Diptera	Tachinidae				1			1
2075	Diptera	Tachinidae					1		1
3872	Diptera	Tachinidae					1		1
3980	Diptera	Tachinidae				1	1		2
3981	Diptera	Tachinidae				1			1
3990	Diptera	Tachinidae						1	1
4001	Diptera	Tachinidae				7			7
498	Diptera	Tachinidae				7	1	7	15
142	Diptera	Therevidae				8	12	2	22
532	Diptera	Therevidae					13	8	21
577	Diptera	Tipulidae				1			1
16	Diptera	Tipulidae				149	65	82	296
2649	Diptera	Tipulidae	Limoniinae			1			1
969	Gastropoda					3	1	3	7
1330	Gastropoda					2			2
1431	Gastropoda					1			1
1527	Gastropoda					1	3		4
3971	Gastropoda						3	1	4
3992	Gastropoda							5	5
3999	Gastropoda					1			1
3873	Gastropoda	Charoipidae		*Pernagera*			1		1
1302	Hemiptera	Acanthosomatidae				1	4		5
2036	Hemiptera	Cicadellidae						1	1
3880	Hemiptera	Cicadellidae				1			1
200	Hemiptera	Cicadellidae					3		3
916	Hemiptera	Cicadidae					1		1
1851	Hemiptera	Cicadidae						1	1
1873	Hemiptera	Cicadidae						1	1

Spec #	Order	Family	Sub Taxa	Genus	Species	Treatment			Total
						ER	SW/SC	GR	
3944	Hemiptera	Cicadidae						1	1
207	Hemiptera	Cicadidae	Tibicininae	*Cicadetta*	*quadricinta*		2	1	3
700	Hemiptera	Coreidae	Coreinae	*Amorbus*	*bispinus*	6			6
221	Hemiptera	Cydnidae		*Adrisa*	*sp*	2	14	29	45
1524	Hemiptera	Dictyopharidae				1			1
1567	Hemiptera	Gelastocoridae	Nerthrinae	*Nerthra*	*sp*	1	1		2
2694	Hemiptera	Gelastocoridae	Nerthrinae	*Nerthra*	*sp*	1		1	2
482	Hemiptera	Hyocephalidae		*Hyocephalus*	*auprugnus*	1	1		2
108	Hemiptera	Membracidae				1	3		4
962	Hemiptera	Pentatomidae				1			1
1466	Hemiptera	Pentatomidae				2			2
2476	Hemiptera	Pentatomidae					2	3	5
3970	Hemiptera	Pentatomidae					1		1
4003	Hemiptera	Pentatomidae						1	1
2214	Hemiptera	Pentatomidae		*Cuspicona*	*sp*		1		1
2618	Hemiptera	Pentatomidae		*Cuspicona*	*sp*			2	2
1227	Hemiptera	Pentatomidae		*Ocirrhoe*	*unimaculata*	4	1		5
599	Hemiptera	Pentatomidae		*Oechalia*	*sp*	1	1		2
1195	Hemiptera	Pentatomidae		*Omyta*	*contralineata*		1		1
838	Hemiptera	Pentatomidae		*Oncocoris*	*sp*	1			1
3154	Hemiptera	Pentatomidae		*Poecilometis*	*lineatus*		3	1	4
669	Hemiptera	Pentatomidae		*Tholosanus*	*sp*			3	3
251	Hemiptera	Pentatomidae				3	2		5
153	Hemiptera	Pentatomidae		*Dictyotus*	*sp*	2	7	3	12
680	Hemiptera	Pentatomidae		*Poecilometis*	*puctiventris*			1	1
2066	Hemiptera	Pentatomidae	Pentatominae	*Platycoris*	*brunneus*	1	1	1	3
886	Hemiptera	Reduviidae				1			1
3986	Hemiptera	Reduviidae				1			1
433	Hemiptera	Reduviidae	Emesinae			1			1
2065	Hemiptera	Reduviidae	Emesinae			1			1
2049	Hemiptera	Reduviidae	Peiratinae				1		1
512	Hemiptera	Reduviidae	Peiratinae			1	2	2	5
3878	Hymenoptera	Anthophoridae					1		1
203	Hymenoptera	Anthophoridae					1		1
1264	Hymenoptera	Anthophoridae		*Amegilla*	*sp*			3	3
3844	Hymenoptera	Apidae					1		1
52	Hymenoptera	Apidae		*Apis*	*mellifera*	8	13	6	27
3861	Hymenoptera	Apidae	Anthophoridae					1	1
1258	Hymenoptera	Braconidae				1			1
2217	Hymenoptera	Braconidae					2		2
3826	Hymenoptera	Braconidae				1			1
3870	Hymenoptera	Braconidae					1		1
2989	Hymenoptera	Colletidae				1			1
