Department of Biodiversity, Conservation and Attractions
Biodiversity and Conservation Science

FORESTCHECK

REPORT OF PROGRESS
Jarrah North West ecosystem fire chronosequence 2021

Produced by the Department of Biodiversity, Conservation and Attractions
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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 photos*: jarrah forest in Amphion block east of Dwellingup last burnt in 1933 illustrating (top) the high stand density and continuous cover of leaf litter on the forest floor and (bottom) a large jarrah tree felled during stand improvement works in the 1930s decade (photos: L. McCaw).

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EXECUTIVE SUMMARY

This report provides a summary of activities undertaken for the FORESTCHECK monitoring project in the Jarrah North West forest ecosystem at five grids comprising a chronosequence of time since fire. Three grids in the chronosequence were monitored in 2014 (FC65 Amphion last burnt in 1933; FC24 Kennedy last burnt in 1975; and FC64 Plavins last burnt in spring 2005). Two grids were added to the chronosequence to provide examples of forest burnt by low intensity fire in spring 2016 (FC66 Amphion adjacent to FC65, and FC67 Kennedy adjacent to FC24). The five grids in the fire chronosequence have similar basal area, size class distribution and projected foliage cover. This provides a level of confidence that differences in other biotic attributes observed across the chronosequence reflect the influence of fire history rather than inherent differences in site characteristics and forest productivity.

Findings from the second round of monitoring at the fire chronosequence grids include:

- Stand basal area increased between 2014 and 2020 at FC65 Amphion and FC24 Kennedy but declined at FC64 Plavins due to the loss of a large mature jarrah that fell following a prescribed burn in autumn 2019. Abundant regeneration of jarrah seedlings was observed at FC64 Plavins in the second winter following the prescribed burn.
- The two grids in Amphion block were distinguished by having a very small proportion of marri and a substantial number of small dead jarrah (<20 cm dbh). This was attributed to the effects of strong competition and the vulnerability of small, suppressed trees to fire.
- Repeated measurements of stand structure at FC24 Kennedy (2004, 2010, 2014, 2020) demonstrated that smaller trees (<20 cm dbh) made a negligible contribution to the growth of the stand over a 16-year period. Almost all increment was added to trees in the 20-70 cm dbh size class.
- Litter loads increased on the two grids that remained unburnt between 2014 and 2020 and were generally consistent with values reported for similar forest in the Jarrah North West ecosystem. Repeated measurements on four occasions suggest that the litter layer at FC24 Kennedy has attained an equilibrium loading where rates of accretion and decomposition are largely in balance.
- Prescribed burning in autumn reduced the volume of coarse woody at FC64 Plavins by 31% which is within the range of consumption reported from other studies of prescribed fire in south-west forests.
- Monitoring undertaken in 2017 provided the opportunity to compare detections by direct trapping with detections from motion sensor cameras and also enabled direct comparison with data from the three grids trapped in 2014. Motion sensor cameras detected some larger animals that would not otherwise be detected by direct trapping, notably the Grey kangaroo (*Macropus fulginosus*) and Western brush wallaby (*Notomacropus irma*).
- Native mammals detected both in wire cage traps and on camera imagery included the chuditch (*Dasyurus geoffroii*), wambenger (*Phascogale tapoatafa*), echidna (*Tachyglossus aculeatus*), mardo (*Antechinus flavipes*) and koomal (*Trichosorus vulpecula*). Of these the koomal was the most common species, being present at all grids and detected consistently by trapping and on camera imagery. No foxes, cats or mice were detected by trapping or on camera imagery in 2017.
- Vascular plant community responses to fire have been reported separately for four of the grids in the chronosequence by Ward et al. (2020).

1. INTRODUCTION

Scope

This report provides a summary of activities undertaken for the FORESTCHECK monitoring project in the Jarrah North West forest ecosystem at five grids that comprise a chronosequence of time since fire. The fire chronosequence is located east of Dwellingup in the Perth Hills District. Initial sampling was undertaken in 2014 and has been reported by Robinson and Tunsell (2016) at www.dbca.wa.gov.au. Here we report on further sampling undertaken between 2017 and 2020.

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 (Whitford and McCaw 2019, Ward et al. 2020).

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 and is necessary for reporting against the Montreal Process criteria and indicators. 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 protocols 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 periodically to incorporate new understandings and technologies, while acknowledging the need to ensure data are consistent and comparable over decadal timescales.

Monitoring strategy

FORESTCHECK monitoring grids have been established at a number of locations throughout the jarrah forest, stratified according to recognized ecological gradients of rainfall, evapotranspiration and soil fertility. Forest ecosystem mapping by Mattiske and Havel (1998, 2000) provides a systematic basis for stratification of sampling. 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 management actions, rather than inherent site differences.

Methodology

Monitoring 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
- 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.

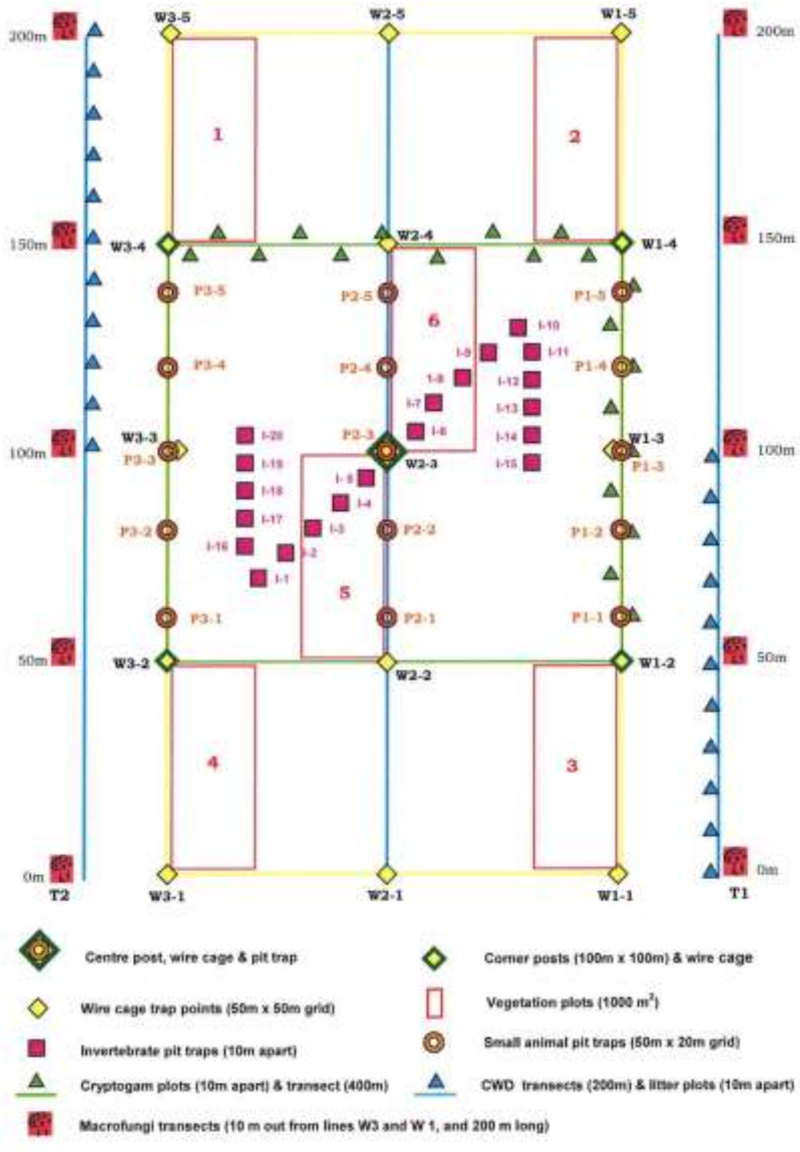

Figure 1.1 FORESTCHECK grid layout

Monitoring in the Jarrah North West forest ecosystem 2017-20

Monitoring was undertaken on five grids that represent a chronosequence of different time since last fire (Table 1.1). The fire chronosequence initially comprised three grids:

- FC24 Kennedy which was last burnt by an experimental fire in autumn 1975 and has been sampled previously in 2003/04 and 2009/10;
- FC64 Plavins which was burnt by prescribed fire in spring 2005 and subsequently in autumn 2019;
- FC65 Amphion which was last burnt in 1933 following silvicultural treatment that included felling of large veteran trees and ringbarking of poorly-formed trees.

