NSW NATIONAL PARKS & WILDLIFE SERVICE

River Red Gum Ecological Thinning Trial

Monitoring report 2020

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Cover photo: Two botanists surveying ground flora in river red gum forest. Evan Curtis.

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Key results

The key results for each monitoring variable analysed in this report are listed below. Statistically significant effects of ecological thinning in 2019 are shaded grey.

Tree growth rates	Thinned plots had faster tree growth rates (by 0.7–2.8 mm per year) than control plots. In thinned plots, small trees grew faster than large trees. In thinned plots, tree growth rates were faster when thinning occurred after flooding.
Tree mortality	Thinned plots had higher proportions of dead trees (10–11 per 100) than control plots (7 per 100) on average in 2019.
Germinants	No effect of thinning was detected on the probability of germinants occurring. There was insufficient data to model germinant abundance.
Seedlings	No effect of ecological thinning was detected on the probability of seedlings occurring.
	Heavily thinned plots on drier (Site Quality 2) sites had higher abundances of seedlings (10 additional seedlings in three 0.04 hectare subplots) than control or moderately thinned plots in 2019.
Saplings	Thinned plots had fewer saplings than control plots in all post-thinning years.
Average crown extent	Thinned plots in drier (Site Quality 2) sites had higher average crown extent (3–4%) than control plots in 2019.
Prevalence of recent decline in crown extent	Thinned plots on drier (Site Quality 2) sites had fewer trees with recent decline in crown extent (10–15% fewer trees) than control plots in 2019.
Magnitude of recent decline in crown extent	No effect of ecological thinning was detected on the magnitude of recent decline in crown extent.
Live canopy visual	Heavily thinned plots on wetter (Site Quality 1) sites had lower (2%) visually assessed average live canopy than control or moderately thinned plots in 2019.
Dead canopy visual	No effect of ecological thinning was detected on visually assessed average dead canopy cover.
Foliage projective cover	Thinned plots had a lesser magnitude of decline (0.07–0.09 decline) in projective foliage cover than control plots (0.13–0.14 decline) between 2015 and 2019.
Plant area index	Thinned plots on wetter (Site Quality 1) sites had lower average plant area index (0.2–0.4 lower) than control plots in 2019. Heavily thinned plots on drier (Site Quality 2) sites had lower average plant area index (0.2 lower) than control or moderately thinned plots in 2019.

Overall fuel hazard	No effect of ecological thinning was detected on overall fuel hazard.
Litter depth	No effect of ecological thinning was detected on litter depth.
Litter cover	No effect of ecological thinning was detected on litter cover.
Surface fuel hazard	No effect of ecological thinning was detected on surface fuel hazard.
Live near surface vegetation	No effect of ecological thinning was detected on live near surface vegetation cover.
Dead near surface vegetation	No effect of ecological thinning was detected on dead near surface vegetation cover.
Near surface fuel hazard	Heavily thinned plots had a lower probability of being in the high category than control or moderately thinned plots in 2019.
Combined surface fuel hazard	No effect of ecological thinning was detected on combined surface and near surface fuel hazard.
Live elevated vegetation cover	No effect of ecological thinning was detected on visually assessed live elevated vegetation cover.
Dead elevated vegetation cover	Thinned plots had lower dead elevated vegetation cover in 2017 and 2018 than in 2015, but not in 2019.
Elevated fuel hazard	Moderately thinned plots had a slightly higher probability (about 5%) of being in the low category than control or heavily thinned plots in 2019.
Native plant richness	No effect of ecological thinning was detected on native plant species richness in 2019. Heavily thinned plots had more (an additional two native species per 0.04 hectare subplot) in heavily thinned plots in 2017 and 2018 than in 2015.
Exotic plant richness	Moderately thinned plots had higher exotic plant species richness (approximately two species per 0.04 hectare subplot) in 2019 than in 2015. In previous years, both moderately and heavily thinned plots had higher exotic plant species richness (about two species per 0.04 hectare subplot) in 2018 than in 2015, as did heavily thinned plots in 2017.
Native plant cover	Heavily thinned plots had slightly lower native plant cover (0.5%) in 2019 than in 2015, with low confidence.
Exotic plant cover	Heavily thinned plots had slightly higher (0.43–0.58% higher) exotic plant cover than control or moderately thinned plots, with low confidence.
Floristic composition	No effect of ecological thinning was detected on native or exotic floristic community composition.
Threatened plants	Floating swamp wallaby grass was recorded in 2015 and 2017 but not in 2018 or 2019.