3994	Hymenoptera	Colletidae					2		2
3995	Hymenoptera	Colletidae						1	1
3996	Hymenoptera	Colletidae				1	2	1	4
4010	Hymenoptera	Colletidae					2		2
696	Hymenoptera	Colletidae				2	2		4
2471	Hymenoptera	Colletidae	Colletinae			3	1		4
3383	Hymenoptera	Colletidae	Colletinae				5		5
545	Hymenoptera	Colletidae	Colletinae				2		2
546	Hymenoptera	Colletidae	Colletinae			1	1		2
4011	Hymenoptera	Colletidae	Hylaeinae				1		1
2001	Hymenoptera	Colletidae				1		4	5

Spec #	Order	Family	Sub Taxa	Genus	Species	Treatment			Total
						ER	SW/SC	GR	
500	Hymenoptera	Evaniidae						2	2
889	Hymenoptera	Formicidae				1			1
1497	Hymenoptera	Formicidae				1	2		3
275	Hymenoptera	Formicidae	Formicinae	*Camponotus*	*sp*		2		2
423	Hymenoptera	Formicidae	Formicinae	*Camponotus*	*sp*	16	29	34	79
1594	Hymenoptera	Formicidae	Formicinae	*Camponotus*	*sp*	1			1
1661	Hymenoptera	Formicidae	Formicinae	*Camponotus*	*sp*	1			1
222	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*analis*	3	10	9	22
252	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*chasei*	1			1
281	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*mandibularis*	1		4	5
408	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*sp*	32	8	2	42
487	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*clarki*	4		4	8
712	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*vindex*	1	1	6	8
1209	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*regularis*	11	2	11	24
1293	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*sp*	2	7	5	14
1535	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*pavida*		1	1	2
2046	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*michaelseni*		2		2
3362	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*rugosa*	2		1	3
3525	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*nigriceps*		1		1
3846	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	*erecta*			1	1
4004	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*				1	1
2982	Hymenoptera	Halictidae						1	1
3179	Hymenoptera	Halictidae				1		2	3
3982	Hymenoptera	Halictidae					1		1
3186	Hymenoptera	Halictidae	Halictinae					3	3
3871	Hymenoptera	Ichneumonidae					1		1
3932	Hymenoptera	Ichneumonidae					1		1
3933	Hymenoptera	Ichneumonidae	Braconidae					1	1
3862	Hymenoptera	Ichneumonidae	Campoleginae					1	1
1055	Hymenoptera	Ichneumonidae	Ophioninae	*Enicospilus*	*sp*	2	4	12	18
1156	Hymenoptera	Ichneumonidae	Ophioninae	*Enicospilus*	*sp*		1		1
2885	Hymenoptera	Ichneumonidae	Ophioninae	*Enicospilus*	*sp*			1	1
1146	Hymenoptera	Ichneumonidae	Ophioninae	*Leptophion*	*sp*		1		1
1038	Hymenoptera	Ichneumonidae	Tryphoninae					1	1
1165	Hymenoptera	Ichneumonidae	Tryphoninae			1			1
3979	Hymenoptera	Megachilidae					1		1
3997	Hymenoptera	Megachilidae						1	1
183	Hymenoptera	Megachilidae						1	1
1359	Hymenoptera	Mutillidae				1			1
1613	Hymenoptera	Mutillidae				5	5	1	11
2100	Hymenoptera	Mutillidae				1			1
2101	Hymenoptera	Mutillidae					1	1	2
2536	Hymenoptera	Mutillidae				1		2	3
3607	Hymenoptera	Mutillidae					1		1
3978	Hymenoptera	Mutillidae					1		1