Two grids were added to the chronosequence in 2016 to provide examples of forest recently burnt by low intensity fire:

- FC66 Amphion was established adjacent to FC65 following a fire in October 2016 ignited by spotting from an adjacent prescribed burning operation. The fire affected a portion of the compartment that had been unburnt since 1933, mostly as a low intensity fire burning during mild weather conditions during the night. Establishment of this grid provided the opportunity to study how the forest responds to fire following an extended period of fire exclusion;
- FC67 Kennedy was established adjacent to FC24 to provide an example of forest burnt during the routine application of prescribed fire in October 2016. This area had previously been burnt by prescribed fire in spring 1999.

All 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). The Forest Management Plan 2014-23 introduced the concept of Landscape Management Units (LMU) as a subdivision of forest ecosystems and all five grids are located in the Central Jarrah LMU.

All five grids are located in forest logged heavily prior to 1940 but not since that time.

Grids FC24 Kennedy and FC65 Amphion are located within Fire Exclusion Reference Areas from which fire is deliberately excluded to provide opportunities for scientific studies of the effect of fire on the environment.

Table 1.1 Location (forest block) and site attributes of FORESTCHECK monitoring grids in the Jarrah North West ecosystem established in 2014 or 2016 and re-measured in 2017-20.

Treatment/grid location	**Grid established**	**Fire history**	**Harvested**
		Year and type of most recent burn[1]	Year
FC65 Amphion	2014	1933 (unknown)	Pre 1920
FC24 Kennedy	2003	Au 1975 (prescribed)	1930–39
FC64 Plavins	2014	Sp 2005 (prescribed) Au 2019 (prescribed)	1930–39
FC66 Amphion	2016	Sp 2016 (ignited by spotting from a nearby prescribed fire)	Pre 1920
FC67 Kennedy	2016	Sp 2016 (planned)	1930-39

[1] Sp= spring, Au = autumn

The second round of monitoring undertaken between 2017 and 2020 included forest structure, leaf litter and twigs, coarse woody debris and terrestrial vertebrates. Time since last fire depended on when field sampling was undertaken and is specified for each attribute in the relevant section of this report. Vascular plant community responses to fire were also monitored and have been reported by Ward et al. (2020).

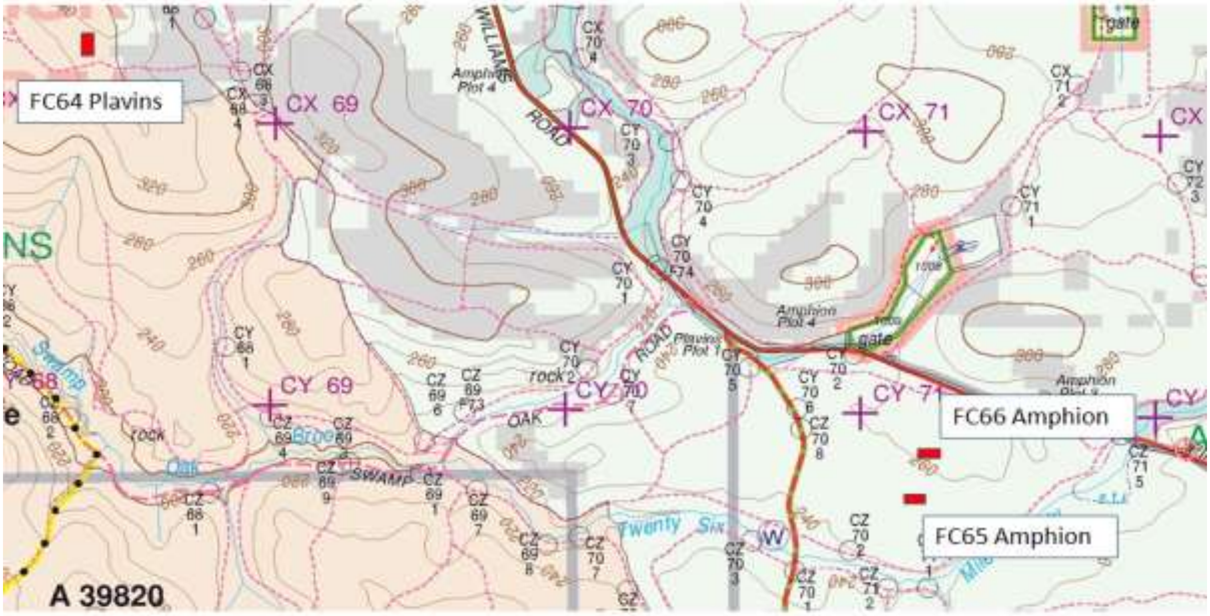

Figure 1.2 Locations of FORESTCHECK monitoring grids FC64 in Plavins block and FC65 and FC66 in Amphion block east of Dwellingup

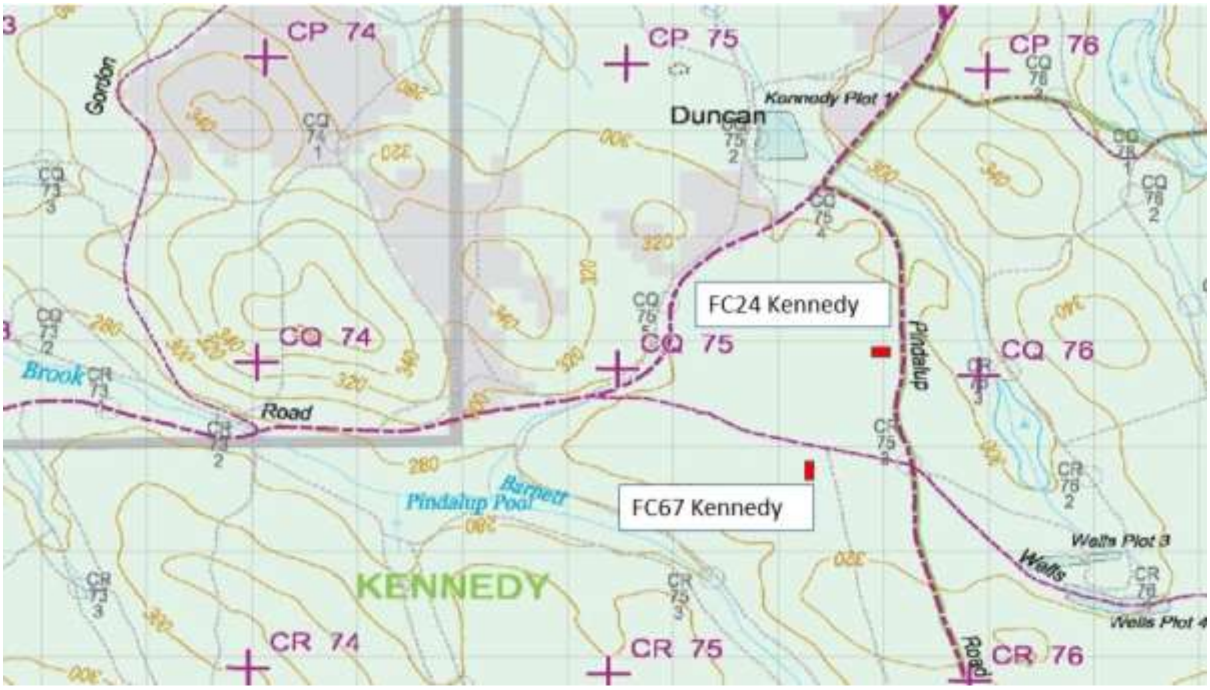

Figure 1.3 Locations of FORESTCHECK monitoring grids FC24 and FC67 in Kennedy block

