Department of Biodiversity, Conservation and Attractions
Biodiversity and Conservation Science

FORESTCHECK

REPORT OF PROGRESS – Jarrah South ecosystem 2020

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This report highlights preliminary results for FORESTCHECK monitoring, determined by basic analysis and field observation. This and previous FORESTCHECK Progress 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 periodically. All FORESTCHECK publications and reports are available on the DBCA web site at www.dbca.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 Easter block photographed (top) in February 2011 during the peak of defoliation caused by outbreak of the gum-leaf skeletoniser (*Uraba lugens*) and (bottom) in March 2020 illustrating recovery of the overstorey canopy (photos: L. McCaw).

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EXECUTIVE SUMMARY

This report provides a summary of activities from the FORESTCHECK monitoring project relating to the Jarrah South ecosystem. Eight monitoring grids were established in 2013 to provide examples of silviculture implemented during the period of the Forest Management Plan 2004–2013. Three grids were established in the Strahan Cattaminup Jigsaw Landscape Management Unit (Boyndaminup and Gobblecannup forest blocks), and five in the Northern karri Landscape Management Unit (Carter, Lewin and Barlee blocks). Grids were established in forest stands that were either uncut or in forest subject to timber harvesting (shelterwood, selective cut and gap release treatments). An existing external reference grid in Easter block established in 2001 was included as a reference for the Lewin and Barlee harvested grids.

These monitoring grids were re-surveyed between March 2018 and April 2020 for a range of attributes including forest structure, regeneration stocking and litter load. Species richness and abundances of vascular plants were re-scored on fixed quadrats. Remote sensor cameras were used to detect activity and abundance of vertebrate fauna including mammals, birds and reptiles. One grid (FC55, Lewin block) was burnt by prescribed fire in November 2018 during the monitoring period, and a second grid (FC49, Boyndaminup block) was burnt in May 2020 after most monitoring activity had been completed. No grids were burnt by unplanned bushfire between 2013 and 2020.

Findings from re-measurement of FORESTCHECK monitoring grids include:

- Between 2013 and 2020 basal area of jarrah increased on all monitoring grids by an amount ranging from 1.1-4.9 m^2ha^{-1}. Total stand basal area also increased on seven of the nine monitoring grids, with two grids declining in basal area due to the loss of large mature marri. Projected foliage cover increased on all grids.
- Repeated measurements at the Easter external reference grid FC10 in 2002, 2008, 2013 and 2020 highlight the fact that old-growth stands are dynamic, and that this stand may be responding to a variety of influences including climate variability and temporary disturbance from defoliation by gumleaf skeletoniser (*Uraba lugens*) during the summers of 2010–11 and 2011–12.
- Litter loads increased on the eight grids that remained unburnt between 2013 to 2020, with the rate of accumulation broadly consistent with predictions from the WA Forest Fire Behaviour Tables. A lesser change in litter load was measured on the grid burnt by mild, patchy fire.
- Over the five years between monitoring events vascular plant species richness declined by 17-20% with the magnitude of decline following the same order as the collective species richness of each set of grids (Carter>Boyndaminup/Gobblecannup>Barlee/Easter/Lewin). This finding is consistent with other studies that have examined changes in the observed floristic composition of south-west forests following fire.
- Quokka were detected on six monitoring grids in 2019 and were present in Gobblecannup/Boyndaminup, Carter and Easter/Lewin forest blocks. Quokka were detected at one external reference grid and all harvested grids indicating that habitat suitable for quokka can develop within a decade of harvesting.
- Feral cats were detected by camera trapping at grids in Carter and Lewin blocks where they had not been detected by trapping in 2013. This is more likely to reflect a reluctance by cats to enter wire cage traps than a change in distribution.
- These findings demonstrate the benefits of remote sensor cameras for detecting activity by medium-sized vertebrates. Camera trapping is less intrusive for animals and involves a considerably reduced commitment of staff time. A potential downside of camera trapping is greater uncertainty in identification of small mammal species.
- Detections of mammals at FC10 in Easter block remain at a low level despite this grid being in old-growth jarrah forest unburnt since 1995. This finding suggests that habitat structure alone may not adequately explain patterns of occupancy for vertebrate fauna, and that fauna population modelling based on habitat attributes should be verified with independent field data.

1. INTRODUCTION

Scope
This report provides a summary of activities undertaken for the FORESTCHECK monitoring project. The aim of the report is to detail activities carried out between 2018 and 2020 in the Jarrah South forest ecosystem within the Donnelly District and to present preliminary interpretations and analyses of the data collected. A report on the findings of previous monitoring of these grids in 2013 can be viewed at www.dbca.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. The initial focus of FORESTCHECK has been on timber harvesting and silvicultural treatments in jarrah (*Eucalyptus marginata*) forest, with staff salaries contributed by the Department of Biodiversity, Conservation and Attractions (the Department) and its predecessors and operational funds provided through Service 8 Implementation of the Forest Management Plan. Monitoring has also been extended to examine ecological responses to fire including the use of prescribed as a land management tool and unplanned bushfires which have, over the course of the project, affected a number of monitoring grids.

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

Staff from the Ecosystem Science Program in the Department's Biodiversity and Conservation Science Directorate are responsible for implementing FORESTCHECK monitoring. Monitoring prototcols were developed with input from scientists and managers within the Department 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. Progress Reports, the Concept Plan and Operations Plan may be viewed on the Department's website at www.dbca.wa.gov.au. Protocols are updated peridocially to incorporate new understandings and technologies, while acknowledging the need to ensure data are consistent and comparable over decadal timescales.

Monitoring strategy
During the period 2004-2013 timber harvesting in jarrah forest was undertaken according to Sustainable Forest Management Guideline No.1 (Anon. 2004), which recognized three silvicultural objectives:

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

Due to past management practices or limits on culling of unmerchantable trees, some areas of jarrah forest are treated as 'selective cut'. Selective cut stands are prescribed burnt in conjunction with burns for other purposes.

Gap creation and shelterwood are the most widespread silvicultural treatments and involve the greatest extent of disturbance to the forest. Selective cutting has been monitored where the structure of the forest dictates that this treatment is undertaken on a significant scale.

FORESTCHECK monitoring sites have been established at a number of locations throughout the jarrah forest, stratified according to recognized ecological gradients of rainfall, evapo-transpiration and soil fertility. Forest ecosystem mapping by Mattiske and Havel (1998, 2000) provides a systematic basis for stratification of sampling. Allocation of sites also takes account of scheduled future harvesting, with priority given to those jarrah forest 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, where available:

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 external reference forest has in a few cases been located some distance from harvested counterparts. Also, it may not always be possible to find gap release and shelterwood treatments together, because underlying relationships between rainfall, soil fertility and jarrah lignotuber development influence the broad pattern of silvicultural treatment across the jarrah forest, as have previous silvicultural activities.

Methodology

Monitoring of biodiversity is based on a standard sampling grid (see Fig. 1.1). The main grid is 200m x 100m, with a central area of 100m x 100m. Since establishment, a range of ecosystem attributes have been monitored on each grid including:

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

Sampling methodologies for each set of ecosystem attributes are described in the FORESTCHECK Operations Plan, together with examples of protocols for data collection and storage. The second round of monitoring undertaken between 2018 and 2020 focussed on a subset of attributes for which expertise and resources were available within the Ecosystem Science program. Remote sensor cameras were used to monitor vertebrate fauna activity for the second round of assessment replacing direct trapping techniques based on wire cage and pitfall traps.

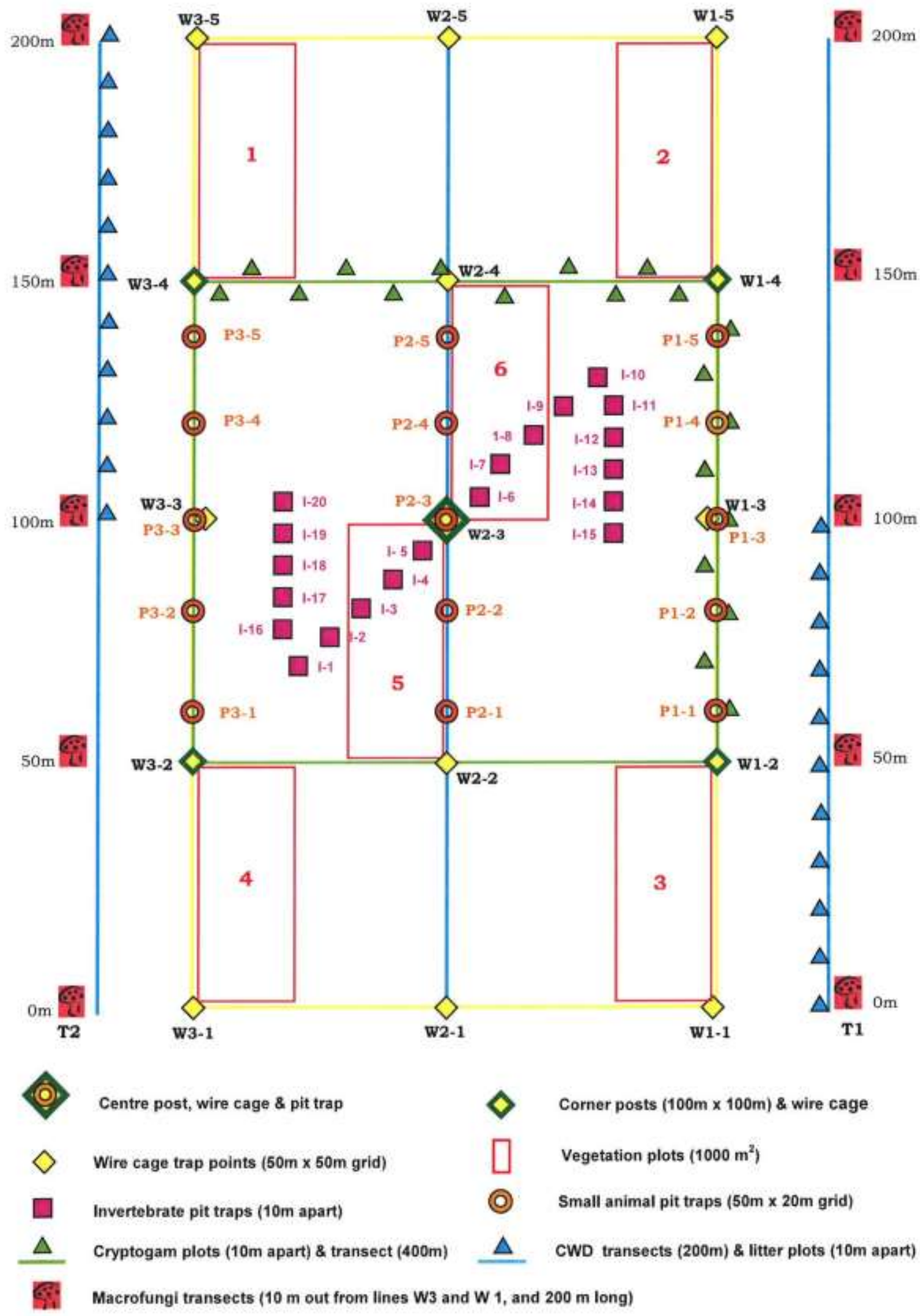

Figure 1.1 FORESTCHECK grid layout

Monitoring in the Jarrah Forest South ecosystem 2018-20

Eight FORESTCHECK monitoring grids were established within three locations in Jarrah South forest ecosystem in the Donnelly District in 2013 (Table 1.1). The Forest Management Plan 2014-23 introduced the concept of Landscape Management Units (LMU) as a subdividion of forest ecosystems and are referred to in this report, where appropriate. Three grids (FC49, FC50 and FC51) were established in the Strahan Cattaminup Jigsaw LMU (Boyndaminup and Gobblecannup forest blocks) (Fig. 1.2), and five in the Northern karri LMU (Carter, Lewin and Barlee blocks) (Figs 1.3 & 1.4). An existing external reference grid (FC10, Easter block) was used as the reference for the silviculturally treated grids in Lewin and Barlee and provided an opportunity to extend the chronological sequence of observations from an example of mature jarrah forest in the high rainfall zone.

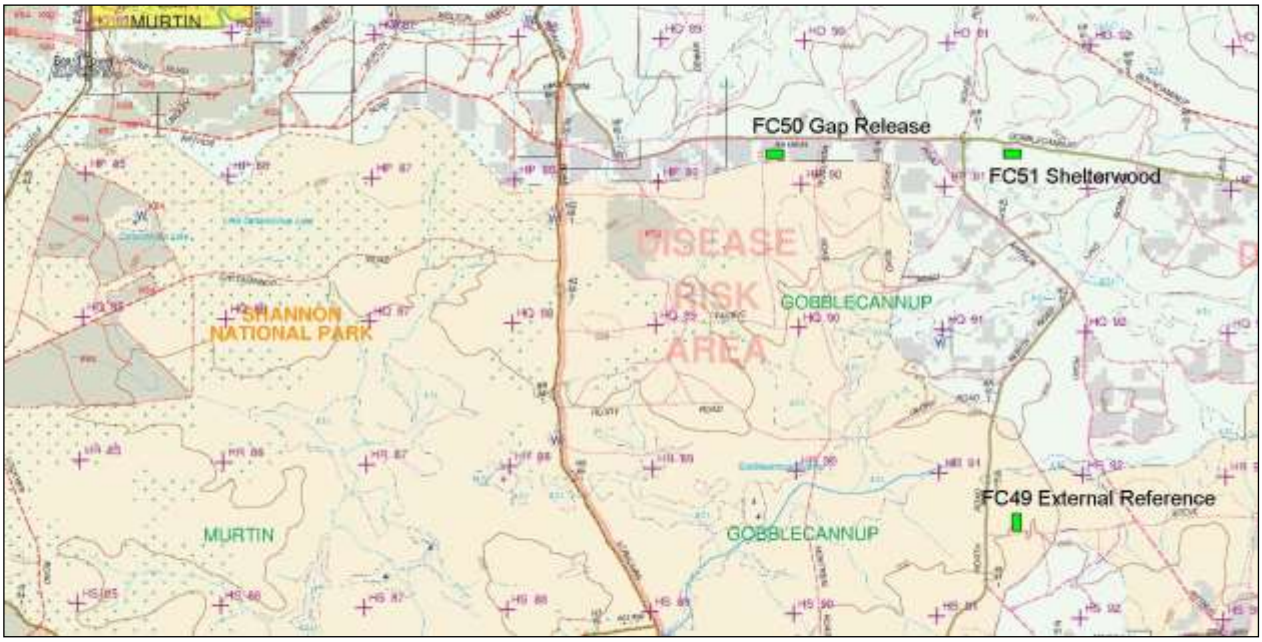

Figure 1.2 Locations of FORESTCHECK monitoring grids in the Strahan Cattaminup LMU

Figure 1.3 Locations of FORESTCHECK monitoring grids in Carter block in the Northern karri LMU

Figure 1.4 Locations of FORESTCHECK monitoring grids in Lewin and Barley blocks, and FC10 in Easter block in the Northern karri LMU

All nine grids are located in the Bevan 1 vegetation complex of Mattiske and Havel (1998). This complex is charatcerised by tall open forests of marri-jarrah (*Corymbia calophylla-Eucalyptus marginata* subsp. *marginata*) on uplands in perhumid and humid zones.