Bird species richness	Moderately thinned plots had higher bird species richness (approximately two species per 2 hectare subplot) than control plots in 2019.
Bird community composition	No effect of ecological thinning was detected on bird community composition.
Threatened birds	No effect of ecological thinning was detected on threatened bird species. Eight threatened bird species were recorded in 2019.
Overall bat activity	Overall bat activity was lowest in control plots and highest in heavily thinned plots in 2020.
Clutter specialist bat activity	Clutter specialist activity was lowest on heavily thinned plots in 2020.
Clutter avoider bat activity	Clutter avoider activity was highest on plots that had been heavily thinned, with marked fluctuations over previous years.
White-striped mastiff bat activity	White-striped mastiff bat activity was slightly higher in thinned plots than control plots in 2020.
Large forest bat activity	Large forest bat activity was lowest in control plots and highest in heavily thinned plots in 2020.

All results are preliminary, and not to be relied upon without consulting the authors. The effectiveness of ecological thinning in achieving the stated trial aims will be evaluated when five years of post-thinning data is available.

1. Introduction

1.1 Ecological thinning trial

The aims and details of the experimental design are fully described in *Ecological thinning trial in New South Wales and Victorian River Red Gum forests: Experimental design and monitoring plan* (OEH 2012), which was included in Appendix 1 of *Public Environment Report: Ecological thinning trial in New South Wales River Red Gum forests* (OEH 2014). The experimental design is also detailed in Gorrod et al. (2017) and summarised briefly below.

Aims of the trial

The ecological thinning trial aims to learn about the effectiveness of ecological thinning for addressing a range of conservation concerns associated with widespread high stem density stands and canopy dieback in *Eucalyptus camaldulensis* (river red gum) forests.

The trial's hierarchy of aims are:

- The primary aim for the trial is to determine whether any of several levels of ecological thinning positively affect biodiversity, canopy condition and resilience to epidemic river red gum mortality within all stands of river red gum forests, and whether these effects depend on water availability and initial stem density.
- The secondary aim for the trial is to determine whether any of several levels of ecological thinning positively affect characteristics of the stands that are reasonably expected to lead to the primary aim, and whether these effects depend on water availability and initial stem density. For example: hollow bearing tree recruitment levels, and understorey species diversity.
- The tertiary aim for the trial is to determine whether any of several levels of ecological thinning positively affect characteristics of the trees that are reasonably expected to lead to the secondary aim, and whether these effects depend on water availability and initial stem density. For example: tree diameter growth rates, tree diameter distribution diversity, crown shape and health.

Five years post-thinning, at the conclusion of the 2021–22 financial year, analyses will be undertaken to determine whether the available data supports, contradicts or remains uncertain as to whether ecological thinning may achieve these aims.

Number of ecological thinning trial sites

A total of 22 sites are located in the Millewa precinct of Murray Valley National Park in New South Wales (Figure 1). The numbers and locations of ecological thinning trial sites were selected to represent a spectrum of within-stand competition (Table 1). Competition was characterised by stem density and a surrogate of water availability (site quality). Site quality is derived from tree height mapping (Baur 1984): Site Quality 1 (SQ1) is associated with increased water availability and taller trees than Site Quality 2 (SQ2). More sites are located in high stem density stands because they are the focus of management interest.

Table 1 Number of sites in the ecological thinning trial

	<200 stems/ha	200–400 stems/ha	>400 stems/ha	Total
Site Quality 1	2	4	5	11
Site Quality 2	2	4	5	11
Total	4	8	10	22