Figure 1.4 FC65 Amphion illustrating dense thatch on balga grasstrees (*Xanthorrhoea preissi*) in forest unburnt since 1933.

Figure 1.5 FC66 Amphion photographed in 2020 illustrating regrowth of thatch on balga grasstrees (*Xanthorrhoea preissii*) four years after fire in 2016.

Figure 1.6 FC64 Plavins photographed in 2020 illustrating abundant regeneration of jarrah seedlings one year following autumn 2019 prescribed fire.

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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. 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 the five monitoring grids in the fire chronosequence in autumn 2020.

Assessment methods were as per the FORESTCHECK Operating Plan (DEC 2006). 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). 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. The dense thatch present on *Xanthorrhoea preissii* in FC65 Amphion prevented measurement of stem diameter and for the purposes of calculating basal area of this species the assumption was made that stems had a mean diameter of 30 cm.

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. The change in basal area of all live trees measured on the grid over the assessment period was determined and expressed as an increment (total and mean annual), noting that on some grids this included reductions in basal area resulting from tree mortality. Basal area increments were not determined for FC66 Amphion and FC67 Kennedy as the period between establishment and subsequent measurement was only three years and therefore insufficient to provide a reliable estimate of stand growth.

Results

Stand structure and species composition

Eucalypt basal area ranged from 42.8–45.4 m^{2}ha^{-1} on the grids in Amphion and Kennedy blocks but was slightly lower on FC64 Plavins due to the loss of a large jarrah tree (dbh 103 cm) (Table 2.1). This tree had a large basal scar and fell following a prescribed burn in autumn 2019. Jarrah contributed >95% of basal area at Amphion and >75% of basal area on grids at Kennedy and Plavins. Jarrah basal area increased by 0.94 m^{2}ha^{-1} at FC65 Amphion and by 1.95 m^{2}ha^{-1} at FC24 Kennedy over the six-year period between measurements with lesser increases in marri basal area reflecting the smaller contribution by this species.

Table 2.1 Basal area of eucalypts >2 m tall for five FORESTCHECK grids in the Jarrah North West ecosystem fire chronosequence in 2020. Basal area increments have not been determined (n.d.) for FC66 Amphion and FC67 Kennedy as the period between establishment and subsequent measurement was only three years.

Grid	Year of last fire	Basal area 2020 (m^{2}ha^{-1})			Basal area increment (m^{2}ha^{-1})		Mean annual increment (m^{2}ha^{-1}yr^{-1})
		Jarrah	Marri	Total	Jarrah	Marri	
FC65 Amphion	1933	41.85	0.95	42.80	0.94	0.07	0.17
FC66 Amphion	2016	42.09	1.86	43.95	n.d.	n.d.	n.d.
FC24 Kennedy	1975	33.08	9.96	43.04	1.95	0.33	0.38
FC67 Kennedy	2016	38.10	7.34	45.44	n.d.	n.d.	n.d.
FC64 Plavins	2019	31.99	5.63	37.62	-11.44	0.47	-1.83

Mid-storey species recorded included *Banksia grandis, Persoonia longifolia* and *Xanthorrhoea preissii* (Fig. 2.1). The large stature and dense thatch present on *X. preissii* were a notable feature of understorey at FC65 Amphion (cover image and Figs 1.4 and 1.5).

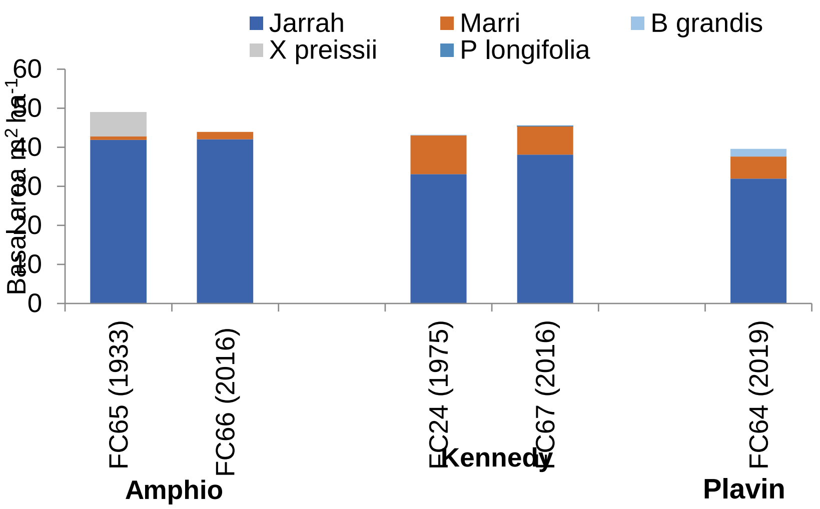


Figure 2.1 Basal area (m^2 ha^{-1}) of jarrah, marri and mid-storey species on five fire chronosequence grids in 2020