Table 1.1 Location (forest block) and site attributes of FORESTCHECK monitoring grids in the Jarrah Forest South ecosystem established in 2013 and re-measured in 2018-20.

Treatment & Forest block	Burnt		Harvested		Landscape Management Unit
	Year and type of burn[1]	Years since fire in 2020[2]	Year	Years since treatment[2]	
External reference					
FC49 Boyndaminup	Sp 2009 (prescribed) 05/2020 (prescribed)	11	Uncut		Strahan Cattaminup Jigsaw
FC54 Carter	Sp 2007 (prescribed)	13	Uncut		Strahan Cattaminup Jigsaw
FC10 Easter	Su 1995 (Bushfire)	25	Uncut		Strahan Cattaminup Jigsaw
Shelterwood/selective cut*					
FC51 Boyndaminup*	Sp 2008 (prescribed)	12	2007	13	Northern karri
FC53 Carter	Sp 2007 (prescribed)	13	2007	13	Northern karri
FC56 Barlee	Sp 2004 (prescribed)	16	2006	14	Northern karri
Gap release					
FC50 Gobblecannup	Sp 2008 (prescribed)	12	2006	14	Northern karri
FC52 Carter	Sp 2006 (prescribed)	14	2006	14	Northern karri
FC55 Lewin	12/2018 (prescribed)	2	2004	16	Northern karri

[1] Su = summer, Sp= spring, Au = autumn
[2] Years since fire or completion of regeneration treatment as of 1 April 2020

Two external reference grids (FC10 and FC49) are situated in uncut forest within the Easter National Park and Shannon National Park respectively. Occasional old stumps in the Boyndaminup external reference grid (FC49) remain from selective harvested in the decade 1960-69. The Carter external reference grid (FC54) is located within a fauna habitat zone adjacent to harvested forest, and although there is no record of any harvesting scattered cut stumps are also present within this stand. The remaining grids are in forest harvested during the period 2004–07 and represent examples of selective cutting (FC51), shelterwood (FC53, FC56) and gap release (FC50, FC52, FC55) (Table 1.1). All grids were harvested during the period of the Forest Management Plan 2004–2013 (Conservation Commission 2004) following the practices described in Sustainable Forest Management Guideline No. 1 (Anon. 2004).

Grid photographs

Reference photographs of each grid taken in June/July 2013 were repeated in April 2020 (Figs. 1.5–1.13). Photographs were taken from a standard photo point at peg W2-1 looking towards the centre peg (W2-3) (refer to Fig. 1.1) providing a reference point for observing changes in vegetation structure and condition.

Fire

Grid FC55 was burnt in early December 2018 as part of a 2240 ha prescribed fire (DON_079). Post-burn survey indicated that about 30% of the grid area was burnt by mild fire with crown scorch heights of 6 m or less. Grid FC49 was burnt in early May 2020 as part of a 700 ha cell in prescribed burn DON_099. Post-burn survey indicated that about 70% of the grid area was burnt by mild fire with crown scorch heights of 6 m or less (Fig. 1.14).

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Figure 1.5 FC49 Boyndaminup external reference (L) in 2013 and (R) in 2020

Figure 1.6 FC50 Gobblecannup gap release (L) in 2013 and (R) in 2020

Figure 1.7 FC51 Boyndaminup shelterwood/selective (L) in 2013 and (R) in 2020

Figure 1.8 FC54 Carter external reference (L) in 2013 and (R) in 2020

Figure 1.9 FC53 Carter shelterwood (L) in 2013 and (R) in 2020

Figure 1.10 FC52 Carter gap release (L) in 2013 and (R) in 2020

Figure 1.11 FC10 Easter external reference (L) in 2013 and (R) in 2020

Figure 1.12 FC56 Barlee shelterwood/selective (L) in 2013 and (R) in 2020

Figure 1.13 FC55 Lewin gap release (L) in 2013 and (R) in 2020

Figure 1.14 Photo of FC49 Boyndaminup taken in June 2020 showing forest burnt by low intensity prescribed fire with residual white ashbed from combustion of a marri log.

2. FOREST STRUCTURE AND REGENERATION STOCKING

Lachlan McCaw and Verna Tunsell

Introduction

The adequacy of regeneration following harvesting and silvicultural treatment is one of the core indicators of ecologically sustainable forest management (ESFM). The current framework of regional level indicators provides for assessment of the area and per cent of harvested area of native forest effectively regenerated (Indicator 2.1.g). This is recognised as a Category A indicator that can be reported upon immediately (Commonwealth of Australia 1998). Regeneration outcomes are assessed as a matter of routine on a sample of the area subject to harvesting and silvicultural treatment in south-west forests (Department of Parks and Wildlife 2014; McCaw 2011).

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, current stand structure and stocking level of saplings and ground coppice 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 nine monitoring grids in jarrah forest in Donnelly District, including one grid (FC10) that had been assessed on three previous occasions in 2002, 2008 and 2013. The location of these grids is referred to as Donnelly 2. Field work was undertaken during autumn 2020.

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 2 m were measured along transects 100 m long by 4 m wide located between marker pegs W1-2 to W1-4 and W3-2 to W3-4 (see Fig. 1.1 on page 4). To improve reliability of long-term measurements of tree growth, mortality and tree fall all stems ≥20cm diameter at breast height were identified with numbered tags. The height and species of regeneration was assessed at four locations on each grid to indicate the rate of regrowth.

Projected foliage cover was measured in winter 2019 by recording intercepts with foliage at 1 m intervals along three 100 m long transects (n= 300 points) defined by pegs 1.2-1.4, 2.2-2.4 and 3.2-3.4. A vertical periscope fitted with a fine crosshair was used to identify intercepts with foliage in height classes of 2-15m and >15m. Contacts with eucalypt foliage were recorded separately to contacts with other plant species.

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

Stand structure and species composition

Eucalypt basal area on external reference grids ranged from 55.8–59.6 m^2ha^{-1} with jarrah contributing 60% or more of the total basal area (Table 2.1). Jarrah basal area on external reference grids increased by 1.1-2.3 m^2ha^{-1} over the six-year period between measurements with slightly smaller increases in marri basal area on grids FC49 Boyndaminup and FC54 Carter. Marri basal area reduced substantially on grid FC10 Easter due to death of a mature tree with a stem diameter of 140 cm.

Basal area on the two shelterwood and the selective cut grids ranged from 25.8–38.4m^2ha^{-1}. Jarrah dominated the basal area on the shelterwood grids at FC53 Carter and FC56 Barlee, with a more even contribution of jarrah and marri at FC51 Boyndaminup selective cut. Jarrah basal area increased by 3.3-4.9 m^2 ha^{-1} and marri basal area by 0.4-9 m^2 ha^{-1} over the seven-year period between measurements.

Live basal area on gap release grid FC50 at Gobblecannup increased from 9.2m^2 ha^{-1} in 2013 to 18.9m^2 ha^{-1} in 2020 with 60% of this increment comprised of marri. Live basal area declined at the Carter grid (FC52) due to the loss of a large mature marri, although this was offset by increment on jarrah and on remaining marri trees. The gap release grid at Lewin (FC55) maintained a high basal area due to several very large jarrah trees sampled on the transect between points W1.2 and W1.4. Marri also contributed around half the standing basal area and basal area increment on this grid. The Lewin gap release grid and Carter shelterwood retained a substantial basal area of dead trees (>10m^2ha^{-1}), as was also the case in 2013.

Table 2.1 Basal area of eucalypts >2 m tall for nine FORESTCHECK grids in the Jarrah Forest South ecosystem in 2020

Treatment/Grid	Basal area 2020 (m^2ha^{-1})			Basal area increment (m^2ha^{-1})		Mean annual increment ($m^2ha^{-1}yr^{-1}$)
	Jarrah	Marri	Total	Jarrah	Marri	
External reference						
FC49 Boyndaminup	34.44	25.14	59.58	2.33	1.74	0.58
FC54 Carter	37.20	22.45	59.65	1.14	0.68	0.26
FC10 Easter	36.83	19.05	55.88	1.70	-18.34	-2.38
Shelterwood/ Selective cut						
FC51 Boyndaminup	14.59	11.20	25.79	3.97	0.36	0.62
FC53 Carter	28.18	8.11	36.29	4.93	8.99	1.99
FC56 Barlee	30.69	7.68	38.37	3.30	2.01	0.76
Gap release						
FC50 Gobblecannup	9.13	9.84	18.96	3.97	5.81	1.40
FC52 Carter	17.24	11.44	28.68	1.92	-11.36	-1.35
FC55 Lewin*	18.48	38.93	57.41	2.28	4.05	0.90
FC55 Lewin	35.63	32.68	68.31	3.69	3.07	0.97

*Data for Sections 3.3-3.3 and 3.3-3.4 only

Mid-storey species recorded included *Banksia grandis and Xanthorrhoea preissii* but their contribution to total basal area on eight of the grids was small (<1m^2ha^{-1}), except for external reference grid FC54 at Carter block (Fig. 2.1).

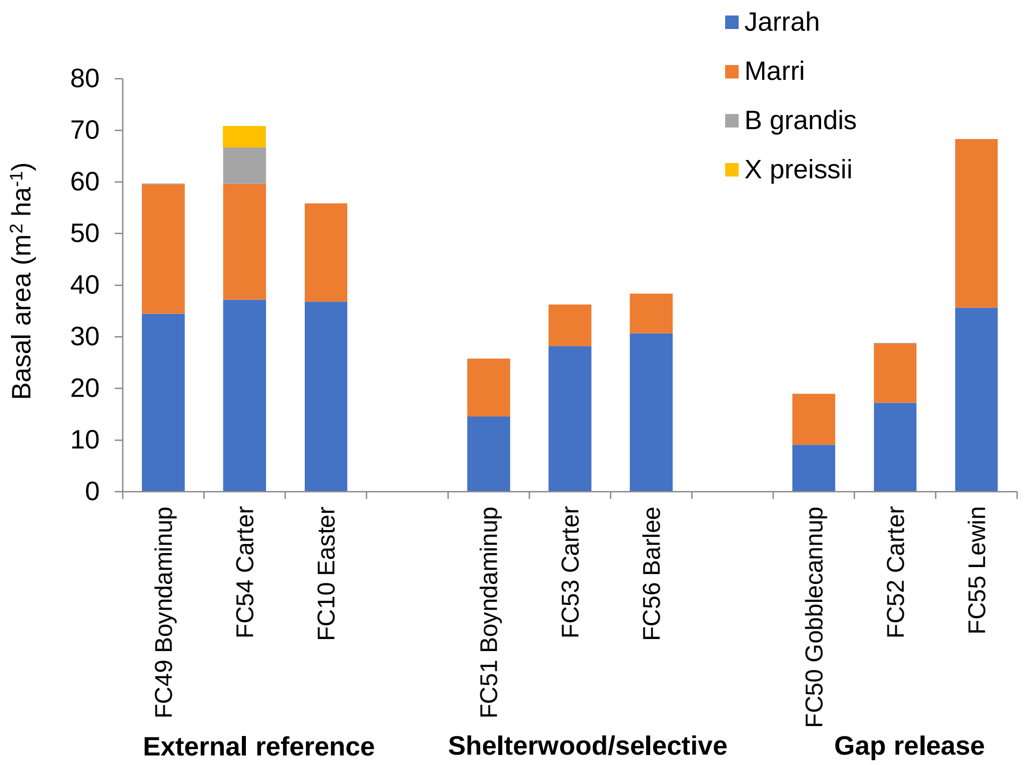

Figure 2.1 Basal area (m^2ha^{-1}) of jarrah, marri and mid-storey species on nine grids at Donnelly 2 in 2020

Stem diameter distributions of eucalypts and mid-storey trees on grids in each treatment are shown in Figures 2.2–2.4. Very large trees including both marri and jarrah with diameter >100cm were recorded on external reference grids at Carter and Easter, and on gap release grids at Carter and Lewin.

External reference grid FC10 Easter has been measured on four occasions between 2002 and 2020 providing the opportunity to examine change in an old-growth stand in the absence of fire. Basal area contributed by trees in three size classes (dbh <20 cm, 20-70 cm, > 70 cm) is shown in Fig. 2.5. Between 2002 and 2020 the basal area of trees <20 cm dbh increased from $4.4m^2ha^{-1}$ to $10m^2ha^{-1}$, and the proportion of stand basal area contributed by this size class increased from 6% to 18%. Trees in the intermediate size class 20-70 cm dbh contributed about 23% of stand basal area with little change over between 2002 and 2020. Mature trees >70cm dbh made the largest contribution to basal area in both actual and percentage terms, although this reduced due to moratlity of very large marri between 2013 and 2020. It is possible that severe defoliation caused by the gum-leaf skeletoniser (*Uraba lugens*) in 2010/11 may have contributed to the declining condition and eventual death of this tree (refer to cover images).

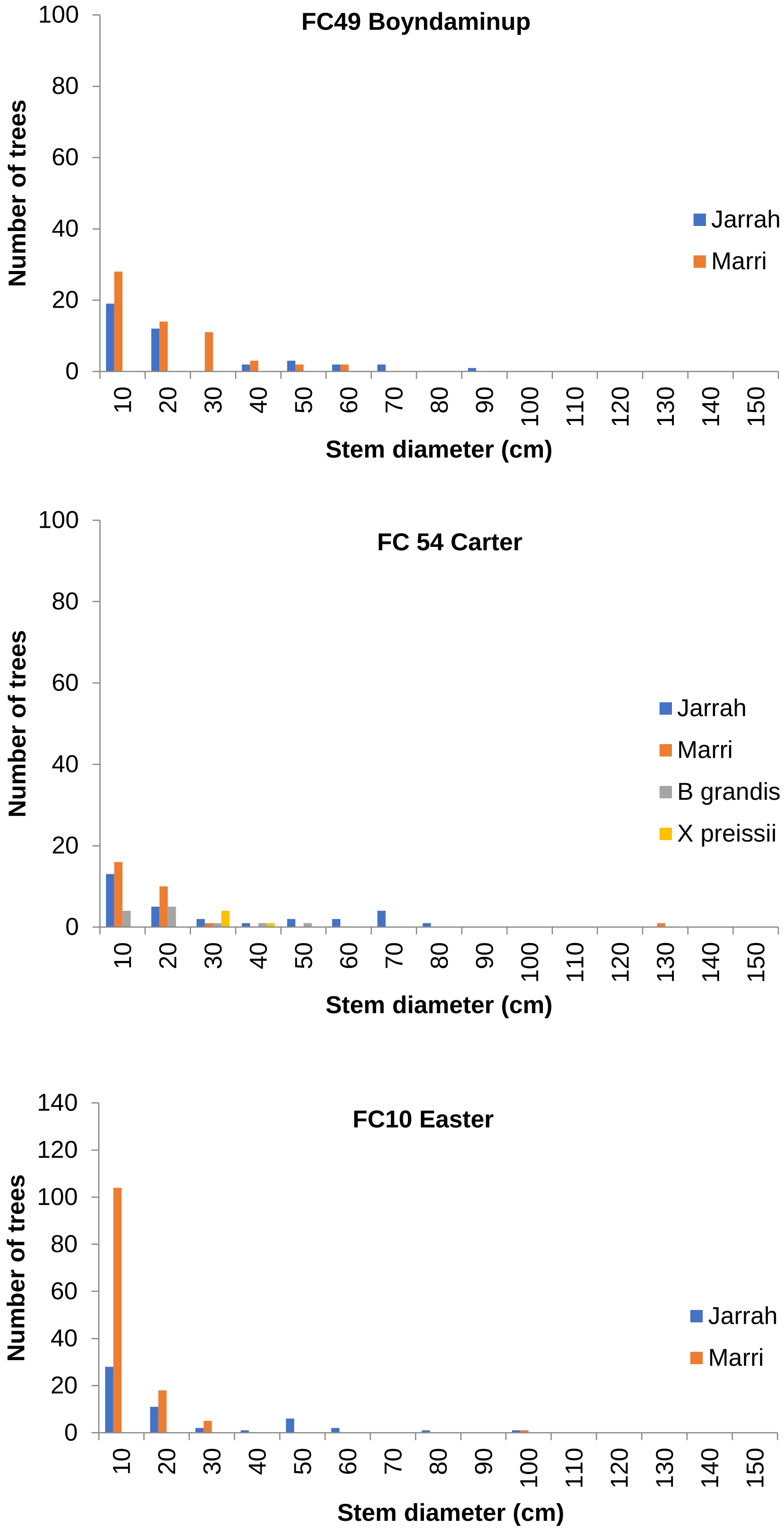

Figure 2.2 Stem diameter distribution by 10cm classes (0–9cm, 10–19cm etc.) for three external reference grids. Note the different scale on the vertical axis for FC10 Easter.