3984	Hymenoptera	Mutillidae						1	1
580	Hymenoptera	Mutillidae				1	1	1	3
1550	Hymenoptera	Pergidae	Perginae	*Perga*	*klugii*		2	1	3
3376	Hymenoptera	Pompilidae					1		1
3864	Hymenoptera	Pompilidae						1	1
584	Hymenoptera	Pompilidae						1	1
612	Hymenoptera	Pompilidae					1		1
3941	Hymenoptera	Tiphiidae						1	1
3863	Hymenoptera	Tiphiidae	Thynninae					1	1

Spec #	Order	Family	Sub Taxa	Genus	Species	Treatment			Total
						ER	SW/SC	GR	
3867	Hymenoptera	Tiphiidae	Thynninae			1			1
1982	Hymenoptera	Tiphiidae	Thynninae	*Aeolothynnus*	*sp*	1	2	1	4
3868	Hymenoptera	Vespidae	Eueminae				1		1
544	Isopoda					33	35	44	112
549	Isopoda					23	7	3	33
1305	Isopoda					23	47	99	169
1586	Isopoda							1	1
1735	Isopoda							1	1
2053	Isopoda					5			5
2416	Isopoda					10	22	31	63
2675	Isopoda					1			1
2676	Isopoda					1			1
3399	Isopoda					1		3	4
262	Isopoda					1			1
539	Isopoda					1	3		4
540	Isopoda						3		3
671	Isopoda					14	4	4	22
2185	Lepidoptera					1			1
3466	Lepidoptera					2			2
3845	Lepidoptera					1			1
3876	Lepidoptera							1	1
3934	Lepidoptera					1			1
315	Lepidoptera					1			1
3847	Lepidoptera	Anthelidae		*Pterolocera*			1		1
381	Lepidoptera	Anthelidae	Anthelinae	*Anthela*	*sp*		7		7
457	Lepidoptera	Anthelidae	Anthelinae	*Anthela*	*ferruginosa*	3	2	1	6
6	Lepidoptera	Arctiidae				32	42	25	99
445	Lepidoptera	Arctiidae	Arctiinae	*Spilosoma*	*sp*		8	1	9
376	Lepidoptera	Arctiidae	Lithosiinae	*Castulo*	*doubledayi*	52	50	25	127
366	Lepidoptera	Arctiidae	Lithosiinae	*Scoliacma*	*sp*	24	16	7	47
2654	Lepidoptera	Arctiidae	Lithosiinae	*Scoliacma*	*aff. nana*	1			1
1519	Lepidoptera	Arctiidae	Lithosiinae	*Threnosia*	*sp*			4	4
1	Lepidoptera	Carthaeidae		*Carthaea*	*saturnioides*	7	6	12	25
3842	Lepidoptera	Cossidae				1			1
324	Lepidoptera	Depressariidae				3		1	4
141	Lepidoptera	Depressariidae		*Thalamarchella*	*alveola*	3	3		6
658	Lepidoptera	Gelechiidae					1		1
358	Lepidoptera	Geometridae						1	1
918	Lepidoptera	Geometridae						1	1
954	Lepidoptera	Geometridae						1	1
1161	Lepidoptera	Geometridae				1			1
1835	Lepidoptera	Geometridae					2	1	3
1857	Lepidoptera	Geometridae				1			1
2635	Lepidoptera	Geometridae						2	2
2637	Lepidoptera	Geometridae				1			1
2703	Lepidoptera	Geometridae				5			5
2891	Lepidoptera	Geometridae				1		1	2
3059	Lepidoptera	Geometridae				1	1		2
3512	Lepidoptera	Geometridae					1		1
3706	Lepidoptera	Geometridae				5	2	2	9
3897	Lepidoptera	Geometridae				2			2
3937	Lepidoptera	Geometridae				2			2
3939	Lepidoptera	Geometridae						1	1
3945	Lepidoptera	Geometridae						1	1

Spec #	Order	Family	Sub Taxa	Genus	Species	Treatment			Total
						ER	SW/SC	GR	
86	Lepidoptera	Geometridae				2			2
369	Lepidoptera	Geometridae					1		1
420	Lepidoptera	Geometridae				11	5	5	21
421	Lepidoptera	Geometridae				14	17	2	33
760	Lepidoptera	Geometridae				59	1		60
776	Lepidoptera	Geometridae				9	2	6	17
66	Lepidoptera	Geometridae	Ennominae			6	2	1	9
323	Lepidoptera	Geometridae	Ennominae			1	1	1	3
345	Lepidoptera	Geometridae	Ennominae					1	1
896	Lepidoptera	Geometridae	Ennominae					1	1