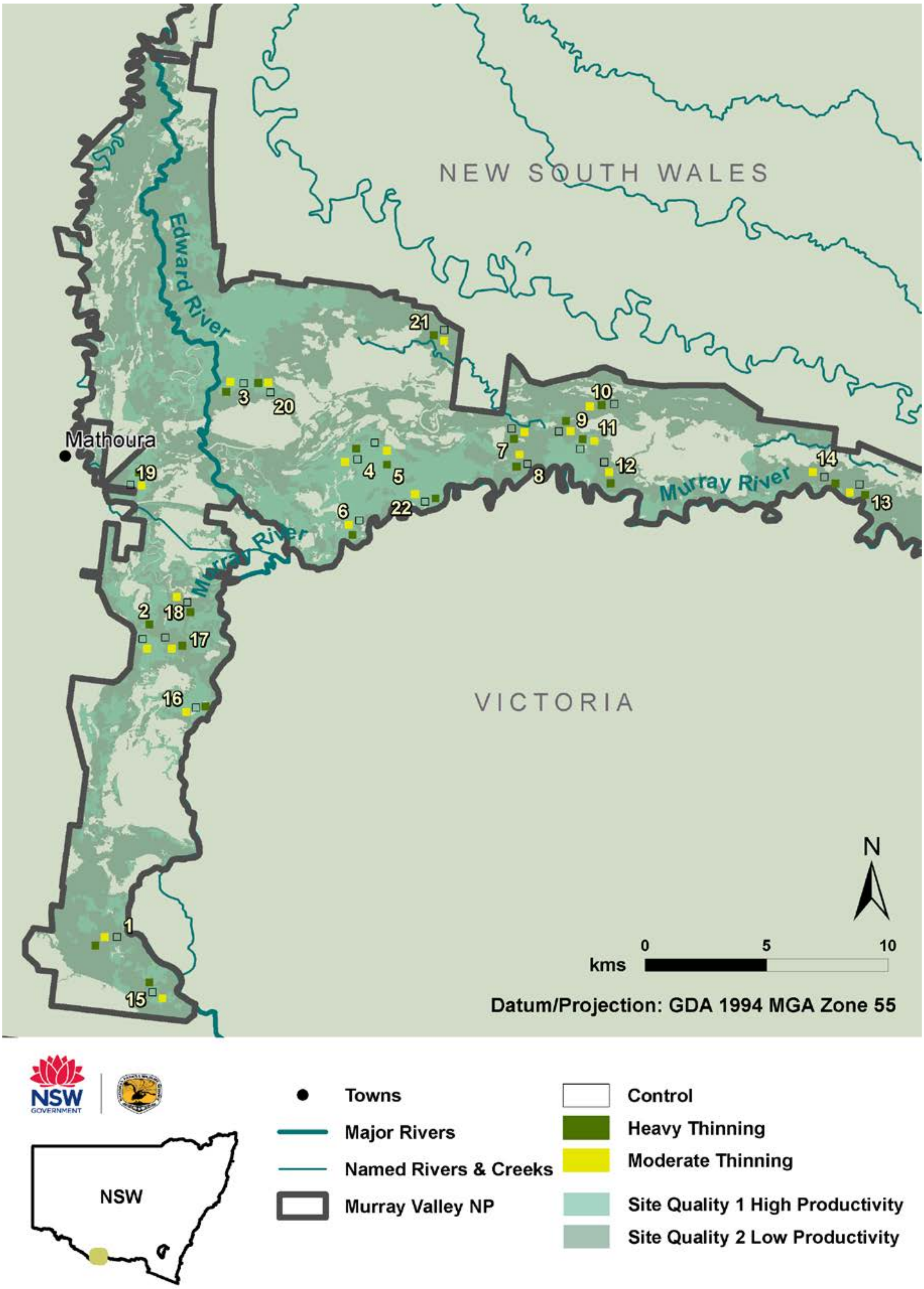

Figure 1 Locations of ecological thinning sites

N.P. = national park; SQ = site quality

Plate 1 River red gum forest with high density of sapling-sized stems
Photo: Evan Curtis.

Size of ecological thinning trial sites

Each site consists of three 9 hectare (ha) treatment plots, which were allocated to control, moderate thinning and heavy thinning treatments. All plots are square in shape with dimensions of 300 x 300 metres (m). The distance between plots within a site is between 100 and 300 metres.

The size of the plot was selected to minimise edge effects from the surrounding forest and detect responses in all of the vegetation, flora and fauna parameters of interest. The three treatment plots were intended to be similar to each other prior to thinning.

Ecological thinning treatments

Three ecological thinning treatments were included in the trial (Table 2): control, moderate thinning and heavy thinning.

The following trees were retained in all treatments:

- all trees with diameter at breast height (dbh) >40 centimetres (cm)
- all trees with a visible hollow
- all dead trees with a dbh of >20 centimetres.

Retention of all trees with these properties aimed to maintain the current quantity and distribution of trees with important habitat values, and trees with the potential to develop hollows over the coming decades.

Table 2 Ecological thinning treatments

Treatment	Specifics	Rationale
Control	No action	Enable comparison with thinning treatments.
Moderate thinning	7 m spacings between retained trees	Widest spacings likely to be implemented in commercial silviculture (7.3 m, Baur 1984), and substantially wider than most silvicultural thinning treatments (3–4 m, Schonau & Coetzee 1989).
Heavy thinning	15 m spacings between retained trees	Equivalent to the crown diameter (approximately 17 m) of a large *Eucalyptus camaldulensis* tree (>80 cm dbh*), to facilitate development of branches and spreading crowns that may lead to hollow development.

*diameter at breast height

Buffer zones, in which all trees were retained, were placed around drainage lines and cultural heritage features.

No prescriptions were given for the treatment of trees with <10 centimetres dbh and therefore retention was variable among sites.

The spacings method of thinning involved selecting a tree for retention, measuring 7 metres or 15 metres from the trunk of that tree, and selecting another tree for retention, and so on.