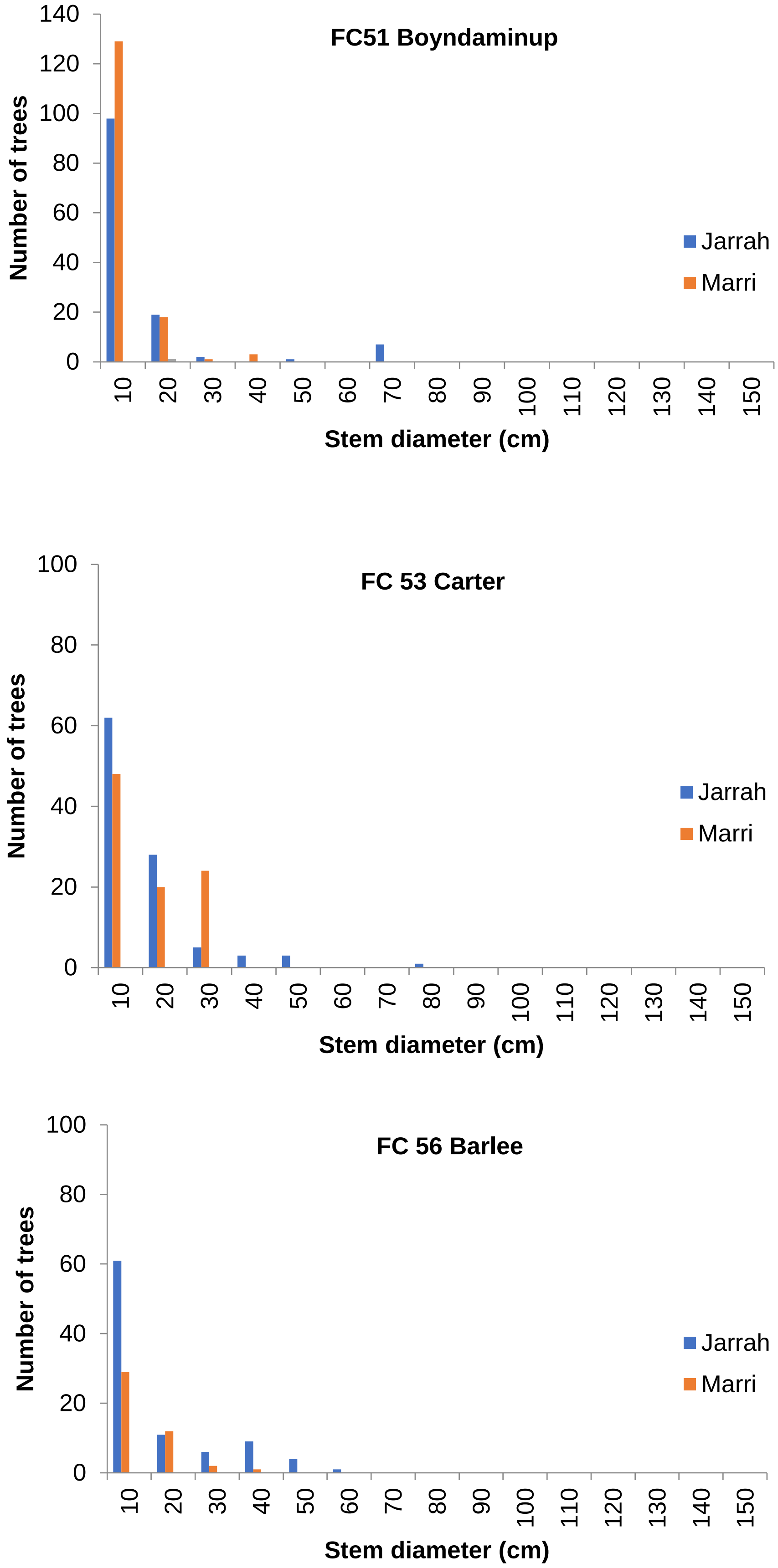

Figure 2.3 Stem diameter distribution by 10cm classes (0–9cm, 10–19cm etc.) for two shelterwood and one selective cut grid. Note the different scale on the vertical axis for FC51 Boyndaminup selective cut.

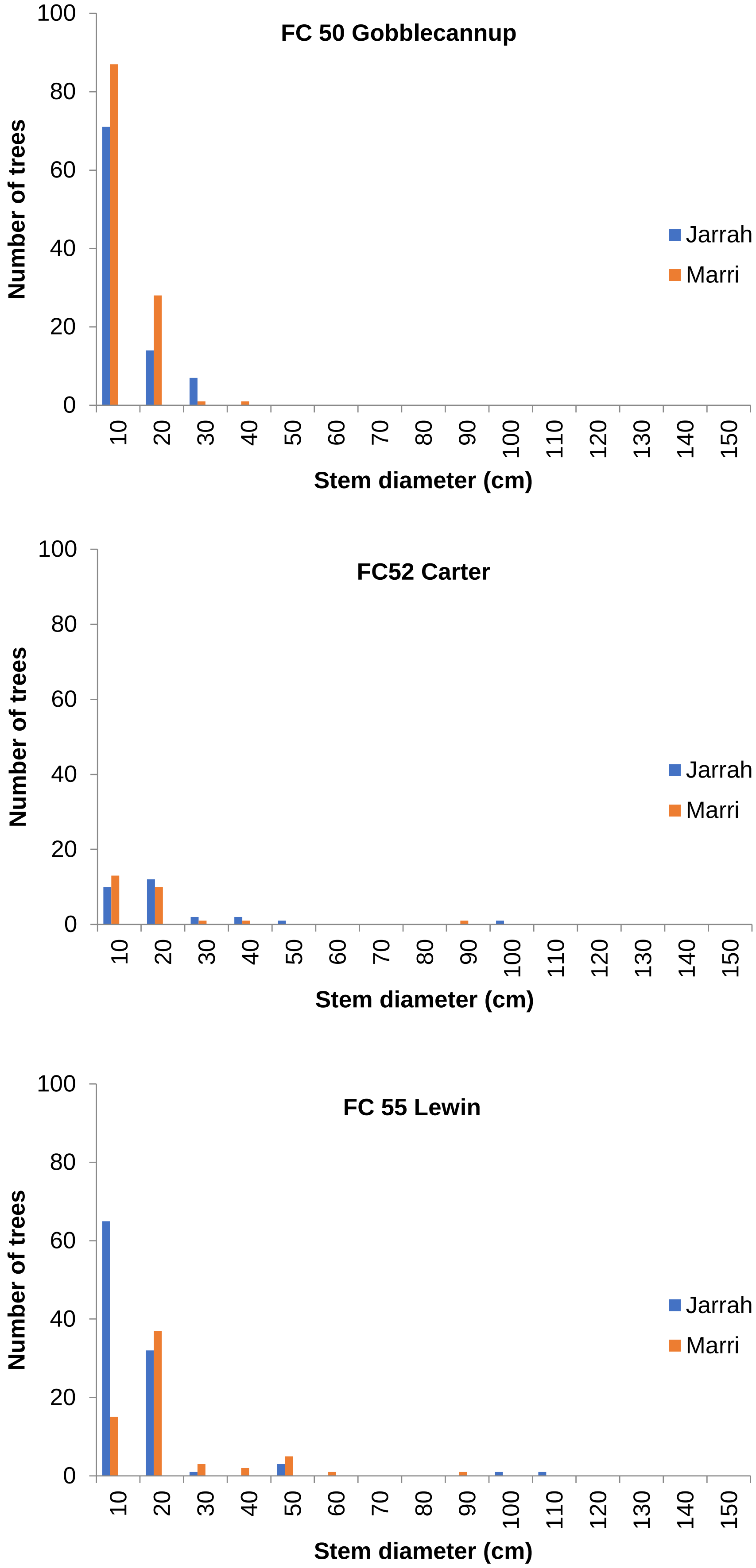

Figure 2.4 Stem diameter distribution by 10cm classes (0–9cm, 10–19cm etc.) for three gap release grids

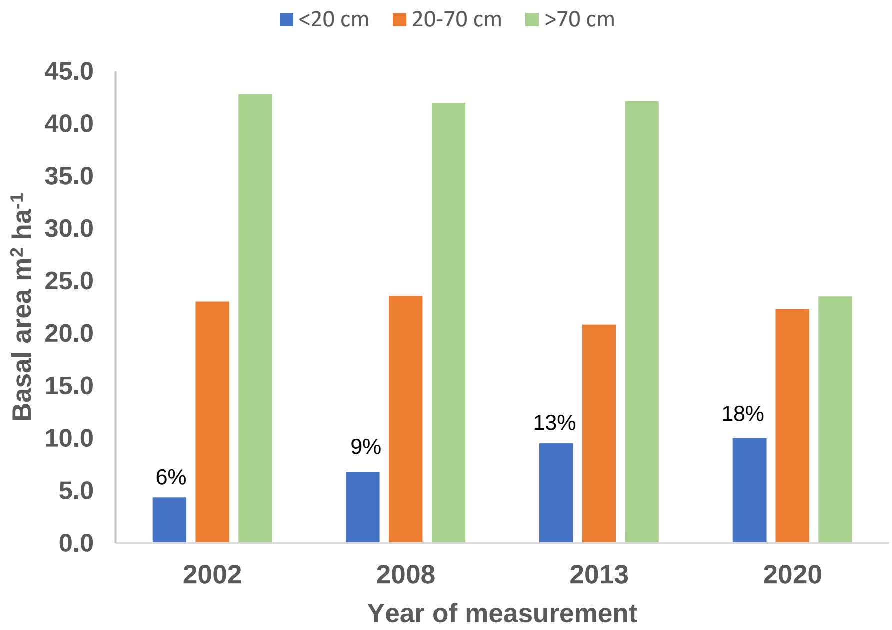

Figure 2.5 Basal area contributed by eucalypts in three size classes (dbh, cm) on external reference grid FC10 at four consecutive measurement events

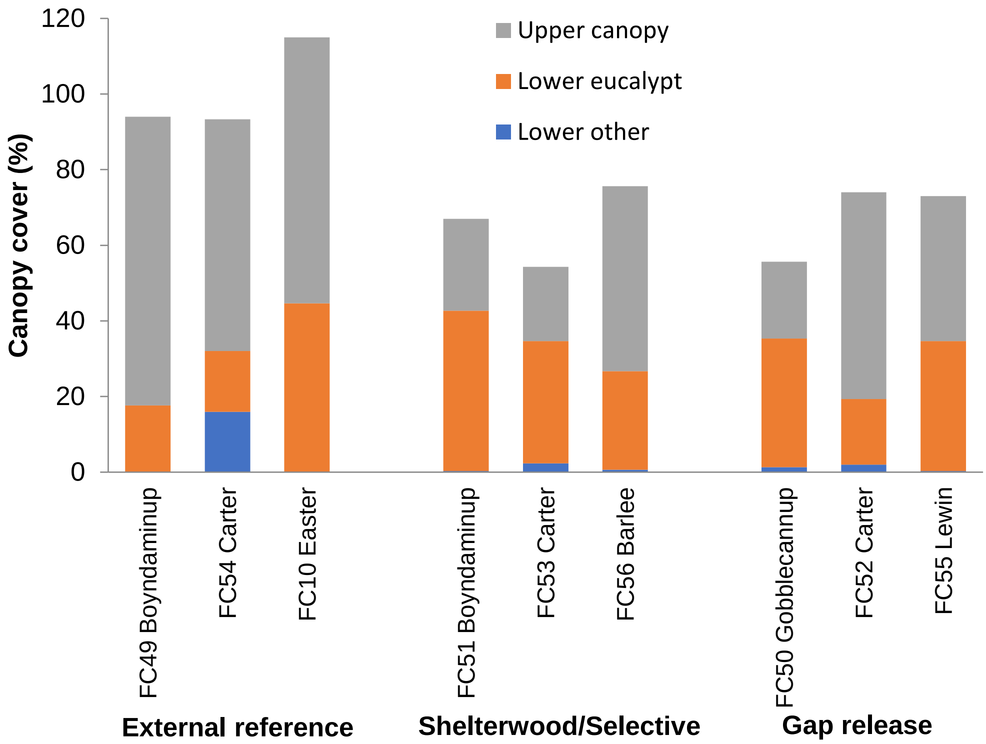

Figure 2.6 Projected foliage cover of eucalypts and other species divided into lower (2–15m) and upper (>15m) storeys