1831	Lepidoptera	Geometridae	Ennominae			3	1	2	6
3111	Lepidoptera	Geometridae	Ennominae			2	1	1	4
3843	Lepidoptera	Geometridae	Ennominae					1	1
3851	Lepidoptera	Geometridae	Ennominae				1	1	2
3936	Lepidoptera	Geometridae	Ennominae			1			1
24	Lepidoptera	Geometridae	Ennominae			2	3	5	10
47	Lepidoptera	Geometridae	Ennominae				1		1
61	Lepidoptera	Geometridae	Ennominae			1	1	1	3
85	Lepidoptera	Geometridae	Ennominae			1	1		2
318	Lepidoptera	Geometridae	Ennominae			7	17	12	36
383	Lepidoptera	Geometridae	Ennominae				1	2	3
422	Lepidoptera	Geometridae	Ennominae			13	6	4	23
655	Lepidoptera	Geometridae	Ennominae				3		3
694	Lepidoptera	Geometridae	Ennominae					1	1
434	Lepidoptera	Geometridae	Ennominae	*Amelora*	*sp*			1	1
436	Lepidoptera	Geometridae	Ennominae	*Casbia*		2	1	1	4
1518	Lepidoptera	Geometridae	Ennominae	*Ciampa*	*arietaria*	1			1
23	Lepidoptera	Geometridae	Ennominae	*Ectropis*	*sp*	18	8	10	36
50	Lepidoptera	Geometridae	Ennominae	*Euphronarcha*		1		2	3
375	Lepidoptera	Geometridae	Ennominae	*Fisera*	*sp*		1	1	2
2116	Lepidoptera	Geometridae	Ennominae	*Fisera*	*sp*		1		1
77	Lepidoptera	Geometridae	Ennominae	*Gastrinodes*	*sp*	1	2		3
403	Lepidoptera	Geometridae	Ennominae	*Melanodes*	*sp*	2	1		3
424	Lepidoptera	Geometridae	Ennominae	*Melanodes*	*sp*	2			2
757	Lepidoptera	Geometridae	Ennominae	*Melanodes*	*sp*			1	1
758	Lepidoptera	Geometridae	Ennominae	*Melanodes*	*sp*	10	1	1	12
449	Lepidoptera	Geometridae	Ennominae	*Paralaea*	*jarrah*	1			1
384	Lepidoptera	Geometridae	Ennominae	*Pholodes*	*sp*	4	1	1	6
858	Lepidoptera	Geometridae	Ennominae	*Stibaroma*	*melanotoxa*			2	2
450	Lepidoptera	Geometridae	Ennominae	*Thalaina*	*clara*		4	2	6
20	Lepidoptera	Geometridae	Ennominae	*Xanthorhoe*	*sp*		1		1
19	Lepidoptera	Geometridae	Geometrinae	*Chlorocoma*	*dicloraria*	1	14	5	20
22	Lepidoptera	Geometridae	Geometrinae	*Chlorocoma*	*sp*	5	11	7	23
330	Lepidoptera	Geometridae	Geometrinae	*Crypsiphona*	*ocultaria*	4	5	3	12
1179	Lepidoptera	Geometridae	Geometrinae	*Euloxia*	*sp*	3		1	4
41	Lepidoptera	Geometridae	Larentiinae			7	4	5	16
82	Lepidoptera	Geometridae	Larentiinae				1		1
83	Lepidoptera	Geometridae	Larentiinae			3	3	7	13
95	Lepidoptera	Geometridae	Larentiinae			12	3	12	27
317	Lepidoptera	Geometridae	Larentiinae			6	5	1	12
362	Lepidoptera	Geometridae	Larentiinae				1		1
641	Lepidoptera	Geometridae	Larentiinae			3	1	7	11
646	Lepidoptera	Geometridae	Larentiinae			1	9	1	11
652	Lepidoptera	Geometridae	Larentiinae			12	6	9	27

						Treatment			
Spec #	**Order**	**Family**	**Sub Taxa**	**Genus**	**Species**	**ER**	**SW/SC**	**GR**	**Total**
395	Lepidoptera	Geometridae	Larentiinae	*Anachloris*	*subochraria*	1	2		3
2630	Lepidoptera	Geometridae	Larentiinae	*Poecilasthena*	*sp*	11	7	24	42
42	Lepidoptera	Geometridae	Larentiinae	*Xanthorhoe*	*sp*	15	4	6	25
417	Lepidoptera	Geometridae	Larentiinae	*Xanthorhoe*	*sp*		1		1
455	Lepidoptera	Geometridae	Larentiinae	*Xanthorhoe*	*sp*	2	3	2	7
923	Lepidoptera	Geometridae	Oenochrominae			1	2		3
1516	Lepidoptera	Geometridae	Oenochrominae				1		1
3459	Lepidoptera	Geometridae	Oenochrominae				1		1