Within the 10–40 centimetres dbh size class, trees with the following features were preferentially selected for retention:

- structurally viable trunk and root attachment
- strong lateral branching (that may develop into spreading, branching form)
- healthy crown
- larger dbh.

Between retained trees, all trees with dbh between 10 and 40 centimetres were removed. Following felling, each stump was painted with Roundup Biactive® within five minutes to restrict coppicing. The felling method minimised damage to retained trees.

Retention protocols resulted in a spatially heterogeneous distribution of trees, and size class diversity.

Thinning using prescribed spacings and retention of all large and habitat trees was selected to increase the proportion of trees in larger size classes, as well as increase the abundance of branching trees that are likely to become hollow bearing in the future.

1.2 Hypotheses

Prior to implementing ecological thinning treatments, a series of hypotheses were specified about: the effects of ecological thinning on individual tree features, tree population characteristics, forest structure and site features; the flow-on effects to indigenous and non-indigenous flora and fauna; and any processes or disturbances associated with implementing the treatments.

It was hypothesised that the effects of ecological thinning would be greatest at sites with high initial stem densities, low post-treatment densities and high levels of water availability. Information concerning the rationale or conceptual process model underpinning each hypothesis, as well as any available published evidence supporting each hypothesis, was provided in the experimental design and monitoring plan (OEH 2012).

Prior to thinning, and for at least five years post-thinning, monitoring data are being collected to evaluate each hypothesis. Each year the trends for each of these parameters is analysed. After the first five years of post-thinning monitoring, at the end of the 2021–22 financial year, the available data will be analysed to determine the effect of thinning on the factors in the hypotheses.

1. **Effects of ecological thinning on tree populations and forest structure:**
    - 1a. Increased survival and growth rates of retained trees
    - 1b. Increased number and proportion of trees occurring in large diameter size classes
    - 1c. Increased spread and hollow development rates of retained trees
    - 1d. Increased tree canopy health (proportion of potential crown that is live) of retained trees
    - 1e. Increased recruitment of tree seedlings in early post-treatment years
    - 1f. Increased survival of seedlings (<1.37 metres) and saplings (>1.37 metres, <10 centimetres dbh)
    - 1g. Increased structural diversity of mid- and understorey strata
    - 1h. Higher levels of coarse woody debris (45–50 tonnes/hectare) maintained in long term
    - 1i. Increased heterogeneity in cover and depth of forest litter in the long term
    - 1j. Decreased persistence of stags in the short term
    - 1k. Increased fuel and fire risk
2. **Effects of ecological thinning on mammalian and avian diversity:**
    - 2a. Increased diversity of bat species, and increased levels of site utilisation by bat species
    - 2b. Increased abundance and frequency of foraging activity by woodland bird species
    - 2c. Increased abundance of gliders
    - 2d. Increased abundance of predators, in particular foxes
3. **Effects of ecological thinning on vascular plant diversity:**
    - 3a. Increased diversity and cover of exotic plant species in understorey in the short term, decreasing in the long term
    - 3b. Increased diversity and abundance of native plant species

1.3 Monitoring

For each hypothesis, a monitoring variable was defined and a monitoring protocol was designed to survey the variable at an appropriate spatial scale. Consequently, the size and number of monitoring plots within each 9 hectare treatment plot differed for each variable (Figure 2). For example, in each 9 hectare treatment plot birds were surveyed within a single 2 hectare monitoring plot and floristics were surveyed in three 0.04 hectare monitoring plots. Details for each monitoring variable are given in the experimental design and monitoring plan (OEH 2012) and are summarised in the results section for each variable in this report.