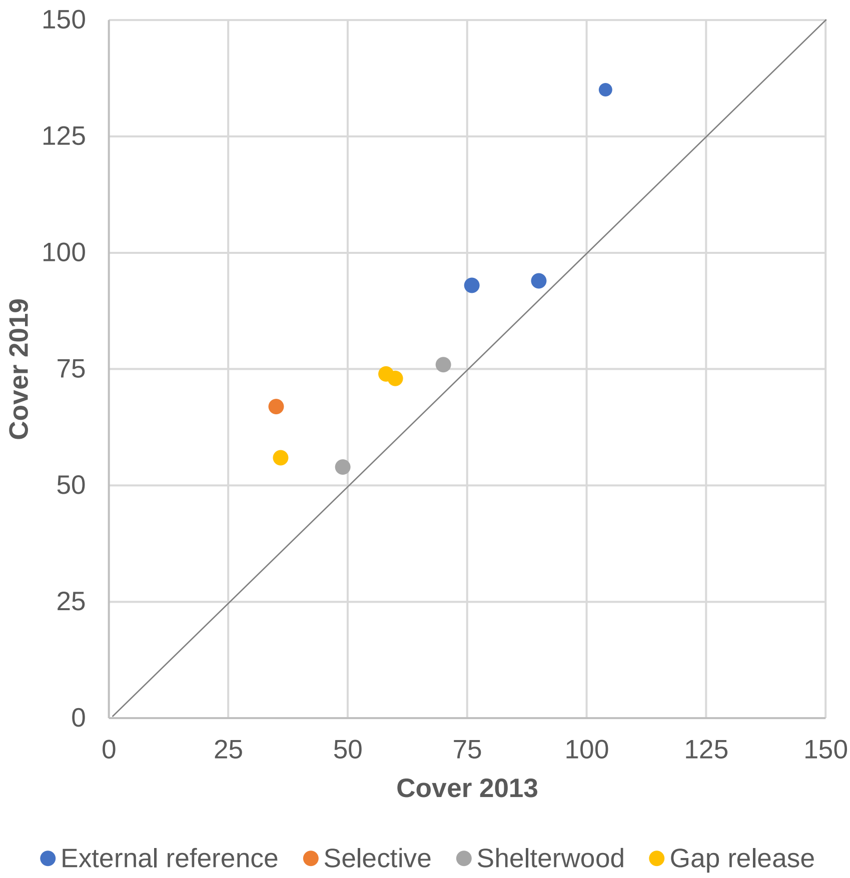

Figure 2.7 Comparison of total projected foliage cover (per cent) on each grid in 2013 and 2019

Eucalypt foliage from the upper storey (>15m height) comprised the largest proportion of projected foliage cover on external reference grids, with upper storey cover in the range 61-76% (Fig. 2.6). Eucalypt foliage from the lower storey also contributed substantially to projected cover, most notably at the Easter external reference grid. Mid-storey trees also contributed 15% projected foliage cover on the Carter external reference grid, consistent with the higher basal area of mid-storey trees recorded on this grid. Eucalypt foliage from the lower storey (2–15m) made the largest contribution to projected cover on the Boyndaminup selective harvest grid (FC51), the Carter shelterwood grid (FC52) and the Gobblecannup gap release grid (FC50). Upper storey foliage made the largest contribution to projected cover at the Barlee shelterwood (FC56) and the gap release grids in Carter (FC52) and Lewin (FC55) which reflected the retention of large mature trees on these sites. Total projected cover increased on all grids between 2013 and 2019 with substantial increases in cover observed on external reference grids as well as harvested grids (Fig. 2.7).

Discussion

Re-measurement of stand structural attributes has demonstrated increases in stand basal on seven of the nine grids. During the seven-year period between measurements basal area of jarrah increased on all grids by an amount ranging from 1.1 to 4.9m^2 ha^{-1}. Marri basal area also increased on most grids except the Easter external reference (FC10) and Carter gap release (FC52) where large individual trees died or fell. Stand basal areas at the three external reference grids are now similar (55.9-59.79$m^2 ha^{-1}$), and at the higher end of the range sampled across the FORESTCHECK monitoring grids (McCaw 2011). Basal areas tend to be higher in the Jarrah South ecosystem due to the greater contribution of marri. Considering the grids harvested during the period of the FMP 2004-13 the grids at Boyndaminup and Gobblecannup in the lower rainfall Strahan Cattaminup Jigsaw LCU carry lower basal areas than those in the Northern karri LMU but exhibited similar or higher levels of jarrah ingrowth between 2013 and 2020.

Repeated measurements of stand structure (2002, 2008, 2013, 2020) at the Easter external reference grid (FC10) provide an interesting insight into the dynamics of an old-growth stand in the absence of fire. This stand is undergoing a gradual process of regeneration with the decline and death of large old trees and the recruitment of a dense mid-storey cohort of saplings and small pole-sized trees that are contributing an increasing proportion of basal area. Projected foliage cover has also increased over the period of measurement, with much of the increase in total projected cover due to increased cover in eucalypts <15m tall. Foliage cover has continued to increase despite severe defoliation during an outbreak of the gum-leaf skeletoniser in 2010/11 (Wills and Farr 2016). Changes in stand structure have implications for carbon storage, with the death and eventual fall of large trees transferring carbon from living biomass into coarse woody debris on the forest floor. Woody debris represents a significant store of carbon in the jarrah forest, with fire regimes influencing the persistence of woody debsirs at a site (Whitford and McCaw 2019). Changes in stand structure may also affect habitat condition and the composition of understorey vegetation and fauna assemblages associated with the site, although such changes are likely to occur gradually over decadal timescales.

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3. LITTER AND TWIGS

Lachie McCaw

Introduction

Litter, small wood and twigs (SWT) and coarse woody debris (CWD) represent important structural and biological components of forest ecosystems. 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. Litter is defined as dead leaves and other dead fine vegetative material less than 1cm in diameter, small wood and twigs is woody material 1–2.5cm in diameter and coarse woody debris is defined as woody plant material larger than 2.5cm in diameter. Disturbances such as timber harvesting and fire affect the volumes and types of debris that occur in forests, and relevant findings for monitoring grids FC1-48 have been analysed and reported by Whitford and McCaw (2019).

Coarse woody debris was measured on grids FC10 and FC49-FC56 in the Jarrah South ecosystem in 2013. Most of these grids remained unburned between 2013 and April 2020 except FC55 which was burnt by mild patchy fire in December 2018. For this reason, it was decided to re-measure only the litter and SWT components which are more likely to have changed over the intervening period. Based on experience in re-measuring CWD material following fire on other grids it was decided that re-measurement of FC55 was not warranted because of the small amount of CWD likely to have been consumed.

Field and Laboratory Measurements

Litter and SWT were sampled on the FORESTCHECK grids in April 2020. Time since fire on the Easter external reference grid (FC10) was 25 years and on all other grids it ranged from 11–16 years. In earlier FORESTCHECK monitoring, external reference grid FC10 Easter was also sampled for litter and small twigs in 2002, 2008 and 2013.

Twenty-two samples each of SWT and litter were collected from each 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

Litter

Litter loads increased between 2013 and 2020 on all grids, with the proportional increase being least on FC55 Lewin which experienced low intensity fire on parts of the grid in spring 2018. In 2020 litter loads on external reference grids ranged from 15.3-17.2 t ha^{-1} with the variability being similar at each grid (Fig. 3.1). For the harvested grids the pattern of change in litter load between 2013 and 2020 was quite similar between the shelterwood/selective and gap release grids. Litter loads on grids FC50 and FC51 in the Strahan Cattaminup Jigsaw LMU increased by 6-7 t ha^{-1} while grids FC52 and FC53 at Carter block in the Northern Karri LMU increased by 12-13 t ha^{-1} attaining litter loads comparable to those of the unharvested grids. Grids FC55 Lewin and FC56 Barlee were 9 years post fire in 2013 and carried greater litter loads than the matching grids in Carter block, and in the case of FC56 Barlee the litter load in 2020 was very similar to that of the external reference grids.

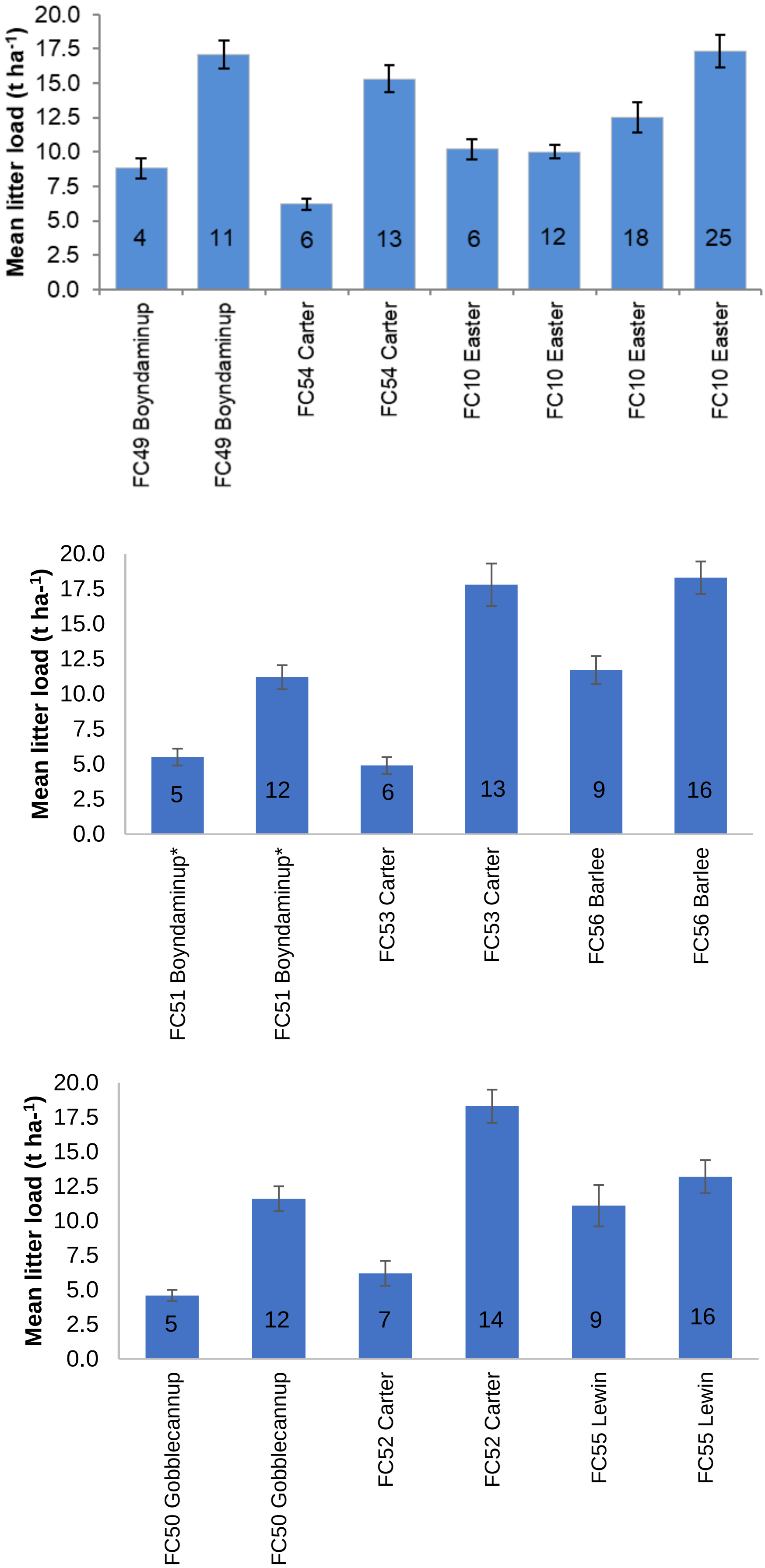

Figure 3.1 Mean litter loads (t ha^{-1} ± sem) measured at FORESTCHECK grid at Donnelly 2 in 2020 compared with previous sampling in 2013. Panels show treatments as follows: External Reference (upper), Shelterwood/Selective cut* (centre), and Gap release (lower). Numbers in columns indicate years since fire.

Small wood and twigs

The load of SWT varied from 1-2 t ha^{-1} and was small compared to the litter load (Fig. 3.2).

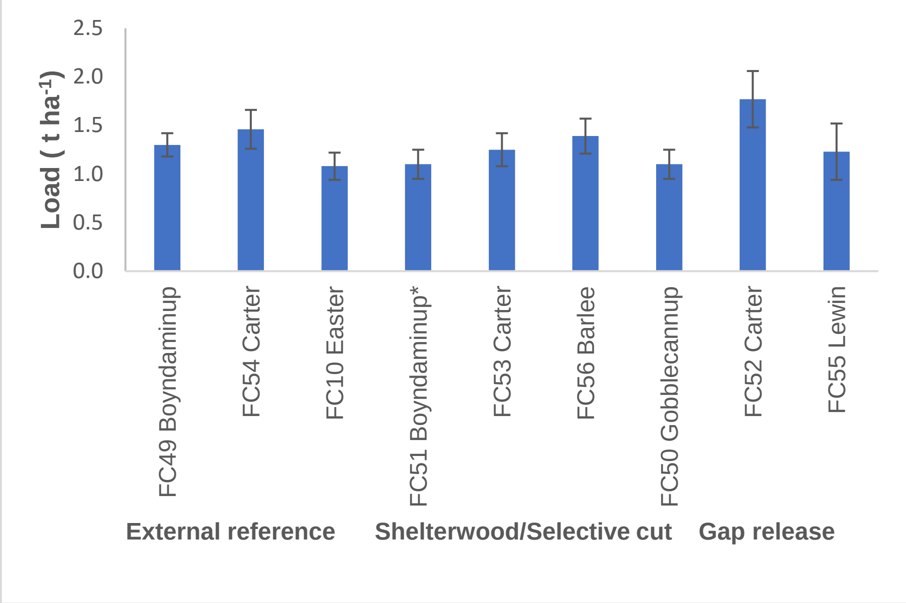

Figure 3.2 Mean loads (t ha^{-1}) of small wood and twigs measured at each FORESTCHECK grid at Donnelly 2 in 2020.

Discusssion

Litter loads increased between 2013 and 2020 on all grids, as expected with increasing time since last fire and the re-establishment of leaf area on grids subject to timber harvesting. The Forest Fire Behaviour Tables for Western Australia predict litter accumulation as a function of time since fire and canopy cover and indicate that 12 years after fire the expected litter load in forest with 60 and 80% canopy cover would range from 14-15.5 tha^{-1} respectively; after 15 years since fire the corresponding range would be 15.6-17.5 tha^{-1}. These loadings are broadly consistent with results obtained from field sampling in 2020. Our results indicate that the litter load is continuing to accumulate at the external reference grid at Easter (FC55) after 25 years since fire. As described in the previous section, canopy cover on this grid increased between 2013 and 2020 with saplings comprising an increasing proportion of total canopy cover and stand basal area.

In 2013 the SWT load on the FC10 Easter external reference grid was more than 3 t ha^{-1} and more than double that measured on any other grid but this was not the case in 2020. This is consistent with the hypothesis that accelerated shedding of small branches following severe defoliation by GLS during 2010–12 resulted in a much-increased SWT load.

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4. VASCULAR PLANTS

Bruce Ward and Verna Tunsell

Introduction

Understorey plants are key organisms for monitoring impacts of timber harvesting and associated silvicultural treatments in jarrah forest. FORESTCHECK monitoring provides comparative data on plant species richness and abundance across silvicultural treatments that include prescribed fire following harvest. Monitoring is applied at an operational scale representative of forest management practices.

Disturbance associated with timber harvesting includes soil mixing and compaction, and direct physical impact on trees and shrubs during felling and extraction operations. Prescribed fire is also applied following harvesting to remove debris and create receptive seedbeds. The combined effect of harvesting and fire may reduce the abundance of some plant species but can also provide opportunities for regeneration by stimulating rootstocks and germination of seed stored in the soil. When analysing species richness data from silviculturally treatment forest time since fire is an important consideration because observed differences may reflect 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 including fire. In most circumstances, and over time, species that were present before disturbance will persist or, if necessary, re-establish. Plant abundances may however change temporarily. Plant species composition and abundance may also be altered more permanently in forest infested with *Phytophthora cinnamomi*, particularly if environmental conditions are altered in a way that favours expression of dieback disease.