631	Lepidoptera	Geometridae	Oenochrominae	*Arcina*	*fulgorigera*	1	1		2
2	Lepidoptera	Geometridae	Oenochrominae	*Arhodia*	*lasiocamparia*	15	14	13	42
389	Lepidoptera	Geometridae	Oenochrominae	*Cernia*	*sp*	2			2
48	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*sp*	46	17	22	85
67	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*sp*	17	16	32	65
855	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*sp*	1			1
1155	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*sp*	1			1
2639	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*sp*		7		7
2905	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*sp*		1		1
3247	Lepidoptera	Geometridae	Oenochrominae	*Dichromodes*	*sp*	2			2
392	Lepidoptera	Geometridae	Oenochrominae	*Epidesmia*		4		2	6
31	Lepidoptera	Geometridae	Oenochrominae	*Oenochroma*	*sp*	3	5	3	11
72	Lepidoptera	Geometridae	Oenochrominae	*Oenochroma*	*sp*		1		1
320	Lepidoptera	Geometridae	Oenochrominae	*Oenochroma*			1	2	3
451	Lepidoptera	Geometridae	Oenochrominae	*Oenochroma*		2	1		3
377	Lepidoptera	Geometridae	Oenochrominae	*Phallaria*	*ophiusaria*	1			1
3940	Lepidoptera	Geometridae	Oenochrominae	*Taxiotus*	*sp*			1	1
958	Lepidoptera	Hepialidae		*Abantiades*	*sp*	2	1		3
373	Lepidoptera	Hepialidae		*Abantiades*	*ocellatus*	6	18	15	39
3998	Lepidoptera	Hesperiidae						2	2
1657	Lepidoptera	Lasiocampidae				1	1		2
1832	Lepidoptera	Lasiocampidae						1	1
426	Lepidoptera	Lasiocampidae	Lasiocampinae	*Entometa*	*sp*	1		1	2
3244	Lepidoptera	Limacodidae				3			3
1625	Lepidoptera	Limacodidae		*Doratifera*	*sp*		3	4	7
332	Lepidoptera	Limacodidae		*Doratifera*	*sp*	1			1
398	Lepidoptera	Limacodidae		*Doratifera*	*sp*	4	1	1	6
60	Lepidoptera	Lymantriidae				1	13	4	18
34	Lepidoptera	Lymantriidae		*Teia*	*athlophora*	6	6	7	19
80	Lepidoptera	Lymantriidae				6			6
657	Lepidoptera	Lymantriidae				1		2	3
2148	Lepidoptera	Lymantriidae						1	1
948	Lepidoptera	Noctuidae				1			1
1161	Lepidoptera	Noctuidae				1			1
3577	Lepidoptera	Noctuidae				1			1
3938	Lepidoptera	Noctuidae				1			1
33	Lepidoptera	Noctuidae					2	1	3
38	Lepidoptera	Noctuidae					3	4	7
140	Lepidoptera	Noctuidae					1		1
407	Lepidoptera	Noctuidae					2		2
185	Lepidoptera	Noctuidae	Agaristinae	*Periscepta*	*polysticta*			1	1
1150	Lepidoptera	Noctuidae	Amphipyrinae				1		1
2948	Lepidoptera	Noctuidae	Amphipyrinae				3		3
39	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*pissonephra*	40	34	55	129
75	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*melanographa*	2	27	10	39
388	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*poliocrossa*	4	8	5	17

						Treatment			
Spec #	Order	Family	Sub Taxa	Genus	Species	ER	SW/SC	GR	Total
414	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*sp*		1	9	10
452	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*epiplecta*	2	1		3
523	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*sp*	2		2	4
770	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*melanographa*	29		13	42
1139	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*sp*			2	2