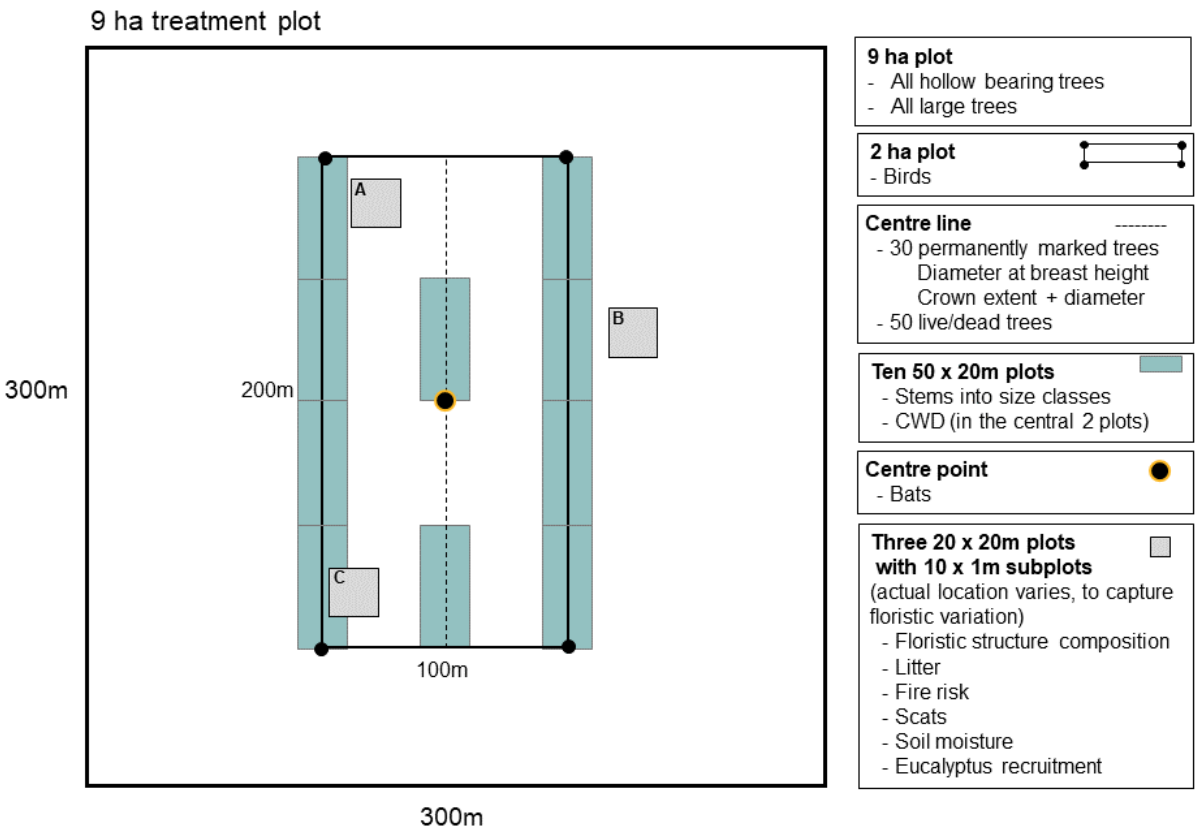

Figure 2 Layout of monitoring subplots within each 9 hectare treatment plot

1.4 Ecological thinning trial implementation and monitoring to date

Pre-thinning monitoring

Half of the sites (1–12) were monitored in 2012–13. These data are not included in this report.

Pre-thinning monitoring surveys were undertaken on all sites between September 2015 and February 2016. All variables were measured in this survey period. Results were described in the *River red gum pre-ecological thinning monitoring report 2017* (OEH 2017).

These data are referred to as the 2015 survey period in this report.

Thinning treatments

Thinning treatments commenced in April 2016. Half of the treatment plots were thinned prior to a major flood event in September 2016, in which all control and treatment plots were inundated. Thinning treatments recommenced in February 2017 and were completed in August 2017.

Post-thinning monitoring

First post-thinning monitoring 2017–18

The first round of post-thinning monitoring commenced in October 2017 and was completed in February 2018. All variables were measured in this survey period. The results of the first post-thinning monitoring are described in the *River red gum ecological thinning trial monitoring report 2018* (OEH 2018).

These data are referred to as the 2017 survey period in this report.

Second post-thinning monitoring 2018–19

The second round of post-thinning monitoring commenced in October 2018 and was completed in February 2019. A subset of variables were measured in the 2018–19 survey period and the results of this monitoring are described in the *River red gum ecological thinning trial monitoring report 2019* (OEH 2019).

These data are referred to as 2018 survey period in this report.

Third post-thinning monitoring 2019–20

The third round of post-thinning monitoring commenced in October 2019 and was completed in February 2020. A subset of variables were measured in the 2019–20 survey period and the results of this monitoring are described in this report

These data are referred to as the 2019 survey period in this report.

Sequence of events

As a result of the 2016 flood event, the sequence of flooding and thinning differed among sites (Figure 3).

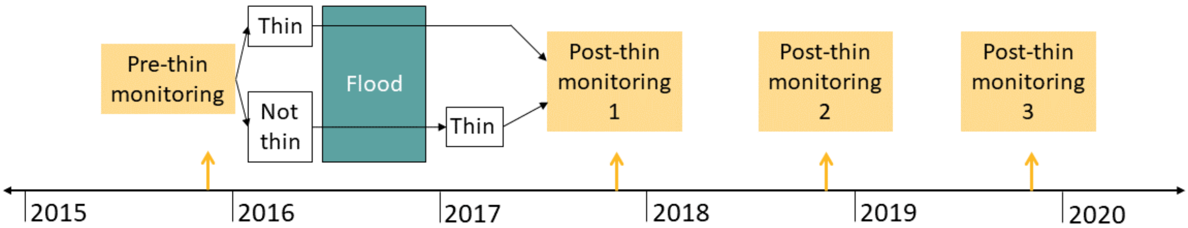

Figure 3 Sequence of monitoring, thinning and flood events

The amount of time that elapsed between thinning implementation and the first post-thinning monitoring varied among sites, and also differed among monitoring variables. For example, time since thinning at the time of survey was between one and 22 months for the tree parameters; and four and 30 months for the floristics.