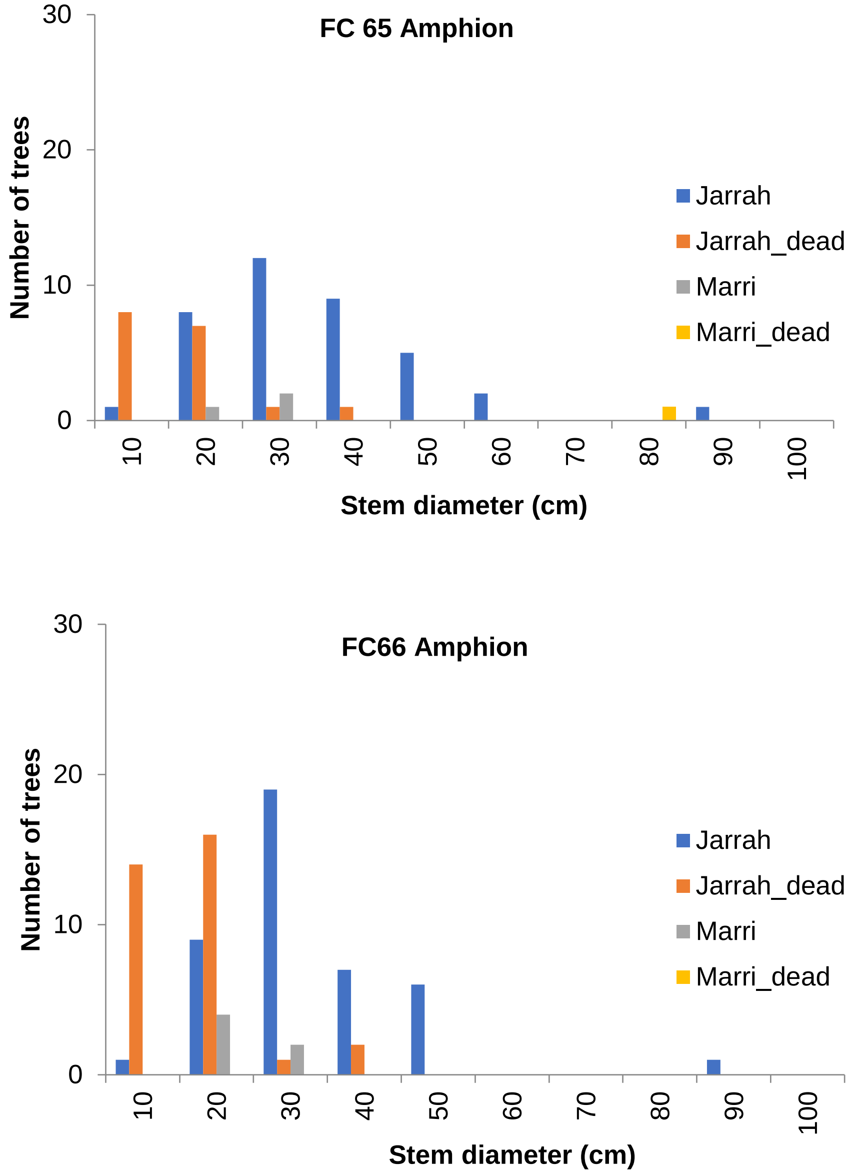
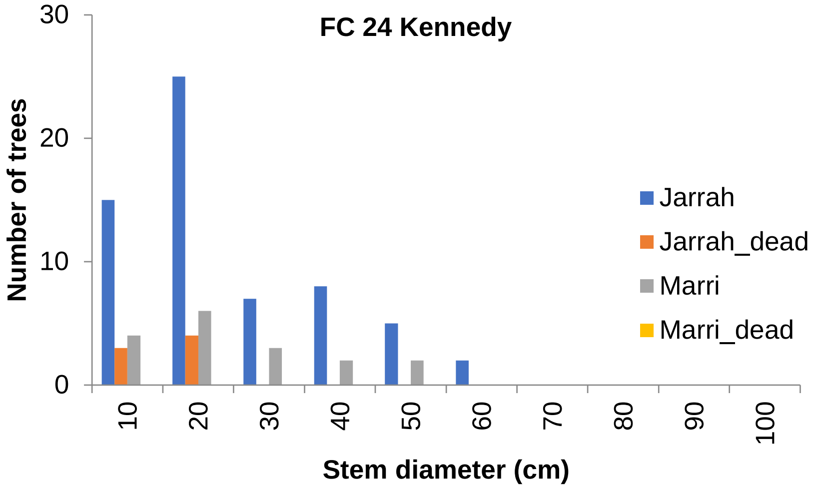
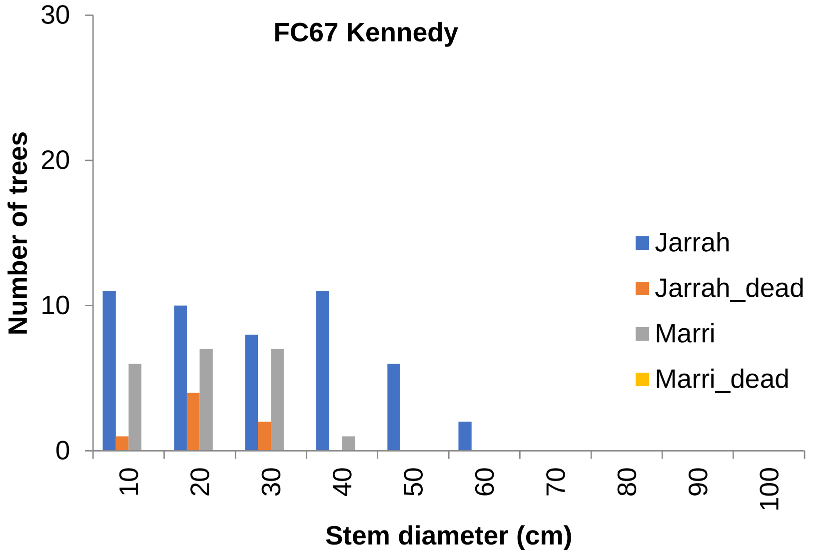


Figure 2.2 Stem diameter distribution by 10cm classes (0–9cm, 10–19cm etc.) for grids FC65 Amphion last burnt in 1933 and FC66 Amphion last burnt in 2016 following eight decades of fire exclusion.

Cut stumps resulting from past timber harvesting were recorded at both of the grids established in 2016. At FC66 Amphion stump surveys indicated that 48 m^2ha^{-1} of basal area had been removed by harvesting with stumps recorded at a frequency of 50 ha^{-1}. Stumps ranged in diameter from 85 -140 cm. At FC67 Kennedy the basal area removed by past harvesting was 12.1 m^2ha^{-1} and the frequency of cut stumps was 25 ha^{-1}. Stumps at Kennedy ranged from 65-90 cm in diameter.

Stem diameter distributions of eucalypts and mid-storey trees on grids in each treatment are shown in Figures 2.2–2.3. Diameter distributions were typically unimodal and dominated by jarrah trees 20-30 cm dbh with isolated veteran trees exceeding 50 cm dbh. Small dead jarrah <20 cm dbh were more frequent on the two grids at Amphion block than on the grids at Kennedy block, and were absent from the Plavins grid.





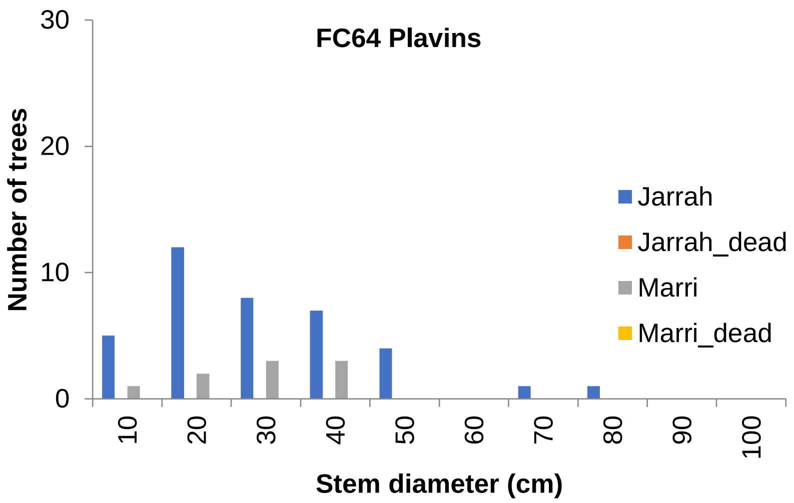


Figure 2.3 Stem diameter distribution by 10cm classes (0–9cm, 10–19cm etc.) for grids FC24 Kennedy last burnt in 1975 and FC67 Kennedy last burnt in 2016, and in FC64 Plavins last burnt in 2019.