1898	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*sp*		6		6
1899	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*sp*	1	1	5	7
2627	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*sp*		1		1
3104	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*sp*		1		1
3220	Lepidoptera	Noctuidae	Amphipyrinae	*Proteuxoa*	*sp*	7			7
415	Lepidoptera	Noctuidae	Catocalinae	*Lyncestis*	*melanoschista*	1	3		4
5	Lepidoptera	Noctuidae	Catocalinae	*Pantydia*	*sp*	5		1	6
329	Lepidoptera	Noctuidae	Catocalinae	*Pantydia*	*sparsa*	3		2	5
2882	Lepidoptera	Noctuidae	Catocalinae	*Pantydia*	*sp*	2		1	3
3051	Lepidoptera	Noctuidae	Catocalinae	*Praxis*	*sp*		1		1
25	Lepidoptera	Noctuidae	Hadeninae			4	3	6	13
391	Lepidoptera	Noctuidae	Hadeninae				1		1
405	Lepidoptera	Noctuidae	Hadeninae				1		1
40	Lepidoptera	Noctuidae	Hadeninae	*Persectania*	*ewingii*	2	2	4	8
336	Lepidoptera	Noctuidae	Heliothinae	*Helicoverpa*	*sp*			1	1
642	Lepidoptera	Noctuidae	Heliothinae	*Helicoverpa*	*sp*			1	1
133	Lepidoptera	Noctuidae	Heliothinae	*Heliothis*	*sp*		1		1
3507	Lepidoptera	Noctuidae	Heliothinae	*Heliothis*	*punctifera*		1		1
43	Lepidoptera	Noctuidae	Hypeninae	*Sandava*	*scitisigna*	3	4	3	10
419	Lepidoptera	Noctuidae	Noctuinae			2	3		5
18	Lepidoptera	Noctuidae	Noctuinae	*Agrotis*	*infusa*	3	10	29	42
686	Lepidoptera	Noctuidae	Nolinae	*Uraba*	*lugens*	3			3
659	Lepidoptera	Noctuidae	Plusiinae	*Chrysodeixis*	*argentifera*		2		2
3850	Lepidoptera	Notodontidae						1	1
4	Lepidoptera	Notodontidae		*Destolmia*	*sp*	17	7	11	35
76	Lepidoptera	Notodontidae		*Gallaba*	*sp*	2	3	3	8
750	Lepidoptera	Notodontidae				1		2	3
57	Lepidoptera	Notodontidae		*Danima*	*banksiae*	2		4	6
58	Lepidoptera	Notodontidae		*Sorama*	*bicolor*	5	2	2	9
1068	Lepidoptera	Notodontidae	Thaumetopoeinae				1		1
3	Lepidoptera	Notodontidae	Thaumetopoeinae	*Epicoma*	*sp*	6	2	3	11
32	Lepidoptera	Notodontidae	Thaumetopoeinae	*Epicoma*	*sp*		1		1
3251	Lepidoptera	Notodontidae	Thaumetopoeinae	*Epicoma*	*sp*		1		1
7	Lepidoptera	Notodontidae	Thaumetopoeinae	*Ochrogaster*	*sp*			3	3
10	Lepidoptera	Notodontidae	Thaumetopoeinae	*Ochrogaster*	*sp*	12	64	70	146
2655	Lepidoptera	Notodontidae	Thaumetopoeinae	*Ochrogaster*	*sp*	3			3
1256	Lepidoptera	Notodontidae	Thaumetopoeinae	*Tanystola*	*isabella*	1			1
594	Lepidoptera	Nymphalidae	Nymphalinae	*Vanessa*	*kershawi*	1			1
1201	Lepidoptera	Nymphalidae	Nymphalinae	*Vanessa*	*kershawi*	1	3	1	5
298	Lepidoptera	Nymphalidae	Satyrinae	*Heteronympha*	*merope dub*		2		2
1626	Lepidoptera	Oecophoridae					2		2
1840	Lepidoptera	Oecophoridae				46	18	22	86
2623	Lepidoptera	Oecophoridae					1		1
62	Lepidoptera	Oecophoridae				3		1	4
65	Lepidoptera	Oecophoridae						2	2
396	Lepidoptera	Oecophoridae				3		2	5
92	Lepidoptera	Oecophoridae	Oecophorinae			3	2	2	7
2642	Lepidoptera	Oecophoridae	Oecophorinae	*Euchaetis*	*sp*		1		1
325	Lepidoptera	Oecophoridae	Oecophorinae	*Zonopetala*	*clerota*		1		1

Spec #	Order	Family	Sub Taxa	Genus	Species	Treatment ER	SW/SC	GR	Total
374	Lepidoptera	Oenosandridae				32	12	23	67
518	Lepidoptera	Oenosandridae		*Discophlebia*	*lucasii*		1		1