1.5 Climate and flooding 2019–20

Flooding

No major floods occurred during 2019 (Figure 4).

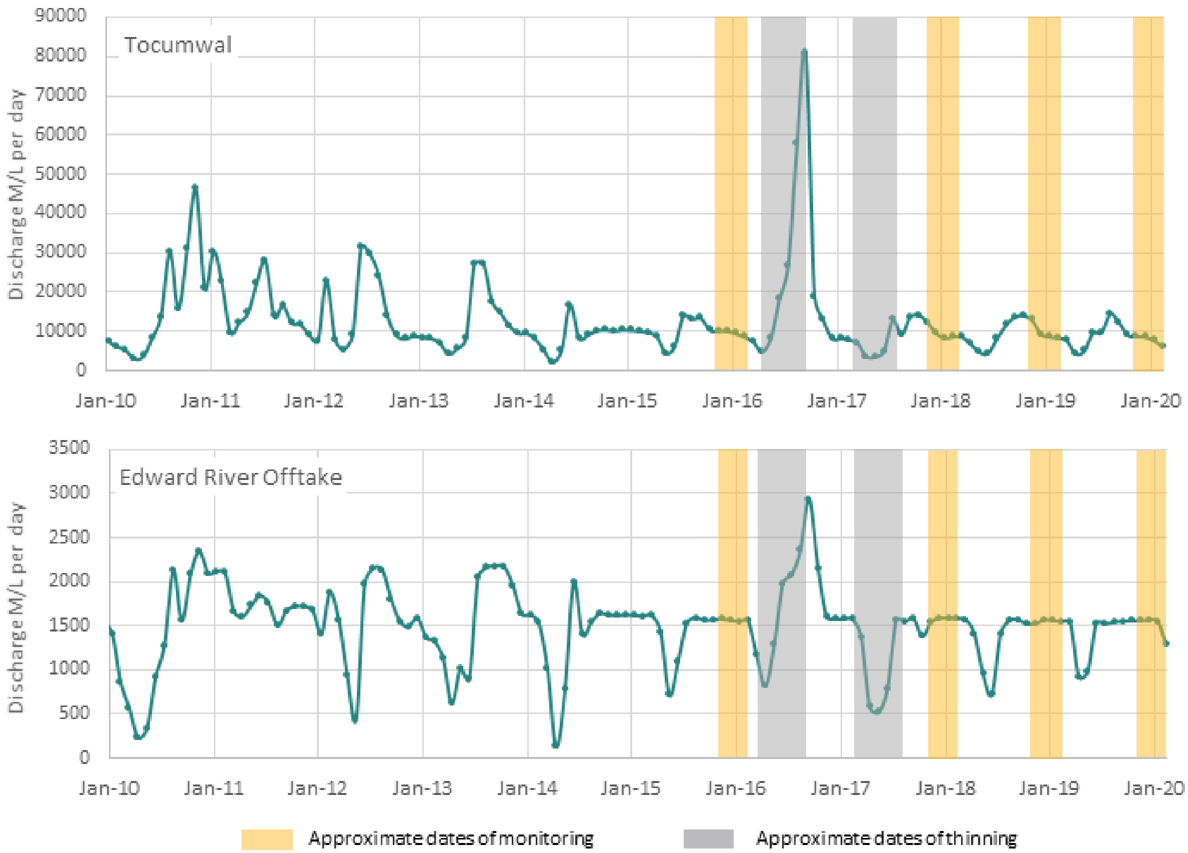

Figure 4 Average daily discharge (in megalitres) through Tocumwal and Edwards River Offtake, averaged per month

Source: Murray–Darling Basin Authority, River Murray Data, accessed 16/04/2020.

Rainfall

Rainfall is winter-dominant rainfall at Mathoura. Autumn and winter rainfall during 2019 was moderately high compared with the previous year, and approximately average compared with the previous decade. Spring and summer rainfall was low compared with the previous decade (Figure 5).