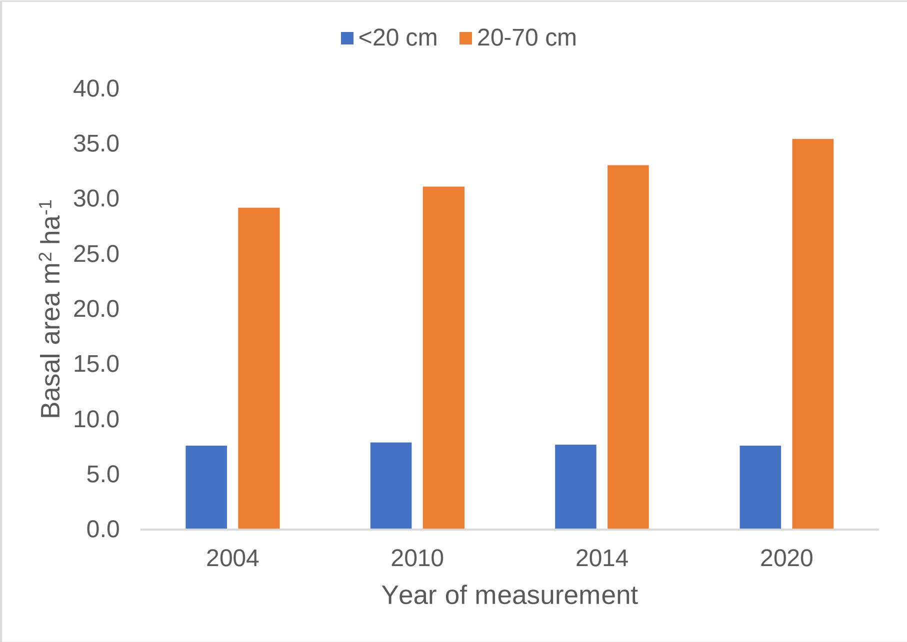


Figure 2.4 Basal area contributed by eucalypts in two size classes (dbh, cm) on grid FC24 Kennedy at four consecutive measurement events

External reference grid FC24 Kennedy has been measured on four occasions between 2004 and 2020 providing the opportunity to examine changes in stand structure in the absence of fire. Basal area contributed by trees in two size classes (dbh <20 cm, 20-70 cm) is shown in Fig. 2.4. Between 2004 and 2020 the basal area of trees <20 cm dbh remained constant (7.6-7.9 m^2ha^{-1}) and the proportion of stand basal area contributed by this size class declined from 21% to 18%. The basal area of trees 20-70 cm dbh increased from 29.2 to 35.4 m^2ha^{-1} and contributed more than 80% of the stand basal area in 2020.

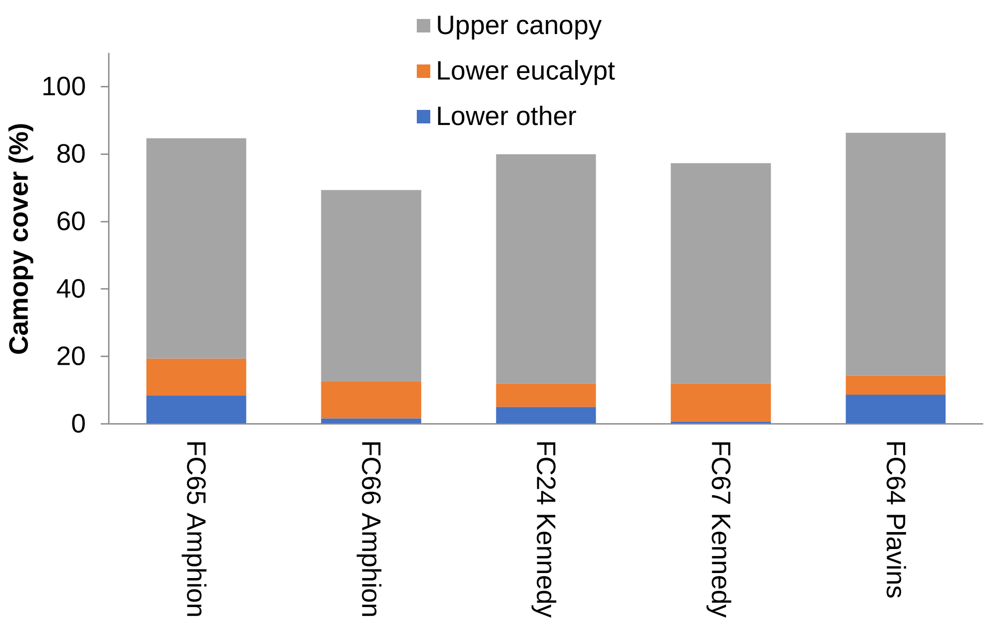


Figure 2.5 Projected foliage cover of eucalypts and other species divided into lower (2–15m) and upper (>15m) storey strata

Eucalypt foliage from the upper storey (>15m height) comprised the largest proportion of projected foliage cover on all grids, with upper storey cover in the range 57-72% (Fig. 2.5). Eucalypt foliage from the lower storey contributed 5-7% to projected cover. Mid-storey trees contributing to projected foliage cover in the lower layer were predominantly *B. grandis*.

Discussion

The five monitoring grids in the fire chronosequence have similar basal area, size class distribution and projected foliage cover. This provides a level of confidence that differences in other biotic attributes observed across the chronosequence do in fact reflect the influence of fire history rather than inherent differences in site characteristics and forest productivity. More extensive replication is desirable and indeed necessary to provide statistical rigour for hypotheses about the effects of fire history but this is difficult to achieve in practice because there are few areas of the Jarrah North West ecosystem from which fire has been excluded for more than four decades. Extensive bushfires in 1961 burnt through much of the forest in the Dwellingup area, and in the following decades prescribed fire has been applied widely to manage fuel loads and as a silvicultural tool. Bauxite mining has also removed the native forest across large parts of the landscape and replaced it with stands of rehabilitated forest that have, to varying degrees, different floristic composition and vegetation structure to that of the original forest. In particular, the nature of mining operations precludes the retention of legacy elements including veteran trees and large ground logs resulting from the fall of mature trees. Fire Exclusion Reference Areas enable scientific studies into the ecological effects of fire by providing areas of forest unburnt for several decades or longer.

Re-measurement in 2020 demonstrated increases in stand basal area at FC65 Amphion and FC24 Kennedy but a decline in basal area at FC64 Plavins due to the loss of a large mature jarrah that fell following a prescribed burn in autumn 2019. The two grids in Amphion block were distinguished by having a very small contribution of marri, and a substantial number of dead jarrah in the smaller size classes (<20 cm dbh). At recently burnt grid FC66 mortality of small stems would reflect both the effects of competition and the vulnerability of small-diameter suppressed trees to fire, while at the long unburnt grid FC65 dead stems would be due to competition-induced mortality alone.

Repeated measurements of stand structure at FC24 Kennedy (2004, 2010, 2014, 2020) have demonstrated that smaller trees (<20 cm dbh) made a negligible contribution to the growth of the stand over a 16-year period. Almost all increment was added to trees in the 20-70 cm dbh size class. The absence of trees >70 cm dbh in Kennedy stand can be attributed to the nature of the timber harvesting that took place here in the 1930s rather than an inability of the site to grow trees of this stature. The pattern of growth at FC24 Kennedy is quite different to that reported for old-growth forest of jarrah and marri at FC10 Easter in the Jarrah South ecosystem trees <20 cm dbh contributed a steadily increasing proportion of stand basal area between 2002 and 2020. Over this period the contribution of trees in the larger size classes remained relatively static (20-70 cm dbh class) or declined due to the death of large mature trees >70 cm dbh (McCaw and Tunsell 2021).