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

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

Monitoring

Nine FORESTCHECK monitoring grids were measured in the Donnelly District during September 2018. These included three external reference (FC49, FC54 and FC10), two shelterwood (FC53, FC56), one selective cut (FC51) and three gap release treatment grids (FC50, FC52, FC55). All occur within the Bevan 1 vegetation complex of Mattiske and Havel (1998) and are located on lateritic uplands in perhumid zones in the Strahan Cattaminup Jigsaw LMU (FC49-51) and the Northern karri LMU (FC10, FC52-56). This set of grids is referred to as Donnelly 2. No grids were burnt between 2013 and the subsequent assessment in 2018.

Species richness and understorey vegetation structure were surveyed on six 1000 m^2 quadrats in each grid by recording each species, estimating its area of cover, frequency of occurrence and measuring its position in the understorey strata. Vegetation structure was determined using Levy contact data at various height categories up to 2 m in the understorey (Levy and Madden 1933). Point samples were taken at 1m intervals on three internal transect lines 100m long (total point samples 300 per grid) with the number of contacts 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 rod. Canopy was rated as present (Y) or not (N) with projected cover calculated as a percentage of the total contacts that have a 'yes' (Y). Cover was divided into mid- and upper-storey ratings. The mid-storey was further split into eucalypt and other species so that the structure of the developing stand could be tracked as it progressed from the sapling stage. Detailed descriptions of all monitoring methods including abundance, cover and frequency ratings is documented in the FORESTCHECK Operations Plan (DEC 2006).

Results

Species richness

A total of 130 vascular plant species were recorded on grids in Donnelly 2 in 2018 (Table 4.1 and Appendix 4.1). This is 41 species of native plants fewer than recorded during flora surveys in 2013. Reduction in species richness was largest in both actual and percentage terms in the grids in Carter block within the Northern karri LMU (Table 4.2). The Carter grids included the largest total number of plant species although the mean number of species per quadrat was not consistently greater than for the grids at the other two localities (Fig. 4.1).

Only one weed species (*Hypochaeris glabra*) was recorded in 2018 which is two less than during previous surveys. This species occurred at the FC51 Boyndaminup shelterwood/selective grid and FC52 Carter gap release grid.

A small number of changes were made to the nomenclature of species used in the report on the 2013 monitoring. These included confirming the identity of *Banksia seminuda* rather than *Banksia littoralis* at FC52 Carter gap release and updating nomenclature following revision of *Logania serpyllifolia* to *Orianthera serpyllifolia* in 2014 (Foster et al. 2014).

Table 4.1 Comparison of total number of plant species and the distribution of unique and shared species recorded between treatments at the Donnelly 2 FORESTCHECK grids in 2013 and 2018.

	Number of species in treatments[1]							
	ER		**SW/SC**		**GR**		**Total**	
	2013	2018	2013	2018	2013	2018	2013	2018
Total	121	94	116	105	118	91	171	130
Unique to treatment	26	11	16	17	21	6		
Common to all							74	62
Common to ER + SW/SC							12	11
Common to ER + GR							10	9
Common to SW/SC + GR							12	14
Weed species								1

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

Table 4.2 Comparison of number of plant species in 2013 and 2013 according to Landscape Management Unit and forest block.

Location	Strahan-Cattaminup Jigsaw		Northern karri (Carter)		Northern karri (Easter, Barlee, Lewin)	
Year	2013	2018	2013	2018	2013	2018
No. of species	107	86	123	91	88	73
Change		-21		-32		-15
Change (%)		20%		26%		17%

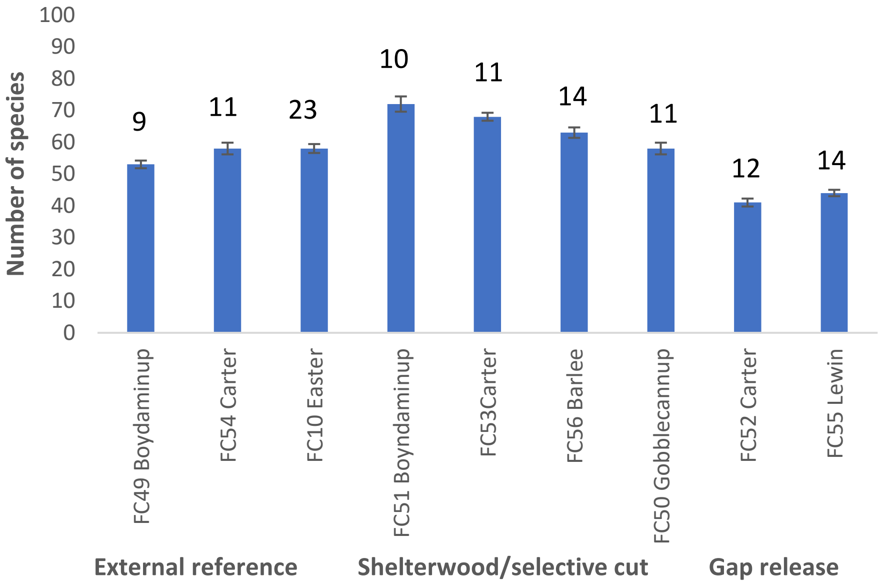

Figure 4.1 Mean number of plant species per quadrat recorded in each monitoring grid at the DONNELLY 2 FORESTCHECK grids in 2018. Numbers above columns indicate years since fire.

Patersonia umbrosa var *umbrosa* | *Pimelia rosea* | *Patersonia umbrosa* var *xanthina* | *Rhodanthe citrina* | *Thysanotus multiflorus*

Figure 4.2. Left to right: *Patersonia umbrosa* var *umbrosa* occurred in all treatments and both LMU in 2013 and 2018 with greatest abundance in gap release grids; *Pimelia rosea*, a tall perennial shrub > 30cm which relies on soil stored seed was recorded in gap release grids in 2013 but not in 2018; *Patersonia umbrosa* var *xanthina,* a close relative of *P. umbrosa* var. *umbrosa*, is a perennial shrub to 30cm which regenerates from a woody rootstock was recorded in reference forest in the Strahan Cattaminup Jigsaw LCU in 2013 but not in 2018; *Rhodanthe citrina* is an annual herb which regenerates from soil stored seed and was recorded in clumped but low abundances in disturbed areas of shelterwood grids in the Strahan Cattaminup Jigsaw LCU in 2013 but not in 2018; *Thysanotus multiflorus*, a geophyte which propagates from a fleshy underground tuber, was recorded at all three grids in the Strahan Cattaminup Jigsaw LCU in 2013 and at two grids in 2018, and was also recorded at the Barlee shelterwood grid in 2018 (see Appendix 4.1).

Plant abundance

The density of plants from six quadrats on each grid was determined by summing the abundance class mid-point values for each species and then converting that value to plants per square metre for each grid. Over the past five years plant abundance reduced on average by 2.5 plants per m^2. Reductions in mean plant density were generally greater at silviculturally treated grids than at external reference grids, although plant density did reduce substantially at the Easter external reference grid FC10.

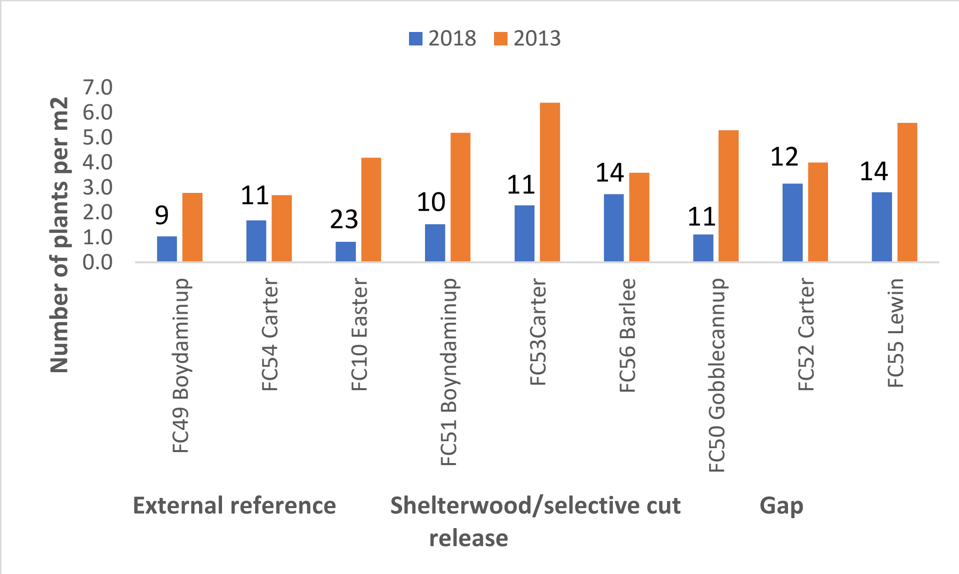

Figure 4.3 Total numbers of plants per square metre on each FORESTCHECK grid at Donnelly 2 in 2013 and 2018. Numbers above columns indicate the years since last fire for each grid at time of sampling in 2018.

The frequency with which plant species contribute to the vegetation composition at each grid is shown in Fig. 4.5. A small number of species occur at very high frequency (>100 per grid) while most species occur at moderate frequency (10-50 per grid).

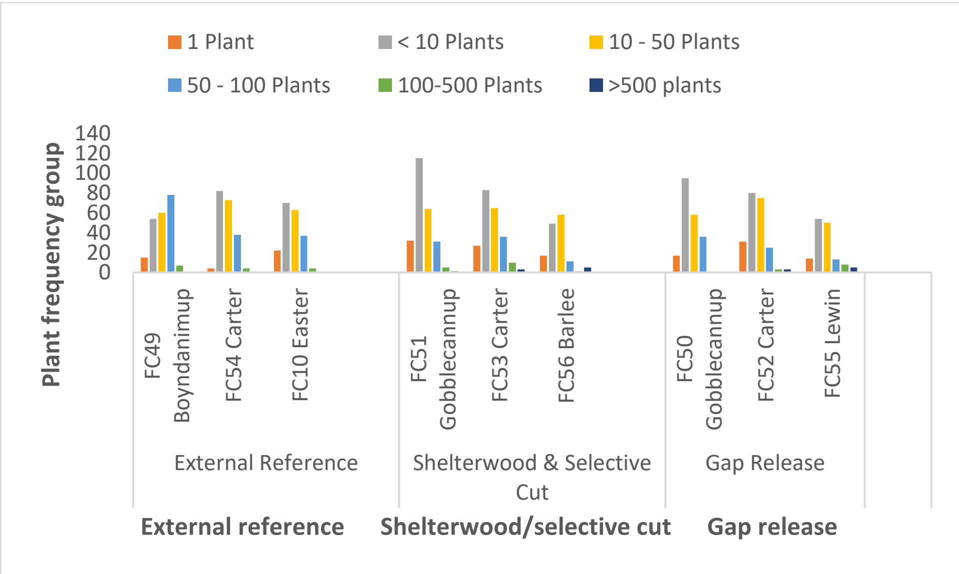

Figure 4.5 The number of plant species per frequency category in each Forestcheck monitoring grid at Donnelly 2 in 2018

Plant life forms and fire responses

Plants were grouped into life-form categories based on similarity of structure and function which also reflects environmental influences. The number of plant species in each life-form category is compared between silvicultural treatments in Fig. 4.6. Overall, the number of species of trees, tall shrub (>30cm) and geophytes was slightly lower on harvested treatments, whereas the number of small shrubs (<30cm) and herbs was slightly greater. For the tree life-form category the dominant overstorey species jarrah and marri were recorded at all grids. Other species categorised as trees included: *Agonis flexulosa* which was present only at FC10 Easter external reference; *Allocasuarina fraseriana* which was present only at FC49 Boyndaminup external reference; *Banksia grandis* which was present at all grids except FC55 Lewin gap release; and *Banksia seminuda* which was present only at FC55 Carter gap release.

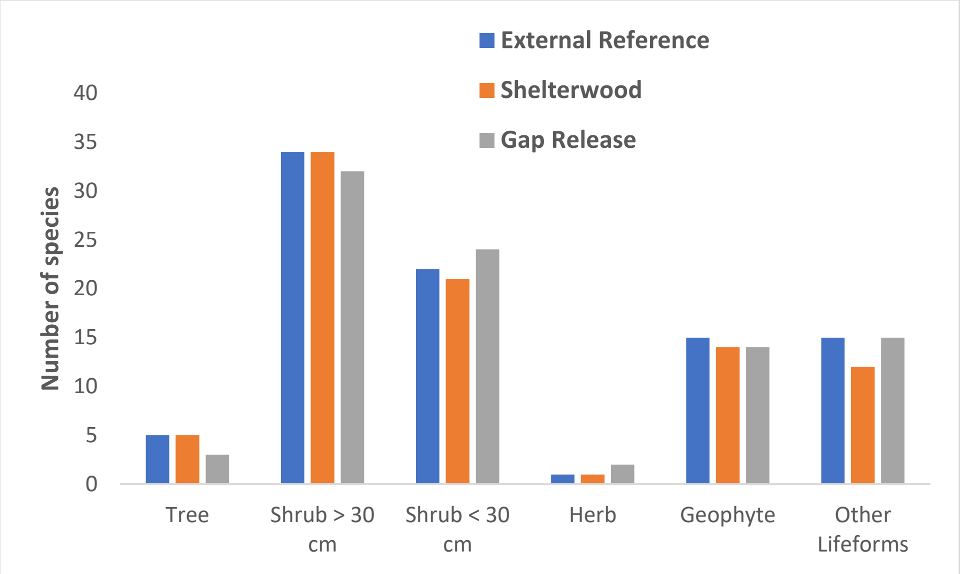

Figure 4.6 Number of species within each life form category in each treatment at the Donnelly 2 FORESTCHECK grids in 2018.

Vegetation structure

Vegetation structure was quantified according to the height and density of the vertical profile as determined by point intercept sampling (Fig. 4.7). Contacts with dead plant material were also measured to determine the level of senescence within the shrubs. For external reference grids the distribution of vegetation density was skewed to the height classes <60 cm with live vegetation comprising about 80% of contacts across all height classes. For gap release and shelterwood/selective cut grids the distribution of vegetation density showed a bimodal distribution with a peak of contacts <60 cm height and a second peak at 200 cm height. The proportion of live contacts tended to increase with height above ground and was greatest in the 200 cm height class.

Overall mean height of the understorey was similar for each treatment although there were effects related to location and time since fire (Fig. 4.8). Mean shrub height was lowest for the three grids in the Strahan-Cattaminup Jigsaw LMU (0.6 m), intermediate for the grids in Carter block (1.4 m) and tallest at the grids in Easter, Barlee and Lewin blocks in the Northern karri LMU (2.7 m). Corresponding mean heights in 2013 were respectively 0.7 m, 1.2 m, and 2.0 m. The six grids in the Northern karri LMU had understoreys dominated by a dense layer of *Bossiaea aquifolium* subsp. *laidlawiana* but this species was not present on the grids in the Strahan-Cattaminup Jigsaw LMU. Grids at Barlee, Easter and Lewin blocks had the longest times since fire ranging from 14-23 years.