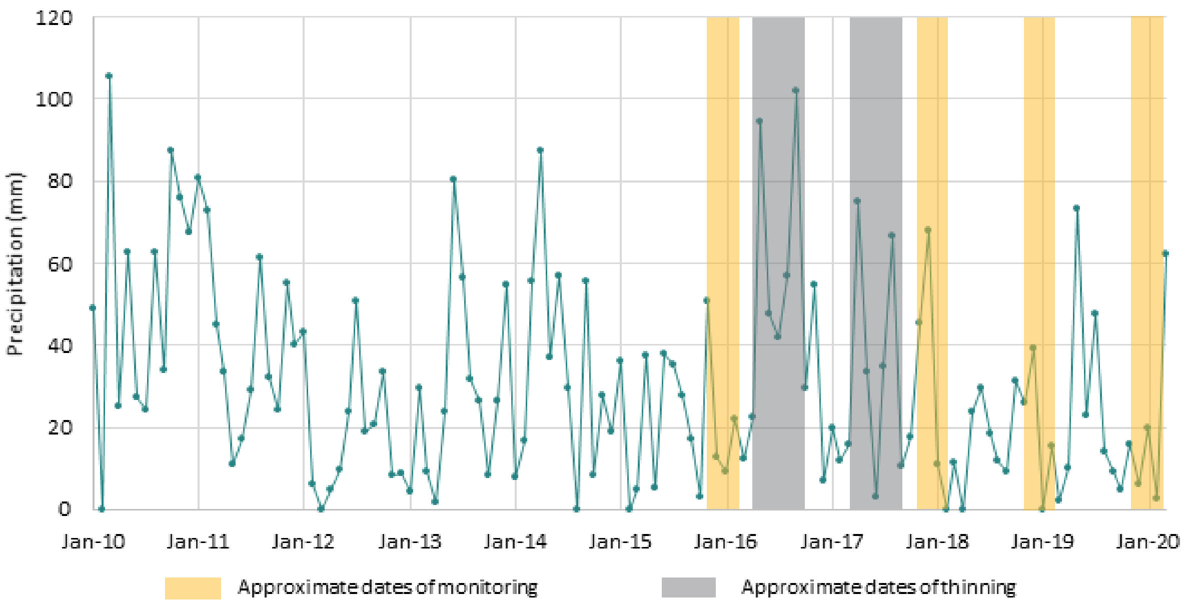

Figure 5 **Total monthly precipitation at Mathoura**
Source: Australian Bureau of Meteorology, gauge no. 074129, accessed 16/04/2020.

Evapotranspiration

Precipitation minus evapotranspiration was below zero in all months after the 2016 flood, with lower minimum values during the summers of 2019 and 2020 than the previous four years (Figure 6).

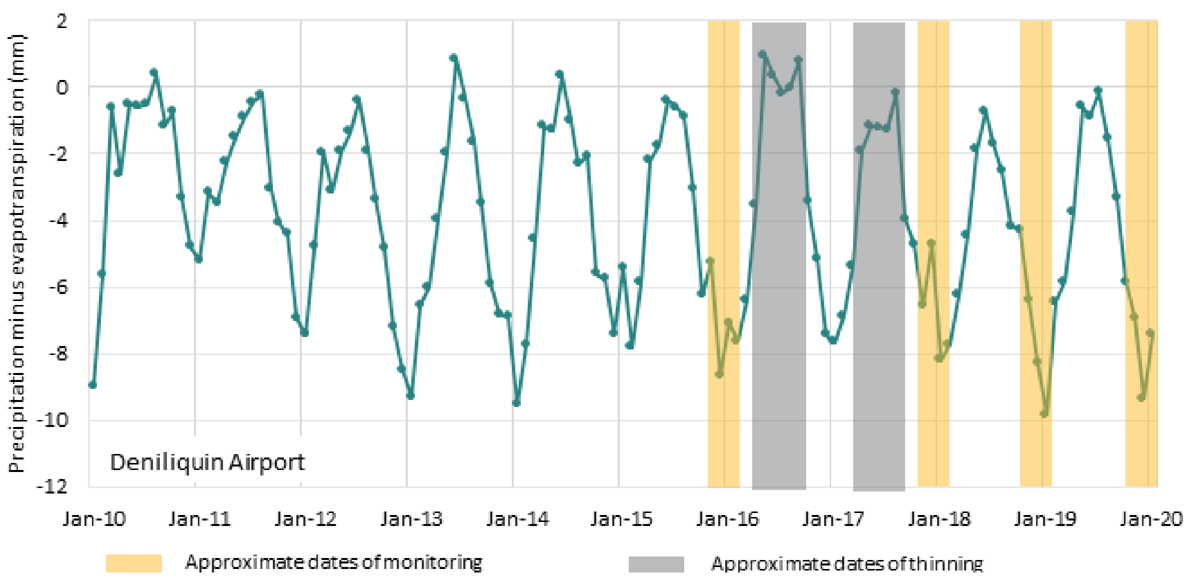

Figure 6 **Monthly precipitation minus evapotranspiration at Deniliquin airport**
Source: Australian Bureau of Meteorology, gauge no. 074258, accessed 16/04/2019.