3841	Lepidoptera	Papilionidae		*Danaus*	*plexipus*		1		1
3983	Lepidoptera	Pieridae		*Pieris*	*rapae*	1	2	2	5
864	Lepidoptera	Psychidae					1		1
63	Lepidoptera	Pyralidae				15	4	4	23
333	Lepidoptera	Pyralidae				6	11	3	20
1051	Lepidoptera	Pyralidae				6	3	4	13
1134	Lepidoptera	Pyralidae					2	1	3
1510	Lepidoptera	Pyralidae						1	1
2883	Lepidoptera	Pyralidae					1		1
2928	Lepidoptera	Pyralidae						1	1
2946	Lepidoptera	Pyralidae						1	1
2955	Lepidoptera	Pyralidae				1		2	3
3105	Lepidoptera	Pyralidae					1		1
3108	Lepidoptera	Pyralidae				1	9		10
3481	Lepidoptera	Pyralidae						1	1
3483	Lepidoptera	Pyralidae				1			1
3496	Lepidoptera	Pyralidae						1	1
3942	Lepidoptera	Pyralidae					1		1
342	Lepidoptera	Pyralidae				10	3	2	15
356	Lepidoptera	Pyralidae				1	1	2	4
397	Lepidoptera	Pyralidae	Crambidae			3		1	4
982	Lepidoptera	Pyralidae	Crambinae				6	3	9
979	Lepidoptera	Pyralidae	Crambinae	*Hednota*	*hoplitella*		1		1
2880	Lepidoptera	Pyralidae	Crambinae	*Hednota*	*vivittella*	1			1
460	Lepidoptera	Pyralidae	Epipaschiinae			4	1	2	7
1126	Lepidoptera	Pyralidae	Epipaschiinae			1			1
2759	Lepidoptera	Pyralidae	Epipaschiinae					1	1
73	Lepidoptera	Pyralidae	Epipaschiinae ?			4	4	5	13
322	Lepidoptera	Pyralidae	Nymphulinae	*Nymphula*	*nitens*	30	22	13	65
1628	Lepidoptera	Pyralidae	Pyraustinae				1		1
84	Lepidoptera	Pyralidae	Pyraustinae	*Uresiphita*	*ornithopteralis*	7	2	6	15
12	Lepidoptera	Pyralidae				15	2	6	23
1490	Lepidoptera	Pyralidae				3	9		12
2441	Lepidoptera	Pyralidae				1		1	2
2923	Lepidoptera	Pyralidae					1		1
3415	Lepidoptera	Pyralidae						1	1
328	Lepidoptera	Saturniidae		*Opodiphthera*	*helena*	241	81	150	472
319	Lepidoptera	Tineidae	Myrmecozelinae	*Moerarchis*	*clathrella*	3	1		4
943	Lepidoptera	Tortricidae						2	2
1172	Lepidoptera	UNIDENTIFIABLE				9	17	11	37
1184	Lepidoptera	Xylorictidae				1			1
1833	Lepidoptera	Xyloryctidae					2		2
1865	Lepidoptera	Xyloryctidae					1		1
1895	Lepidoptera	Xyloryctidae					1		1
316	Lepidoptera	Xyloryctidae				44	40	20	104
45	Lepidoptera	Zygaenidae		*Pollanisus*	*cupreus*	4	1	1	6
78	Lepidoptera	Zygaenidae		*Pollanisus*	*sp*	9	2		11
132	Mantodea	Amorphoscelidae	Paraoxypilinae	*Paraoxypilus*	*sp*	4	3	1	8
250	Mecoptera	Bittacidae		*Harpobittacus*	*phaeoscius*	4	3		7
908	Mecoptera	Bittacidae		*Harpobittacus*	*similis*	1			1
89	Mecoptera	Meropeidae		*Austromerope*	*poultoni*	1	1		2
3156	Mygalomorphae							1	1

						Treatment			
Spec #	**Order**	**Family**	**Sub Taxa**	**Genus**	**Species**	**ER**	**SW/SC**	**GR**	**Total**
3285	Mygalomorphae					1			1
3339	Mygalomorphae						2		2
3537	Mygalomorphae						1		1
3542	Mygalomorphae					1	1		2
3356	Mygalomorphae	Actinopodidae		*Missulena*	*granulosa*			1	1
1401	Mygalomorphae	Nemesiidae				2			2
1560	Mygalomorphae	Nemesiidae					1		1
3314	Mygalomorphae	Nemesiidae						1	1
567	Mygalomorphae	Nemesiidae		*Chenistonia*	*sp*			1	1
581	Mygalomorphae	Nemesiidae		*Chenistonia*	*sp*	2	2	2	6
1350	Mygalomorphae	Nemesiidae		*Chenistonia*	*sp*	3	6	4	13
283	Mygalomorphae	Nemesiidae				1			1
585	Mygalomorphae	Nemesiidae				5	7	3	15