Prescribed burning in autumn 2019 resulted in abundant regeneration of jarrah seedlings at FC64 Plavins (Fig. 1.6). Many seedlings survived the following summer and were evidently vigorous and healthy in June 2020 despite the presence of a layer of leaf litter and a canopy cover with >80% projected foliage cover. Jarrah recruitment is typically episodic and dependent on the coincidence of ample seed supply and favourable seedbed conditions (Cargill *et al*. 2019). Ongoing measurement at this grid would provide an opportunity to determine how many of these seedlings persist to eventually be recruited into the ground coppice stage of development and to subsequently become saplings.

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3. LITTER, TWIGS AND COARSE WOODY DEBRIS

Lachie McCaw

Introduction

Litter, small wood and twigs (SWT) and coarse woody debris (CWD) are important structural and biological components of forest ecosystems. Wood and leaf litter on the forest floor provide 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).

Loadings of SWT and volumes of CWD on grids FC24 Kennedy, FC64 Plavins and FC65 Amphion were measured in 2014 and reported by Robinson and Tunsell (2016). Further sampling was undertaken in 2017 to quantify CWD volume and condition on FC66 Amphion and FC67 Kennedy following establishment of these grids. Loadings of SWT at FC24 Kennedy and FC65 Amphion were re-sampled in June 2020 to determine the trend of accumulation in forest subject to multi-decadal fire exclusion. Grid FC66 Amphion was also resampled to quantify the initial pattern of SWT accumulation in this stand.

Field and Laboratory Measurements

Litter and SWT were sampled on grids FC24 Kennedy, FC65 Amphion and FC66 Amphion in June 2020. Times since last fire were respectively 45 years, 87 years and 4 years. Grid FC24 Kennedy had previously been sampled for SWT in 2004, 2010 and 2014.

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}).

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) and Whitford and McCaw (2019).

Results and Discussion

Litter

Litter loadings increased between 2014 and 2020 in the continued absence of fire at FC24 Kennedy and FC65 Amphion (Fig. 3.1). The increase in loading on FC24 Kennedy (1.3 tha^{-1}) was smaller than that measured at FC65 Amphion (3.2 tha^{-1}). Over the 16-year period between 2004 and 2020 the litter loading on FC24 Kennedy remained in the range 10.9-13.2 tha^{-1} with a tendency for reduced variability in more recent sampling as indicated by the declining magnitude of the sem (Fig. 3.1). At grid FC66 Kennedy litter loading increased from 2.4 tha^{-1} to 8.2 tha^{-1} in the three years between 2017 and 2020.

Small wood and twigs

Loadings of SWT varied from 1-2 t ha^{-1} and were small compared to litter loadings (Fig. 3.2). Over the 16-year period between 2004 and 2020 the SWT loading on FC24 Kennedy increased steadily from 0.8 t ha^{-1} to 1.7 tha^{-1}, while maintaining a similar magnitude of variability.

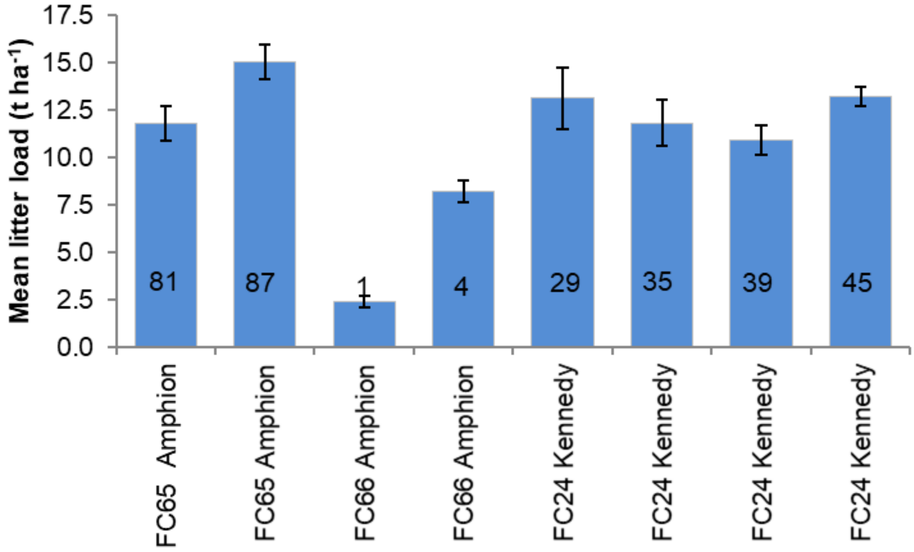

Figure 3.1 Mean litter loads (t ha^{-1} ± sem) measured at three FORESTCHECK grids in the fire chronosequence at different times since fire. Numbers in columns indicate years since fire.

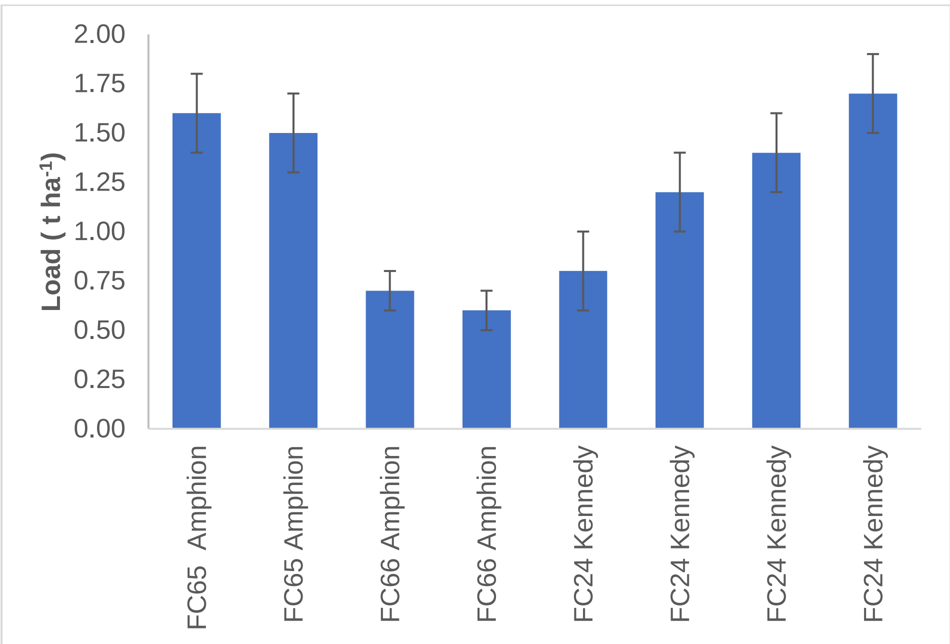

Figure 3.2 Mean loads ((t ha^{-1} ± sem) of small wood and twigs measured at each FORESTCHECK grid at Donnelly 2 in 2020. Time since fire for each grid is indicated in Fig.3.1.

Coarse woody debris

Table 3.1 shows volumes of CWD on the five grids. Data reported previously for FC65 Amphion, FC24 Kennedy and FC64 Plavins have been included here for comparative purposes, noting that the volumes given here for these grids are slightly lower (1-2%) than reported by Robinson and Tunsell (2016) due to differences in the computational method used. The largest volume of CWD was recorded in the long unburnt forest at FC65 Amphion where logs >500 mm diameter contributed almost 75% of the total volume (refer to cover photo). In adjacent forest burnt in spring 2016 the total volume of CWD was considerably lower and represented about 40% of the volume measured in the long unburnt forest. The reverse situation was observed for the two grids in Kennedy block where the volume of CWD on the grid burnt in 2016 was greater than on the grid from which fire had been excluded since 1975.