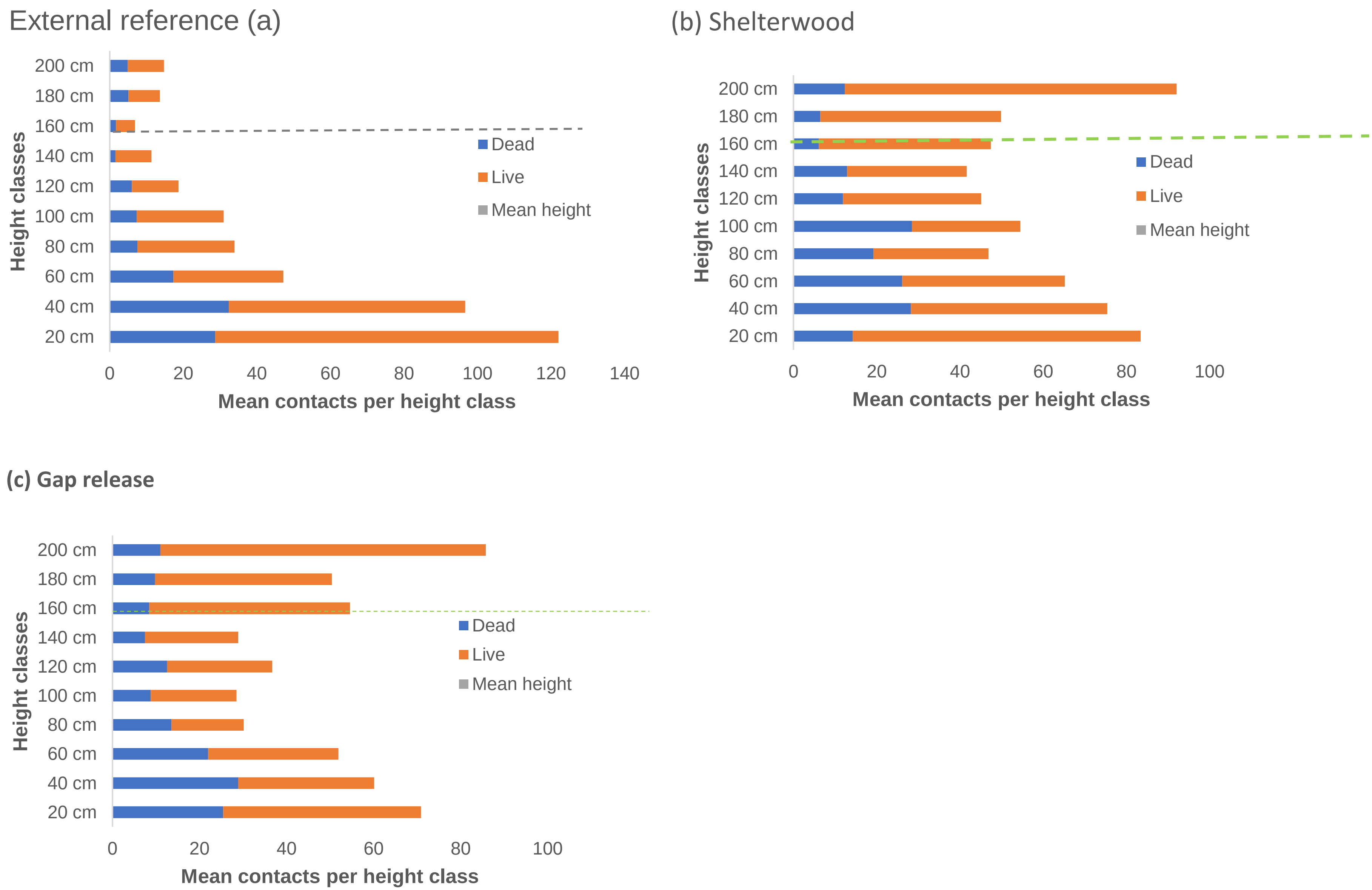

Figure 4.7 Vertical structure profile of (a) external reference, (b) shelterwood/selective cut and (c) gap release in 2018 as shown by density of contacts in live and dead vegetation for 20 cm height classes up to 2 m in height. The green dashed line represents the mean height of all point samples for each treatment.

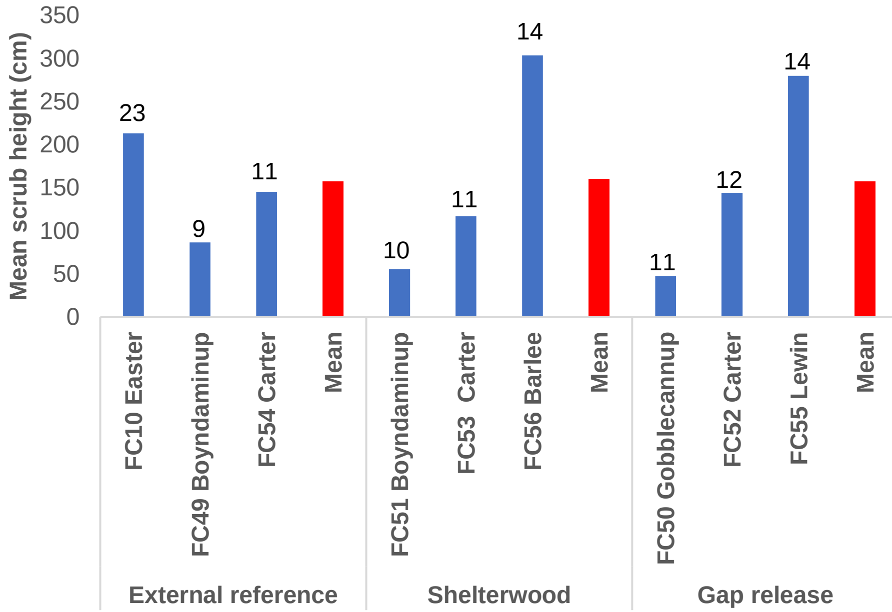

Figure 4.8 Mean height of understorey vegetation in each grid at the Donnelly 2 FORESTCHECK grids, showing the overall mean (± se) per treatment as red columns. Numbers above columns indicate time since the last fire on each grid.

Discussion and conclusions

The Jarrah South ecosystem, as represented by the Donnelly 2 FORESTCHECK monitoring grids, has a rich and diverse flora. Landscape Management Units introduced in the Forest Management Plan 2014-2023 provide a finer resolution of the forest ecosystems based on landform, soils and climate and some attributes of the data gathered during flora monitoring in 2018 have been examined at this scale. Grids at Carter block in the Northern karri LMU collectively had the highest species richness although the mean number of species per quadrat was not consistently greater than for the grids at the other two localities. This finding indicates that the variation in species composition between grids was greater at Carter block than at the other two localities, despite these grids being located within 1 km of each other and matched using mapped vegetation complexes. This variability is likely to reflect differences in soil texture rather than the influence of other environmental factors. The next most species rich grids were those at Boyndaminup and Gobblecannup blocks in the Strahan Cattaminup Jigsaw LMU at the south-eastern extent of the Jarrah South ecosystem. This area is characterised by gently undulating landforms and open forests with a less dense understorey than those typical of the Northern karri LMU. Collective plant species richness was lowest at the grids in Easter, Barlee and Lewin blocks.

All but one of the grids remained unburnt between 2013 and 2018, and the grid that was subject to prescribed burning in spring 2018 experienced a mild and patchy fire that did not substantially alter the structure or floristic composition of the vegetation in the monitoring quadrats. Over the five years between monitoring events species richness declined by 17-20% with the magnitude of decline following the same order as the collective species richness of each set of grids (Carter>Boyndaminup/Gobblecannup>Barlee/Easter/Lewin). This finding is consistent with other studies that have examined changes in the observed floristic composition of south-west forests following fire (Bell and Koch 1980; Burrows and Wardell-Johnson 2003; Burrows et al. 2019). Such changes have been interpreted as reflecting the disappearance of short-lived post fire ephemerals, and changes in the abundance of species due to competition. Between 2013 and 2018 the number of weed species declined from three to one, as did the number of monitoring grids in which the remaining species (*Hypochaeris glabra*) was recorded. Some of the difference in species richness between sampling events would also be attributable to seasonal variation in the flowering of orchids and herbaceous species that are not readily detected or identified unless they are flowering.

Other changes observed between 2013 and 2018 included a reduction in plant density (Fig. 4.3), and an increase in the mean height of the understorey across all treatments. Mean understorey height increased for grids in the Northern karri LMU where the vegetation was dominated by *Bossiaea aquifolium subsp laidlawiana* but declined slightly in the more open forest of the Strahan Cattaminup Jigsaw LMU.

Acknowledgements
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Appendix 4.1 Vascular plants recorded at the Donnelly 2 FORESTCHECK grids in 2013 and 2018 including weed species*. Data represent the number of monitoring grids where each species was recorded. Sampling locations are grouped by Land Management Unit as follows:
Strahan Cattaminup Jigsaw (FC49-51), Northern karri (Carter block, FC52-54), and Northern karri (Easter, Lewin, Barlee blocks FC10, FC55-56).

Landscape Management Unit		SC Jigsaw	SC Jigsaw	N karri Carter	N karri Carter	N karri E/B/L	N karri E/B/L
Species	Alien	2013	2018	2013	2018	2013	2018
Acacia browniana		3	3	3	3	3	2
Acacia extensa		1	1	2	3	0	0
Acacia myrtifolia		2	0	2	1	0	0
Acacia pulchella		0	0	3	3	2	1
Acacia urophylla		1	1	0	0	0	1
Agonis flexuosa		0	0	0	0	1	1
Aira cupaniana	*	2	0	0	0	0	0
Allocasuarina fraseriana		1	1	0	0	0	0
Amperea ericoides		0	3	0	1	0	2
Amphipogon amphipogonoides		2	2	3	2	3	3
Amphipogon strictus		0	0	0	2	0	0
Anarthria prolifera		0	2	0	0	0	0
Andersonia caerulea		0	0	1	1	0	1
Anigozanthos flavidus		0	1	0	0	0	0
Asterolasia pallida		0	0	1	0	0	0
Astroloma drummondii		0	0	1	0	2	0
Astroloma pallidum		1	1	2	2	0	0
Astroloma sp.		0	0	1	0	0	0
Banksia grandis		3	3	3	3	2	2
Banksia seminuda		0	0	1	1	0	0
Billardiera floribunda		1	1	0	0	1	1
Billardiera heterophylla		0	0	0	1	0	0
Billardiera variifolia		1	2	0	1	1	2
Boronia gracilipes		0	0	0	0	2	2
Boronia megastigma		0	0	1	0	0	0
Boronia spathulata		1	1	0	0	0	0
Bossiaea aquifolium subsp. laidlawiana		0	0	3	3	3	3
Bossiaea linophylla		1	1	1	1	1	1
Bossiaea ornata		0	1	2	2	0	0
Caladenia flava		3	0	1	0	0	0
Caladenia macrostylis		0	1	1	0	0	0
Caladenia reptans		1	3	3	3	2	0
Calytrix leschenaultii		0	0	1	0	0	0
Cassytha racemosa		0	1	0	1	1	2
Centaurium erythraea	*	2	0	1	0	0	0
Centrolepis aristata		1	0	0	0	0	0
Chamaescilla corymbosa		2	2	3	3	1	0
Chorilaena quercifolia		0	0	0	1	1	1
Chorezima nanum		0	0	0	0	0	1
Chorizema retrorsum		0	0	0	0	1	0
Clematis pubescens		2	2	2	2	1	1
Comesperma calymega		0	1	1	1	0	1

Comesperma confertum		0	2	1	1	1	3
Comesperma virgatum		0	0	1	0	0	0
Conostylis serrulata		0	0	0	1	0	0
Conostylis setigera		1	1	0	0	0	0
Corymbia calophylla		3	3	3	3	3	3
Cyanicula sericea		3	0	1	0	0	0
Cyathochaeta avenacea		0	0	0	0	1	0
Cyrtostylis huegelii		3	1	3	2	3	2
Dampiera alata		1	0	0	0	0	0
Dampiera hederacea		0	0	0	0	1	0
Dampiera linearis		1	2	1	0	0	0
Daucus glochidiatus		1	0	0	0	1	0
Desmocladus fasciculatus		1	3	1	2	0	0
Desmocladus flexuosus		0	0	3	3	1	1
Dianella revoluta		0	0	1	2	0	0
Drosera erythrorhiza		0	0	2	2	0	0
Drosera huegelii		3	0	3	0	2	0
Drosera menziesii		0	0	2	0	3	2
Drosera pallida		0	3	0	3	0	3
Elythranthera brunonis		0	0	0	1	0	0
Eucalyptus marginata		3	3	3	3	3	3
Euchiton collinus		2	1	2	0	1	1
Gastrolobium bilobum		0	0	2	1	0	0
Geranium solanderi		0	0	1	0	0	0
Gompholobium capitatum		0	0	1	0	0	0
Gompholobium ovatum		0	1	1	1	0	0
Gompholobium preissii		0	0	2	0	0	0
Gonocarpus benthamii		1	2	0	0	1	0
Goodenia eatoniana		0	0	1	0	0	0
Grevillea centristigma		0	0	1	1	0	0
Grevillea pulchella		3	3	0	0	0	0
Hakea amplexicaulis		3	3	3	3	3	3
Hakea cyclocarpa		0	0	0	0	1	1
Hakea lasianthoides		0	2	0	0	0	0
Hakea lissocarpha		0	0	3	3	0	0
Hakea prostrata		0	0	2	0	1	0
Hardenbergia comptoniana		1	0	0	1	0	0
Hemigenia pritzelii		0	0	2	0	1	0
Hibbertia amplexicaulis		3	3	3	3	2	3
Hibbertia commutata		3	3	3	3	2	2
Hibbertia cuneformis		1	0	0	0	0	0
Hovea chorizemifolia		0	3	3	3	0	1
Hovea elliptica		3	3	1	1	2	2
Hovea trisperma		0	0	1	2	0	0
Hybanthus debilissimus		2	1	1	0	0	1
Hydrocotyle alata		1	0	0	0	0	0
Hypocalymma cordifolium		0	0	0	0	1	1
Hypochaeris glabra	*	1	1	3	1	0	0