1057	Neuroptera	Chrysopidae					1		1
2710	Neuroptera	Chrysopidae				1			1
360	Neuroptera	Hemerobiidae				2	1	2	5
1938	Neuroptera	Osmylidae				5	1		6
3402	Neuroptera	Osmylidae						2	2
400	Neuroptera	Osmylidae				24	16	26	66
2663	Oligochaeta						1		1
2971	Oligochaeta					1			1
3877	Oligochaeta							1	1
4007	Oligochaeta					1			1
2679	Oligochaeta	Megascolecidae				1		1	2
3858	Oligochaeta	Megascolecidae						1	1
3859	Oligochaeta	Megascolecidae				2			2
3865	Oligochaeta	Megascolecidae					2		2
3973	Oligochaeta	Megascolecidae						1	1
3977	Oligochaeta	Megascolecidae				2			2
3993	Oligochaeta	Megascolecidae					2		2
520	Oligochaeta	Megascolecidae	collective			6			6
2999	Onychophora					5	3		8
1447	Opilionida					1			1
1799	Opilionida						4	2	6
2921	Orthoptera	Acrididae				1			1
3136	Orthoptera	Acrididae						1	1
3370	Orthoptera	Acrididae						2	2
3436	Orthoptera	Acrididae		*Phaulacridium*	*vittatum*		1		1
174	Orthoptera	Acrididae				1	1		2
1323	Orthoptera	Acrididae	Catantopinae	*Adreppus*	*sp*			1	1
690	Orthoptera	Acrididae	Catantopinae	*Cedarinia*	*sp*			1	1
890	Orthoptera	Acrididae	Catantopinae	*Cedarinia*	*sp*	4	1	2	7
231	Orthoptera	Acrididae	Catantopinae	*Coryphistes*	*sp*	2	1	1	4
232	Orthoptera	Acrididae	Catantopinae	*Goniaea*	*vocans*		1		1
233	Orthoptera	Acrididae	Catantopinae	*Goniaea*	*sp*	2			2
272	Orthoptera	Acrididae	Catantopinae	*Goniaea*	*sp*		2		2
1470	Orthoptera	Acrididae	Catantopinae	*Goniaea*	*sp*		2	1	3
1984	Orthoptera	Acrididae	Catantopinae	*Goniaea*	*sp*			1	1
2019	Orthoptera	Acrididae	Catantopinae	*Goniaea*	*sp*	2			2
293	Orthoptera	Acrididae	Catantopinae	*Phaulacridium*	*crassum*	2		2	4
1349	Orthoptera	Gryllidae					1		1
3535	Orthoptera	Gryllidae					1		1
180	Orthoptera	Gryllidae					1		1
609	Orthoptera	Gryllidae					3	11	14

Spec #	Order	Family	Sub Taxa	Genus	Species	Treatment ER	SW/SC	GR	Total
3530	Orthoptera	Stenopelmatidae				1			1
526	Orthoptera	Stenopelmatidae	Henicinae	*Onosandrus*	*sp*	28	53	77	158
881	Orthoptera	Tettigoniidae				1			1
3849	Orthoptera	Tettigoniidae				1	1		2
2202	Phasmatodea							1	1
3272	Phasmatodea					1			1
3860	Phasmatodea							1	1
1314	Phasmatodea	Phasmatidae				1			1
303	Phasmatodea	Phasmatidae				1			1
785	Phasmatodea	Phasmatidae					1		1
2423	Platyhelminthes					1	2	2	5
2487	Platyhelminthes						2	1	3
3869	Platyhelminthes						1	1	2
3924	Platyhelminthes						2		2
3976	Platyhelminthes							1	1
4005	Platyhelminthes							1	1
1385	Platyhelminthes	Tricladida				1		1	2
1404	Platyhelminthes	Tricladida						1	1
1568	Platyhelminthes	Tricladida				1			1
521	Platyhelminthes	Tricladida				2			2
1600	Scorpionida					8	6	2	16
2683	Scorpionida					1			1
2693	Scorpionida					3	2	10	15
469	Scorpionida					4	7	3	14
1849	Trichoptera	Hydropsychidae					7		7
1852	Trichoptera	Hydropsychidae					1		1
2448	Trichoptera	Hydropsychidae				1			1
2903	Trichoptera	Hydropsychidae					5		5
144	Trichoptera	Hydropsychidae				12	22	26	60
145	Trichoptera	Hydropsychidae				4	5	4	13
146	Trichoptera	Hydropsychidae					3		3
					TOTAL	2298	1904	2057	6259