Consumption of CWD during the autumn 2019 prescribed burn at FC64 Plavins was quantified directly by comparing volumes measured in 2014 and again in 2020. The prescribed burn reduced CWD volume by 30.8 m^3 which represented a proportional reduction of 31%. Percentage reductions in volume were greatest for small CWD (91%) and least for large CWD (14%).

Table 3.1 Volume of CWD by diameter class at five FORESTCHECK grids in the Jarrah North West ecosystem fire chronosequence

Grid	Year last burnt	Volume of CWD (m^3 ha^{-1}) by diameter class				
		25-75 mm	76-225 mm	225-500 mm	>500 mm	Total
FC65 Amphion	1933	3.2	19.0	54.1	220.4	296.7
FC66 Amphion	2016	1.9	12.1	27.5	75.4	116.9
FC24 Kennedy	1975	1.6	8.8	26.9	50.8	88.1
FC67 Kennedy	2016	4.9	20.2	24.9	90.1	140.1
FC64 Plavins	2005	4.5	15.0	27.2	51.1	97.8
	2019[1]	0.4	5.7	17.0	43.9	67.0

[1] CWD re-measured in 2020 following prescribed burning in autumn 2019.

Discusssion

Litter loads increased on the two grids that remained unburnt between 2014 and 2020. The Forest Fire Behaviour Tables for Western Australia predict litter accumulation as a function of time since fire and canopy cover and indicate that after 25 years without fire the expected litter load in forest with 60 canopy cover could approach 20 tha^{-1}. Litter loadings measured on FC65 Amphion and FC24 Kennedy were below this value, although including the SWT component reduced this difference somewhat. Loadings were generally consistent with values reported by Burrows (1994) and Gould *et al*. (2012) for similar forest in the Jarrah North West ecosystem. Repeated measurements at FC24 Kennedy on four occasions over a 16-year period are consistent suggest that the litter layer has attained an equilibrium loading where rates of accretion and decomposition are largely in balance. Climatic factors affecting canopy condition, leaf area and rates of decomposition would account for some of the variation between sampling events. Consecutive measurements also indicate a gradual increase in woody components of the surface fuel layer with small but steady increments in SWT. Increases in the twig and non-leaf components of forest floor litter have been demonstrated for karri (*Eucalyptus diversicolor*) forest and reflect the slower rates of decay typical of more woody material (O'Connell 1987). The rate of litter accumulation during the first four years since fire at FC66 Amphion is consistent with predictions from the Forest Fire Behaviour Tables and the model of Gould et al. (2011).

Prescribed burning in autumn reduced the volume of CWD at FC64 Plavins by 31%. Previous studies of woody fuel consumption during prescribed fires in south-west forests have ranged from 30% to 49% (Hollis et al. 2016; Hollis et al. 2018). Consumption measured during autumn burning is generally greater than during spring burning, although the number of observations from autumn fires has to date been small. Greater consumption during autumn fires is expected on theoretical grounds due to the typically dry condition of the soil and woody debris following the summer drought, and the typically greater consumption of fine dead fuels that contribute to pre-heating and ignition of woody debris. FORESTCHECK monitoring has provided an important opportunity to better quantify woody fuel consumption during fires in the jarrah forest as fuel characteristics are described in detail on all grids, and over time the number of grids burnt by prescribed fires and bushfires continues to grow. Fuel consumption has been quantified for more than 20 monitoring grids, with some grids experiencing several fire events since being established.

The large difference in CWD volume measured on the burnt and unburnt grids in Amphion block suggests that the fire in spring 2016 consumed a substantial quantity of woody fuel. While consumption cannot be quantified accurately the sampling protocol for CWD has been shown to provide estimates of volume with a co-efficient of variation of less than 20%. Differences in CWD volumes between FC65 and FC66 are much larger than would be explained by sampling variability alone, particularly for logs with a diameter >225 mm. Logs larger than this contributed a much greater volume on FC65 Amphion than on any of the other grids, despite the fact that other attributes of stand structure (basal area, size class distribution) were similar between all five grids. Fire has been excluded from FC65 for more than 80 years and this would enable large logs to progress to advance stages of decay without being partially or fully consumed by fire. Hollis et al. (2018) observed that logs in advanced stages of decay are more likely to be consumed than logs that are sound and contain only a small proportion of decayed wood.

Considering the paired grids in Kennedy block the volume of CWD was substantially greater on the recently burnt grid (FC66) than on the grid that was last burnt in 1975 (FC24). The most likely explanation for this difference is that the 1975 fire was conducted under dry conditions in March as an experiment with the deliberate intent of generating moderate to high intensity fire behaviour. Fire burning under these conditions will typically consume a large proportion of CWD, and Whitford and McCaw (2019) have shown that the volume of CWD is inversely related to the number of times that a stand has been burnt by unplanned fire.

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4. VERTEBRATE FAUNA

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Introduction

Monitoring of vertebrate fauna on FORESTCHECK grids in the Jarrah North West fire chronosequence was undertaken in 2017 using a combination of wire cage and pitfall traps, and portable remote sensor cameras. 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. This section reports on camera trapping undertaken in 2017 and compares findings to previous trapping results from 2014.

Monitoring

Cameras were deployed at five grids in autumn and spring 2017 with details of deployment dates and sampling effort provided in Table 4.1. Five remote sensor 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 2015/37.

Trapping was conducted in 2017 over two sessions of four nights each, approximately one month apart in autumn and spring using protocols described 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. Deployment dates and sampling effort for trapping undertaken in 2014 on grids FC24 Kennedy, FC64 Plavins, FC65 Amphion and provided in Table 4.1 for comparative purposes.

Table 4.1 Details of sampling events and effort for vertebrate fauna monitoring at five FORESTCHECK grids in the Jarrah North West ecosystem fire chronosequence

Method	Sample year	Sampling dates	Sampling effort total trap nights per grid
Camera	2017	5-31 May 3 Nov–5 Dec	26 x 5 cameras 33 x 5 cameras
Wire cage / pitfall	2017	2-5 May 30 May-2 Jun 31 Oct-3 Nov 6-9 Dec	60 per trap type 60 per trap type 60 per trap type 60 per trap type
Wire cage / pitfall	2014	25-28 Mar 6-9 May 23-26 Sep 4-7 Nov	60 per trap type 60 per trap type 60 per trap type 60 per trap type

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 4.1 and 4.2. 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 possums were observed in pairs 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 (%).

Figure 4.1 Wambenger (*Phascogale tapoatafa*) at FC64 Plavins in May 2017

Figure 4.2 Chuditch (*Dasyuris geoffoii*) at FC67 Kennedy in May 2017

Results
Monitoring undertaken in 2017 provided the opportunity to compare detections by direct trapping with detections from motion sensor cameras, and also enabled direct comparison with data from the three grids trapped in 2014. Motion sensor cameras detected some larger animals that would not otherwise be detected by direct trapping, notably the Grey kangaroo (*Macropus fulginosus*) and Western brush wallaby (*Notomacropus irma*) (Table 4.2). Kangaroo were detected at all grids with a tendency for slightly fewer detections at the two grids in Kennedy block. Brush wallaby were detected at four of the five grids in the chronosequence except at FC66 Amphion. Brush wallaby were detected less often than kangaroo, with the highest number in recently burnt forest at FC67 Kennedy.