Isopogon sphaerocephalus	0	0	0	0	0	1
Isotoma hypocrateriformis	1	0	0	0	1	0
Isotropis cunefolia	0	0	1	0	0	0
Johnsonia lupulina	0	0	0	0	1	0
Kennedia coccinea	3	1	2	1	1	0
Kunzea glabrescens	0	0	0	2	0	0
Lagenophora huegelii	3	3	3	3	1	2
Lasiopetalum floribundum	0	0	0	0	1	1
Lechenaultia biloba	0	0	1	0	0	0
Leptomeria cunninghamii	0	1	3	2	0	0
Leucopogon australis	3	3	3	3	1	2
Leucopogon capitellatus	3	3	3	3	2	2
Leucopogon obovatus subsp. revolutus	1	0	0	0	0	0
Leucopogon pendulus	3	3	0	2	0	0
Leucopogon propinquus	2	3	3	3	2	2
Leucopogon pulchellus	1	0	3	0	0	1
Leucopogon verticillatus	3	3	3	3	2	2
Levenhookia pusilla	2	1	2	0	2	0
Lindsaea linearis	2	2	1	0	2	1
Logania vaginalis	0	0	0	0	1	1
Lomandra caespitosa	2	1	3	3	1	0
Lomandra drummondii	3	3	1	0	0	0
Lomandra hermaphrodita	1	0	1	0	0	0
Lomandra integra	3	2	3	2	1	3
Lomandra pauciflora	3	3	0	0	1	2
Lomandra sericea	2	2	3	3	0	0
Lomandra sonderi	2	0	1	0	2	0
Macrozamia riedlei	3	3	3	3	3	3
Melaleuca thymoides	0	0	1	0	0	0
Microlaena stipoides	2	0	0	0	0	0
Millotia tenuifolia	1	0	3	0	0	0
Mirbelia dilatata	1	1	0	0	0	0
Monotaxis occidentalis	2	0	1	0	3	0
Opercularia hispidula	3	3	3	3	3	2
Orianthera serpyllifolia	2	2	0	0	3	0
Orthrosanthus polystachyus	0	0	0	0	1	0
Oxalis exilis	0	0	1	1	0	0
Paraserianthes lophantha	1	0	0	0	0	0
Patersonia babianoides	1	1	3	2	0	0
Patersonia occidentalis	1	0	3	1	2	0
Patersonia umbrosa	3	2	3	3	2	3
Patersonia umbrosa var. xanthina	1	0	0	0	0	0
Pentapeltis peltigera	0	0	1	0	1	0
Pentapeltis silvatica	0	0	1	0	0	1
Persoonia longifolia	3	3	3	3	3	3
Petrophile diversifolia	2	2	0	0	0	0
Phyllangium paradoxum	1	0	0	0	0	0
Pimelea rosea	1	0	1	0	0	0

Platysace filiformis	0	0	1	0	1	1
Platysace tenuissima	0	0	3	2	1	1
Podocarpus drouynianus	3	3	3	3	3	3
Poranthera huegelii	1	1	0	0	0	0
Pteridium esculentum	3	3	2	2	3	3
Pterostylis barbata	1	0	1	0	0	0
Pterostylis pyramidalis	2	3	3	3	3	3
Pterostylis recurva	0	3	0	2	0	2
Pterostylis vittata	3	3	3	2	2	1
Ptilotus manglesii	0	0	1	0	0	0
Rhodanthe citrina	1	0	0	0	0	0
Rytidosperma caespitosum	1	0	3	0	1	0
Scaevola striata	3	3	2	1	0	0
Senecio hispidulus	2	0	3	1	1	0
Sphaerolobium medium	2	2	1	0	2	2
Stackhousia monogyna	1	1	2	1	0	0
Stylidium amoenum	2	2	3	2	1	0
Stylidium brunonianum	0	0	1	0	0	0
Stylidium bulbiferum	0	2	0	0	0	0
Stylidium calcaratum	1	0	0	0	0	0
Stylidium cilatum	0	0	3	2	0	0
Stylidium luteum	2	0	1	0	2	0
Stylidium rhynchocarpum	0	0	2	3	3	3
Stylidium sp.	1	0	0	0	1	0
Stylidium spathulatum	0	0	1	0	0	0
Taxandria parviceps	3	3	3	3	3	2
Tetraria capillaris	2	3	3	3	3	3
Tetraria octandra	1	0	0	0	1	0
Tetrarrhena laevis	3	3	3	3	3	3
Tetratheca affinis	0	3	1	2	0	0
Thelymitra crinita	1	0	0	0	1	0
Thelymitra sp.	0	0	0	0	1	0
Thysanotus manglesianus	0	1	2	2	1	1
Thysanotus multiflorus	3	2	0	0	0	1
Thysanotus sparteus	1	0	0	0	0	0
Thysanotus tenellus	3	0	1	0	0	0
Tremandra diffusa	3	3	3	2	2	2
Tremandra stelligera	0	0	1	1	1	1
Trichocline spathulata	0	0	3	3	3	3
Trymalium odoratissimum subsp. odoratissimum	0	0	1	1	2	1
Velleia trinervis	1	1	1	0	0	1
Veronica calycina	2	0	2	3	2	1
Xanthorrhoea gracilis	3	3	3	3	3	3
Xanthorrhoea preissii	0	0	1	1	0	0
Xanthosia atkinsoniana	3	2	0	0	0	0
Xanthosia candida	3	3	3	1	0	1
Xanthosia huegelii	2	1	2	1	3	1
Xylomelum occidentale	0	0	1	1	0	0

5. VERTEBRATE FAUNA

Lachie McCaw, Bruce Ward and Graeme Liddelow

Introduction

Monitoring of vertebrate fauna on FORESTCHECK grids in the Jarrah South ecosystem in 2013 was undertaken by trapping using a combination of wire cage and pitfall traps. Increased availability and sophistication of portable remote sensor cameras has resulted in changing the monitoring protocol to monitor fauna activity using cameras instead of manual trapping methods. Advantages of camera detection include avoiding the need to confine and handle animals, less stringent conditions on sampling times, substantially reduced staff costs and the ability to sample over longer time periods. During the initial monitoring of this series of sites in 2013 preliminary trials of camera detection began using two cameras per grid. This section reports on camera trapping undertaken in 2018, 2019 and 2020 and compares these findings to previous trapping results from 2013.

Monitoring

Cameras were deployed at nine grids in autumn 2018 and autumn 2019 with details of deployment dates and sampling effort provided in Table 5.1. Five motion activated infra-red cameras (RECONYX HyperFire model HC600) were installed in each of nine grids at pegs 1.3, 2.2, 2.3, 2.4 and 3.2 (refer to Fig. 1.1). Cameras were placed at a height of 1.4 m above ground and directed downwards at an angle of 45° from the vertical. No lures or baits were used, and disturbance was limited to removal of vegetation in the field of view of the camera that might otherwise lead to false activation. Camera trapping was undertaken in accordance with conditions of the Department's Animal Ethics Committee Approval 2018/33.

Additional camera deployment took place in July 2020 at grids in the Strahan Cattaminup Jigsaw to monitor vertebrate fauna activity following a prescribed burn in early May 2020. This prescribed burn affected only grid FC49 but cameras were also deployed at grids FC50 and FC51 to provide comparative information for unburnt forest.

Deployment dates and sampling effort for monitoring undertaken in 2013 are also provided in Table 5.1 for comparative purposes. Trapping was conducted in 2013 over two sessions of four nights each, one month apart in autumn and spring using protocols outlined in the FORESTCHECK Operations Plan. Fifteen wire cage traps (20cm x 20cm x 45cm) and 15 20-litre pitfall traps (25cm dia. X 40cm deep) were deployed in a 50m x 50m grid pattern on each two-hectare grid.

Table 5.1 Details of sampling events and effort for vertebrate fauna monitoring. Three grids were located in the Strahan Cattaminup Jigsaw LMU (FC49-51) and six grids in the Northern karri LMU (FC10, FC 52-56).

Method	Landscape Management Unit	Sampling dates	Sampling effort total trap nights per grid
Wire cage / pitfall	Strahan Cattaminup Jigsaw and Northern karri	15-19 Apr 2013	60 per trap type
	both	13-17 May 2013	60 per trap type
	both	28 Oct - 1 Nov 2013	60 per trap type
	both	2-6 Dec 2013	60 per trap type
Camera	both	5-20 Nov 2013	30
	both	6-20 Dec 2013	28
	Strahan Cattaminup Jigsaw	16 Mar-9 Apr 2018	120
	Northern karri	19 Mar-10 Apr 2018	110
	Strahan Cattaminup Jigsaw	13 Mar–5 Apr 2019	115
	Northern karri (FC52-FC56)	13 Mar–4 Apr 2019	110
	Northern karri (FC10)	14 Mar–4 Apr 2019	105
	Strahan Cattaminup Jigsaw	3-31 Jul 2020	150

Data
Camera images were downloaded into the CPW Photo Warehouse (Newkirk 2016) to enable storage, species identification and analysis of detection events. Identifications were performed by an experienced officer and where necessary verified by a second officer. Examples of camera images are shown in Figs 5.1 and 5.2. For the purposes of this report a detection event is defined as the identification of a species during the 24-hour period after 6 pm on a given day. Most detections took place overnight during the hours of darkness and animals were solitary, although pairs of quokka were observed on several occasions in which case two detections were recorded for the period. Using this definition of a detection avoids the possibility of an individual animal being recorded more than once during a given period thereby making it comparable to a record of an animal obtained by trapping; however, it could potentially underestimate the number of animals at a location. Detections of individual species were standardised according to sample effort and expressed as the number of detections per 100 trap nights (%).

Results
Use of motion sensor cameras to monitor fauna activity resulted in detection of some larger animals that would not otherwise be detected by direct trapping, notably the Western brush wallaby (*Notomacropus irma*) and Grey kangaroo (*Macropus fulginosus*) (Tables 5.2-5.4). Brush wallaby were detected by cameras on all sampling occasions between 2018 and 2020 at external reference grids FC10 and FC 49, and at all three grids in Carter block (FC52-54). Detection rates for brush wallaby ranged from 0.9-2.9%. Kangaroos were also common and detected at all sites except for the gap release in Lewin block (FC55), at similar rates to brush wallaby.

Medium-sized native mamals detected both in wire cage traps and on camera imagery included the woylie (*Bettongia peniccillata*), quokka (*Setonix brachyurus*), koomal (*Trichosorus vulpecula*) and quenda (*Isodon obesulus*). Chuditch (*Dasyurus geoffroii*), wambenger (*Phascogale tapoatafa*) and echidna (*Tachyglossus aculeatus*) were also detected at a low frequency in the Strahan Cattaminup Jigsaw LMU but not in the Northern karri LMU (Table 5.2).

Woylie were detected at the two harvested grids in the Strahan Cattaminup Jigsaw LMU (FC50, FC51) but not at the corresponding external reference grid (FC49). Comparison of data from 2013 when both wire cage traps and cameras were deployed indicates that for woylie the rate of detection by cameras is similar to that for direct trapping, and possibly greater. Woylie were detected again at both harvested grids in autumn 2018 but only at FC51 in 2019. Woylie were not detected at either site during sampling in July 2020.

Figure 5.1 Woylie (*Bettongia peniccillata*) at FC51 Boyndaminup selective harvest grid in March 2018

Figure 5.2 Wambenger (*Phascogale tapoatafa*) at FC50 Gobblecannup gap release grid in March 2019

Quokka were detected at all grids in the Strahan Cattaminup Jigsaw LMU and at three grids in the Northern karri LMU. Detection rates for quokka were consistently greater from camera imagery than from direct trapping based on the 2013 data. For the Strahan Cattaminup Jigsaw LMU quokka were detected at all three grids in 2018 and 2019, mostly at a rate lower than in 2013. Camera monitoring undertaken in July 2020 indicated that quokka continued to occupy grid FC49 following the prescribed burn of May 2020, noting that detection rates at the unburnt grids were also lower than during previous sampling in 2018 and 2019. This may reflect a seasonal influence on quokka activity. For the Northern karri LMU quokka were detected in three harvested grids but not in either external reference grid. Gap release grids were occupied by quokka in 2013, 2018 and 2019 with stable or increasing rates of detection, including at FC55 which was burnt by mild prescribed fire in November 2018 between the two most recent camera surveys. For the shelterwood harvested sites quokka were not detected at FC56 after 2013 but were detected for the first time in 2019 at FC53.

Koomal were detected in 2013 by both trapping and camera imagery at the two harvested grids in the Strahan Cattaminup Jigsaw LMU (FC50, FC51) but not at the external reference grid. Subsequent camera surveys detected koomal in 2018 at the gap release grid (FC50). In the Northern karri LMU koomal were detected in 2013 by both trapping and camera imagery at the three grids in Carter block but not at any of the grids in Easter, Lewin or Barlee blocks. Subsequent camera surveys detected koomal in 2018 at the Carter external reference (FC54) and in 2019 at the Carter shelterwood (FC 53). Detection rates for koomal were higher at grids in Carter block than in the Strahan Cattaminup Jigsaw LMU.

Quenda were detected by trapping in 2013 at the Carter block external reference grid (FC54) and in 2018 and 2019 by camera imagery at the external reference and shelterwood grid (FC53). Quenda were also detected in 2019 at the shelterwood grid (FC51) in the Strahan Cattaminup Jigsaw LMU.

Bush rats (*Rattus fuscipes*) were detected at one grid in the Strahan Cattaminup Jigsaw LMU by direct trapping in 2013 (FC51) and on camera imagery in 2019 (FC49). In the Northern karri LMU bush rats were detected by trapping in 2013 at three harvested grids (FC52, FC55, FC56) and again on camera imagery in 2019 at FC55 and FC56. Mardo (*Antechinus flavipes*) were detected at all grids in 2013, predominantly by wire cage traps but also on camera imagery at some grids. Mardo were not detected on camera imagery in 2018, 2019 or 2020. Small mammals recorded from pitfall trapping in 2013 included the mundarda (*Cercatetus concinnus*), dunnart (*Sminthopsis* sp.) and House mouse (*Mus musculus*) but none of these species were detected by subsequent camera sampling.

The Black rat (*Rattus rattus*) was the most frequently detected introduced mammal and was persistent at sites FC10, FC55 and FC56 in the Northern karri LMU. The Black rat was also detected at FC49 in the Strahan Cattaminup Jigsaw LMU during camera sampling in 2018, 2019 and 2020. Feral cats were detected by camera sampling at grids FC54, FC55 and FC56 in the Northern karri LMU. Other introduced species recorded occasionally on cameras included Rabbit (*Oryctolagus cuniculus*) and Pig (*Sus scrofa*).

Southern heath monitor (*Varanus rosenburgi*) were recorded in wire cage traps or on camera imagery in 2013 at the three grids (FC49, FC50, FC51) in the Strahan Cattaminup Jigsaw LMU, and at grids FC52, FC55 and FC56 in the Northern karri LMU. Heath monitor were recorded again on camera imagery at FC49 in 2019, and at all three grids in carter block (FC52, FC53, FC54) in 2018 or 2019. No other species of reptile or amphibian were recorded on camera imagery.

A variety of ground-active bird species were also recorded on camera imagery (Table 5.5).

Discussion

As expected, the use of remote sensor cameras for observing vertebrate fauna activity favours detection of larger species over smaller species. Cameras provide useful information about activity patterns for kangaroo and brush wallaby, as well as for species such as echidna that are seldom observed directly or caught in wire cage traps. Introduced species including feral pigs and cats are also readily detected on camera imagery. Medium-sized species including koomal, quenda, quokka, woylie, and rats were detected consistently by both cameras and wire cage trapping. Small mammals including dunnart, mardo and mundarda were either not detected at all on camera imagery, or only at very low frequency compared with the results of pitfall trapping conducted in 2013. Similarly, cameras detected very few reptiles or amphibians other than the large southern heath monitor. Differences in sampling technique therefore need to be taken into account when results from monitoring in 2018-2020 are compared with results from 2013.