Medium-sized native mammals detected both in wire cage traps and on camera imagery included the chuditch (*Dasyurus geoffroii*), wambenger (*Phascogale tapoatafa*), echidna (*Tachyglossus aculeatus*) and koomal (*Trichosorus vulpecula*) (Table 4.2). Of these species the koomal was the most common, being present at all grids and detected consistently by trapping and on camera imagery. The only grid where koomal were not trapped in 2017 was FC66 Amphion. Koomal were most common at FC64 Plavins and FC24 Kennedy, but less common in the long unburnt forest at FC65 Amphion and in recently burnt forest at FC66 Amphion and FC67 Kennedy. Trap success for koomal was similar in 2014 and 2017 at FC64 Plavins and FC65 Amphion, but lower in 2017 at FC24 Kennedy.

Echidna were the next most common of the medium-sized native mammals being detected on camera imagery at four of the five grids, other than FC66 Amphion. Echidna were also trapped in 2017 at FC64 Plavins and FC67 Kennedy.

Chuditch were detected in 2017 at the two recently burnt grids FC66 Amphion and FC67 Kennedy (Fig. 4.2). Imagery showed chuditch moving past the cameras at high speed, in contrast to most other species which tended to remain in the field of view and be captured on multiple images whilst foraging.

Wambenger were detected by trapping and on camera imagery at FC64 Plavins but not at the other four grids. Fewer wambenger were detected in 2017 than in 2014.

Smaller mammals detected in 2017 included the mardo (*Antechinus flavipes*), mundarda (*Cercatetus concinnus*) and dunnart (*Sminthopsis* sp.) (Table 4.2). Mardo were trapped on all grids in 2017 and were detected by cameras at FC24 Kennedy and FC65 Amphion. Trap success for mardo in 2017 was not strongly influenced by time since fire with the same trap success rate recorded in long unburnt forest at FC65 Amphion and FC67 Kennedy which was burnt less than eight months prior to trapping. Trap success was lower in 2017 than in 2014 at FC64 Plavins and FC65 Amphion but similar in 2014 and 2017 at FC24 Kennedy.The mundarda at FC24 Kennedy and dunnart at FC66 Amphion were detected in pitfall traps.

The Southern Heath Monitor (*Varanus rosenbergi*) was detected on camera imagery at FC65 Amphion and at the two grids in Kennedy block, and a monitor was also trapped at FC67 Kennedy.

No foxes, cats or mice were detected by trapping or on camera imagery in 2017.

Six species of ground active bird were recorded on camera imagery in 2017, with the greatest number in recently burnt forest at FC67 Kennedy (Table 4.3).

Table 4.2 Vertebrate fauna recorded at five FORESTCHECK monitoring grids in the Jarrah North West ecosystem fire chronosequence in 2014 (trapping) and 2017 (trapping and camera imagery). Year of last burn prior to sampling is shown. 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	FC65 Amphion Last burnt 1933		FC66 Amphion Last burnt 2016	FC24 Kennedy Last burnt 1975		FC67 Kennedy Last burnt 2016	FC64 Plavins Last burnt 2005	
MAMMALS		2014	2017	2017	2014	2017	2017	2014	2017
Antechinus flavipes	Mardo	8.3	4.6 *0.3*	0.4 -	2.9	2.5 *0.3*	4.6 -	4.2	2.1 -
Cercatetus concinnus	Mundarda	-	- -	-	-	0.4 -	-	-	- -
Dasyurus geoffroii	Chuditch	-	- -	0.4 -	0.4 -	- -	0.4 *0.3*	-	- -
Isoodon obesulus	Quenda	-	- -	- -	-	- -	- -	-	- -
Macropus fulginosus	Grey kangaroo	n.d.	n.d. *3.7*	n.d. *3.7*	n.d.	n.d. *2.4*	n.d. *0.7*	n.d.	n.d. *3.4*
Notomacropus irma	Western brush wallaby	n.d.	n.d. *1.0*	n.d. -	n.d. -	n.d. *0.7*	n.d. 1.4	n.d.	n.d. *0.7*
Phascogale tapoatafa	Wambenger	3.3	- -	- -	0.4	- -	- -	-	0.8 *0.3*
Sminthopsis sp.	Dunnart	0.4	 -	1.3 -	-	- -	- -	-	- -
Tachyglossus aculeatus	Echidna	-	- *0.3*	- -	- -	- *1.7*	0.4 *0.3*	0.4	0.4 *0.3*
Trichosurus vulpecula	Koomal	0.8	0.8 *1.0*	- *0.3*	11.3 -	5.8 *4.1*	0.8 *0.3*	2.5	2.9 *3.4*
Mus musculus	House Mouse	-	- -	- -	-	- -	- -	-	- -
Vulpes vulpes	Red fox	n.d.	n.d. -	n.d. -	n.d.	n.d. -	n.d. -	n.d.	n.d. -
REPTILES									
Varanus rosenbergi	Southern Heath Monitor	-	- 1.0	- -	-	- *0.7*	0.4 *0.3*	 -	

Table 4.3 Bird species recorded on camera imagery at five FORESTCHECK monitoring grids in the Jarrah North West ecosystem fire chronosequence in 2017.

Species	Common name	FC65 Amphion Last burnt 1933	FC66 Amphion Last burnt 2016	FC24 Kennedy Last burnt 1975	FC67 Kennedy Last burnt 2016	FC 64 Plavins Last burnt 2005
Dromaius novahollondiae	Emu			✓	✓	✓
Platycercus spurius	Red-capped parrot				✓	
Barnardius zonarius semitorquatus	Australian ringneck parrot				✓	
Neophema elegans	Elegant parrot				✓	
Climacteris rufa	Rufous treecreeper		✓		✓	
Sterpera versicolor	Grey currawong			✓	✓	

Discussion

Koomal and the mardo were the most widespread and frequently detected mammals in the Jarrah North West fire chronosequence. This finding is consistent with results from trapping undertaken in 2014, and with earlier trapping at FC24 Kennedy (spring 2003/autumn 2004, and spring 2009/autumn 2010). Koomal have been detected at all four monitoring events, and mardo have been detected in 2009/10, 2014 and 2017. Chuditch were also trapped at FC24 Kennedy in 2004

Comparison of trapping results between 2014 and 2017 shows that trap success for koomal reduced by about half at FC24 Kennedy but remained the same at the two other grids monitored in both 2014 and 2017. In contrast, trap success for mardo reduced at FC65 Amphion and FC64 Plavins but remained at a similar level at FC24 Kennedy. These results suggest that variations in abundance and activity of these species may be attributable to factors other than time since fire, which in this case increased on all grids.

Mardo were found to be equally active in recently burnt forest at FC67 Kennedy as in long-unburnt forest at FC65 Amphion. The trapping points at FC67 are located several hundred metres west of the track that separates the forest burnt in spring 2016 from the forest burnt in March 1975, raising the possibility that mardo residing in the longer unburnt forest are also foraging in the recently burnt forest.

Use of remote sensor cameras for monitoring vertebrate fauna activity favours detection of large species over smaller species, as noted for the Jarrah South ecosystem. Cameras provide useful information about activity patterns of kangaroo and brush wallaby, as well as species such as echidna that are seldom observed directly or trapped in wire cage traps. Cameras are effective for detecting large reptiles such the Southern Heath monitor but not for smaller reptiles and amphibians.

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