Recent monitoring has confirmed that quokka continue to occupy a variety of forest types across the Strahan Cattaminup Jigsaw and Northern karri LMU including areas subject to timber harvesting in 2004 and 2007. Monitoring results from 2013 confirm that quokka may occupy harvested areas within six years of post-harvest burning. Post-harvest burning is a standard silvicultural practice in jarrah forest and while there may be little scope to leave substantial unburnt patches within harvested cells, retention of unburnt forest in stream zones adjacent to harvested areas is likely to favour early recolonization as the density of the vegetation within harvested areas increases. Bain et al. (2016) found that quokka are capable of recolonising areas of forest within 2-3 years of fire, with early recolonization enabled by mild, patchy fires and retention of some unburnt habitat. Early results from monitoring following the prescribed burn undertaken in Gobblecannup block in May 2020 indicate that quokka have continued to occupy and utilise areas burnt by low intensity fire.

Monitoring has also demonstrated that woylie may occupy and utilise jarrah forest within six years of post-harvest burning, and that woylie populations have persisted at these sites from 2013-2019. This finding is consistent with the conclusions of an extensive study by Wayne et al. (2016) which examined woylie population density in harvested and unharvested forest across the Yornup Wilgarup Perup LMU over a 15-year period. Woylie populations underwent a substantial and widespread decline from 2000 onwards with little evidence of sustained recovery over the subsequent 14 years (Wayne et al. 2017). Monitoring sites in Boyndaminup and Gobblecannup forest blocks are towards the southern limit of the current known range of the woylie and the observations from FORESTCHECK monitoring inform our understanding of the distribution of this species. The absence of records of the woylie from external reference grid FC49 in Gobblecannup block is more likely to be attributable to low population densities at the southern extent of its range rather than unsuitable habitat conditions.

The number of grids at which koomal were recorded reduced from five in 2013 to two in 2018/19, with this species occupying both external reference and harvested grids. No koomal were recorded in the series of grids at Easter, Barlee and Lewin blocks during any of the sampling events suggesting either that koomal are uncommon in this part of the Northern karri LMU, or that if present their pattern of activity makes them difficult to detect. Defoliation by the gum-leaf skeletoniser (*Uraba lugens*) was widespread across the Strahan Cattaminup Jigsaw and Northern karri LMU during 2010 and 2011 (Wills and Farr 2016; cover image) and could have adversely affected populations of folivores such as the koomal at the time of the first round of monitoring in 2013. However, this factor is unlikely to account for the reduction in number of grids where koomal were detected in 2018 and 2019.

External reference grid FC10 is in high site quality old-growth jarrah forest in Easter block and was last burnt in 1995. This grid has been monitored on four occasions (2001/02, 2007/08, 2013 and 2018/19) providing a chronological sequence of observations of forest structure, understorey structure composition and structure, and associated species assemblages. Only a limited number of vertebrate species have been detected by trapping at this grid including dunnart (2001/02 and 2013), a single koomal (2001/2), and bush rat (2007/08); black rats were detected by trapping in 2007/08 and 2013, and again on camera imagery in 2019. Cameras also detected kangaroo in 2018 and brush wallaby in 2018 and 2019. There is no obvious reason why the composition of the vertebrate fauna at this grid should be depauperate relative to other grids in the Northern karri LMU, given that habitat elements such as large old trees and ground logs are in ample supply and the understorey is dense and complex in structure. An important implication from this finding is that habitat structure alone may not always adequately explain patterns of occupancy for vertebrate fauna, and that fauna population modelling based on habitat attributes should be verified with independent field data.

Brush wallaby were recorded on camera imagery at five of the nine grids spanning both the Strahan Cattaminup Jigsaw and Northern karri LMU and external reference and harvested forest. Prior to routine use of remote sensor cameras detections of brush wallaby relied on spotlight surveys and ad-hoc observations. Brush wallaby are one of a suite of mammal species proposed by Wayne et al. (2016) as having declined in population size in the Yornup Wilgarup Perup LMU. Observations from FORESTCHECK monitoring provide an additional source of data that can be used to quantify the distribution of species and their occupancy of forest subject different management practices.

The small number of records of species such as echidna, quenda and wambenger preclude any firm conclusions being drawn as to their response to timber harvesting and associated post-harvest burning, other than to confirm that these species are not limited to external reference grids and do occupy and utilise forest following timber harvesting.

For future monitoring, a combination of remote sensor cameras and dry pitfall trapping would enable effective sampling of a broad suite of vertebrate fauna including mammals, reptiles and amphibians.

Acknowledgements

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Table 5.2 Vertebrate fauna recorded at three monitoring grids in the Strahan Cattaminup Jigsaw LMU in 2013, 2018, 2019 and 2020. Values indicate the number of times a species was detected per 100 sampling nights by trapping or on camera imagery (*in italics on lower line of each record*). Records shown with a dash (-) indicate that the species was not detected during that sampling event. Records shown as n.d. indicate no data as these species would not be detected using the trapping method.

Species	Common name	External reference FC49				Selective harvest FC51				Gap release FC50			
MAMMALS		2013	2018	2019	2020	2013	2018	2019	2020	2013	2018	2019	2020
Antechinus flavipes	Mardo	3.3				0.4				3.3			
		-	-	-	-	-	-	-	-	-	-	-	-
Bettongia penicillata	Woylie	-				12.5				0.4			
		-	-	-	-	*10.3*	*9.2*	*4.3*	-	*3.4*	*0.8*	-	-
Cercartetus concinnus	Mundarda	-				-				-			
		-	-	-	-	-	-	-	-	-	-	-	-
Dasyurus geoffroii	Chuditch	0.8				-				-			
		-	-	-	-	-	-	-	-	-	-	-	
Isoodon obesulus	Quenda	-				-			-				
		-	-	-	-	-	-	*0.9*	-	-	-	-	-
Macropus fulginosus	Grey kangaroo	n.d.				n.d.				n.d.			
		1.7	*1.7*	-	*4*	-	*0.8*	*1.7*	-	-	-	*1.0*	*2.0*
Notomacropus irma	Western brush wallaby	n.d.				n.d.				n.d.			
		1.7	*0.8*	*2.6*	*2.7*	-	-	-	-	-	-	-	-
Phascogale tapoatafa	Wambenger	-				-				-			
		-	-	-	-	-	-	-	-	-	-	*0.9*	-
Setonix brachyurus	Quokka	0.4				1.7				1.7			
		12.1	*10.0*	*5.2*	*0.7*	*10.3*	*4.2*	*0.9*	-	*19.0*	*4.2*	*4.3*	*2.0*
Sminthopsis sp.	Dunnart	6.3	-	-	-	3.3				1.3			
		-	-	-	-	*1.7*	-	-	-	-	-	-	-
Tachyglossus aculeatus	Echidna	-				-				-			
		-	-	-	-	*1.7*	*0.8*	-	-	-	-	-	-
Trichosurus vulpecula	Koomal	-				2.1				2.5			
		-	-	-	-	*1.7*	-	-	-	*1.7*	*0.8*	-	-
Rattus fuscipes	Western Bush Rat	-				1.7				-			
		-	-	*0.9*	-	-	-	-	-	-	-	-	-
Felis catus	Cat	-				-				-			
		-	-	-	-	-	-	-	-	-	-	-	-
Mus musculus	House Mouse	1.7				0.8				0.4			
		-	-	-	-	-	-	-	-	-	-	-	-
Oryctolagus cuniculus	Rabbit	-				-				-			-
		-	-	-	-	-	-	-	-	*1.7*	-	-	*1.3*
Rattus rattus	Black Rat	-	-	-	-	-				-			
		-	*4.2*	*2.6*	*0.7*	-	-	-	-	-	-	-	-
Sus scrofa	Pig	n.d.				n.d.				n.d.			
		-	-	-	-	-	-	-	-	-	-	-	*0.7*
REPTILES													
Varanus rosenbergi	Southern Heath Monitor	0.4	-	-	-	-	-	-	-	-	-	-	-
		-	-	*1.7*	-	*3.4*	-	-	-	*3.4*	-	-	-

Table 5.3 Vertebrate fauna recorded at three monitoring grids in the Northern karri LMU (Carter forest block) in 2013, 2018 and 2019. Values indicate the number of times a species was detected per 100 sampling nights by trapping or on camera imagery (*in italics on lower line of each record*). Records shown with a dash (-) indicate that the species was not detected during that sampling event. Records shown as n.d. indicate no data as these species would not be detected using the trapping method.

Species	Common name	External reference FC54			Shelterwood FC53			Gap release FC52		
MAMMALS		2013	2018	2019	2013	2018	2019	2013	2018	2019
Antechinus flavipes	Mardo	1.7			0.8			2.5		
		-	-	-	-	-	-	*1.7*	-	-
Bettongia penicillata	Woylie	-			-			-		
		-	-	-	-	-	-	-	-	-
Cercartetus concinnus	Mundarda	3.3			0.4			0.8		
		-	-	-	-	-	-	-	-	-
Dasyurus geoffroii	Chuditch	-			-			-		
		-	-	-	-	-	-	-	-	-
Isoodon obesulus	Quenda	1.3			-			-		
		-	*1.8*	*1.8*	-	*3.6*	*0.9*	-	-	-
Macropus fulginosus	Grey kangaroo	n.d.			n.d.			n.d.		
		-	*0.9*	*2.7*	*1.7*	-	*1.8*	*1.7*	*0.9*	-
Notomacropus irma	Western brush wallaby	n.d.			n.d.			n.d.		
		1.7	*1.8*	*0.9*	*1.7*	*0.9*	*0.9*	*1.7*	*0.9*	*1.8*
Phascogale tapoatafa	Wambenger	-			-			-		
		-	-	-	-	-	-	-	-	-
Setonix brachyurus	Quokka	-			-			1.7		
		-	-	-	-	-	*1.8*	*1.7*	*4.5*	*9.1*
Sminthopsis sp.	Dunnart	0.8			-			-		
		-	-	-	-	-	-	-	-	-
Tachyglossus aculeatus	Echidna	-			-			-		
		-	-	-	-	-	-	-	-	-
Trichosurus vulpecula	Koomal	16.3			8.3			14.6		
		8.6	*9.1*	-	*3.4*	-	*0.9*	*12.1*	-	-
Rattus fuscipes	Western Bush Rat	-			-			0.8		
		-	-	-	-	-	-	-	-	-
Felis catus	Cat	-			-			0.4		
		-	*0.9*	*0.9*	-	-	-	-	-	--
Mus musculus	House Mouse	-			-			-		
		-	-	-	-	-	-	-	-	-
Rattus rattus	Black Rat	2.1			2.1			0.4		
		-	-	-	*1.7*	-	-	-	-	-
REPTILES										
Varanus rosenbergi	Southern Heath Monitor	-			-			0.8		
		-	*1.8*	-	-	*0.9*	*1.8*	*1.7*	*0.9*	-

Table 5.4 Vertebrate fauna recorded at three monitoring grids in the Northern karri LMU (Easter, Barlee and Lewin forest blocks) in 2013, 2018 and 2019. Values indicate the number of times a species was detected per 100 sampling nights by trapping or on camera imagery (*in italics on lower line of each record*). Records shown with a dash (-) indicate that the species was not detected during that sampling event. Records shown as n.d. indicate no data as these species would not be detected using the trapping method.

Species	Common name	External reference FC10			Shelterwood FC56			Gap release FC55		
MAMMALS		2013	2018	2019	2013	2018	2019	2013	2018	2019
Antechinus flavipes	Mardo	5.4			2.5			3.8		
		-	-	-	*5.2*	-	-	-	-	-
Bettongia penicillata	Woylie	-			-			-		
		-	-	-	-	-	-	-	-	-
Cercartetus concinnus	Mundarda	-			-			-		
		-	-	-	-	-	-	-	-	-
Dasyurus geoffroii	Chuditch	-			-			-		
		-	-	-	-	-	-	-	-	-
Isoodon obesulus	Quenda	-			-			-		
		-	-	-	-	-	-	-	-	-
Macropus fulginosus	Grey kangaroo	n.d.						-		
		1.7	*1.7*	-	-	*1.8*	-	-	-	-
Notomacropus irma	Western brush wallaby	n.d.			-			-		
		1.7	*0.9*	*2.9*	-	-	-	-	-	-
Phascogale tapoatafa	Wambenger	-			-			-		
		-	-	-	-	-	-	-	-	-
Setonix brachyurus	Quokka	-			0.8			0.4		
		-	-	-	*1.7*	-	-	*3.4*	*0.9*	*3.6*
Sminthopsis sp.	Dunnart	0.4			1.3			0.4		
		-	-	-	-	-	-	-	-	-
Tachyglossus aculeatus	Echidna	-			-			-		
		-	-	-	-	-	-	-	-	-
Trichosurus vulpecula	Koomal	-			-			-		
		-	-	-	-	-	-	-	-	-
Rattus fuscipes	Western Bush Rat	-			1.3			5.0		
		-	-	-	-	-	*2.7*	-	-	1.8
Felis catus	Cat	-			0.4			-		
		-	-	-	-	*0.9*	-	-	-	*4.5*
Mus musculus	House Mouse	-			-			-		
		-	-	-	-	-	-	-	-	-
Rattus rattus	Black Rat	12.5			8.8			2.9		
		-	-	*10.5*	*12.1*	*4.5*	*0.9*	*8.6*	*0.9*	-
REPTILES										
Varanus rosenbergi	Southern Heath Monitor	-			0.4			-		
		-	-	-	*3.4*	-	-	*1.7*	-	-

Table 5.5 Bird species recorded on camer imagery at FORESTHECK monitoring grids in Jarrah Forest South ecosystem. Observations from 2018 and 2019 have been combined.

Species	Common name	ER	S/S	GR	ER	S/S	GR	ER	S/S	GR
		FC49	**FC51**	**FC50**	**FC54**	**FC53**	**FC52**	**FC10**	**FC56**	**FC55**
Turnix varia	Painted button-quail									✓
Phaps chalcoptera	Common bronzewing	✓	✓				✓		✓	
Platycercus interotis	Western rosella								✓	✓
Barnardius zonarius semitorquatus	Australian ringneck parrot									✓
Eopsaltria georgiana	White-breasted robin		✓						✓	
Malurus elegans	Red-winged fairy-wren									✓
Climacteris rufa	Rufous treecreeper								✓	
Sterpera versicolor	Grey currawong	✓	✓							

6. 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
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 data 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. The data are saved and secured when the Department's 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 an ecteronic survey database. All field data sheets are presently filed at the Manjimup Research Centre.

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

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

Each voucher 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 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, making them available for further examination. The 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.

Voucher collections 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 6.1 Example of flora collection labels generated in Max-V3

WESTERN AUSTRALIAN HERBARIUM, PERTH
Flora of Western Australia

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

Lauraceae

Identified by:

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

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

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

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

Voucher: Forestcheck Monitoring Program

WESTERN AUSTRALIAN HERBARIUM, PERTH
Flora of Western Australia

Lomandra nigricans T.Macfarlane

Dasypogonaceae

Identified by:

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

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

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

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

Voucher: Forestcheck Monitoring Program

WESTERN AUSTRALIAN HERBARIUM, PERTH
Flora of Western Australia

Leucopogon capitellatus DC.

Epacridaceae

Identified by:

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

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

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

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

Voucher: Forestcheck Monitoring Program

WESTERN AUSTRALIAN HERBARIUM, PERTH
Flora of Western Australia

Leucopogon pulchellus Sond.

Epacridaceae

Identified by:

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

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

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

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

Voucher: Forestcheck Monitoring Program

Appendix 6.2 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		