1.6 This report

The analyses in this report seek to explore the effects of ecological thinning on a range of variables.

This report describes the third post-thinning monitoring data that were collected in 2019–20 and compares them with data collected in previous years.

Monitoring and reporting will continue annually until 2022, at which time the monitoring plan will be reviewed.

As specified in the experimental design and monitoring plan (OEH 2012), variables that are expected to change from year-to-year are monitored annually (Table 3).

Photographs of a selection of sites in each survey year are included in the separate Appendices document.

Table 3 Variables monitored annually

Variable
Tree diameter at breast height over bark (trees ≥10 cm dbh)
Live/dead status of 50 trees (trees ≥10 cm dbh)
Tree crown extent
Foliage projective cover
Occurrence of seedlings
Occurrence of saplings
Cover of litter and bare ground
Depth of forest litter
Bat species richness and diversity; use level by individual and all species
Occurrence of woodland bird species
Fox track or scat evidence
Richness and cover of exotic plant species
Richness and cover of native plant species
Photo points
Fuel assessment method

In addition, this year plant area index from hemispherical photos is reported on, as it has not been reported on previously.

Variables not included in this report

As specified in the experimental design and monitoring plan (OEH 2012), variables that are expected to change over longer timeframes were monitored prior to thinning in 2015–16, in the first year post-thinning in 2017–18 and will not be monitored again until five years post-thinning in 2021–22 (Table 4).

These variables are therefore not included in this report.

Table 4 Variables monitored five-yearly

Variable
Distribution of trees amongst size classes
Number of trees with hollows
Number of trees with glider notches
Opaque crown (m^2)
Cover, abundance and height of dominant species in understorey strata
Count of standing dead trees (stags)
Volume of coarse woody debris (>10 cm diameter)
Basal area
Survival of trees ≥80 cm dbh
Tree height

2. Methods

2.1 Data analysis approach

An estimation approach to analyses was used to interpret the recorded data and detect ecologically important effects of thinning.

Data analysis for each monitoring variable was undertaken to estimate the following:

- the direction of change between monitoring surveys
- the magnitude of change between monitoring surveys
- the certainty or precision that we have regarding that change
- differences in the direction, magnitude and/or certainty of change between control sites and sites that were moderately or heavily thinned.

In this approach, the statistical significance ('p value' and confidence intervals) generated for a regression model are only one piece of information used to draw conclusions about the importance of ecological thinning for the ecological and biodiversity features of interest.

All analyses were conducted in the R statistical environment (R Core Team 2019).

2.2 Data summaries

The analysis approach involved first summarising the raw data recorded in the field. Two common methods of summarising raw data are probability density curves (Figure 7) and boxplots (Figure 8). Probability density curves show the relative abundance of different values of the monitoring variable among monitoring plots. Boxplots break the data up into four equal portions. They show the middle (median) value, the spread of each quarter of the data, and highlight outliers.

These plots are useful for viewing the recorded data and showing coarse trends or differences among thinning treatments, survey year and site quality. One or both of these plots were reported for each variable.

After initial exploration, data were analysed using mixed regression models to identify whether changes were likely to differ among control and thinning treatments given background and yearly variability.

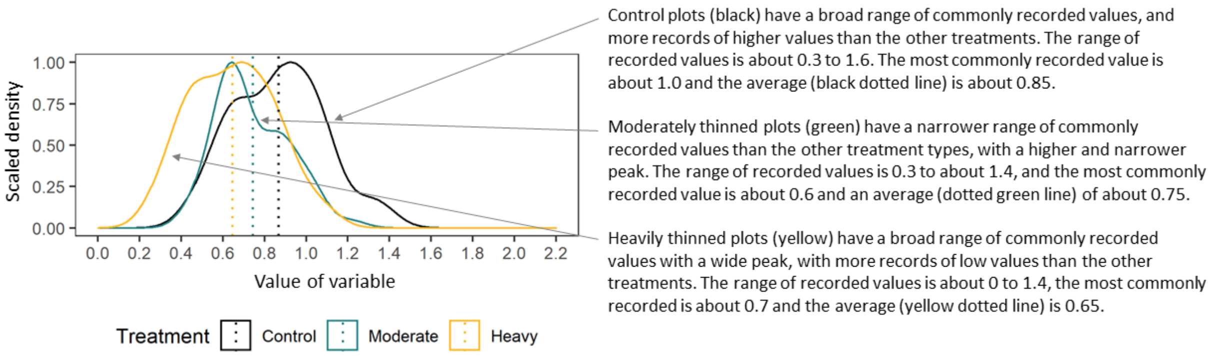

Figure 7 Generic density plot

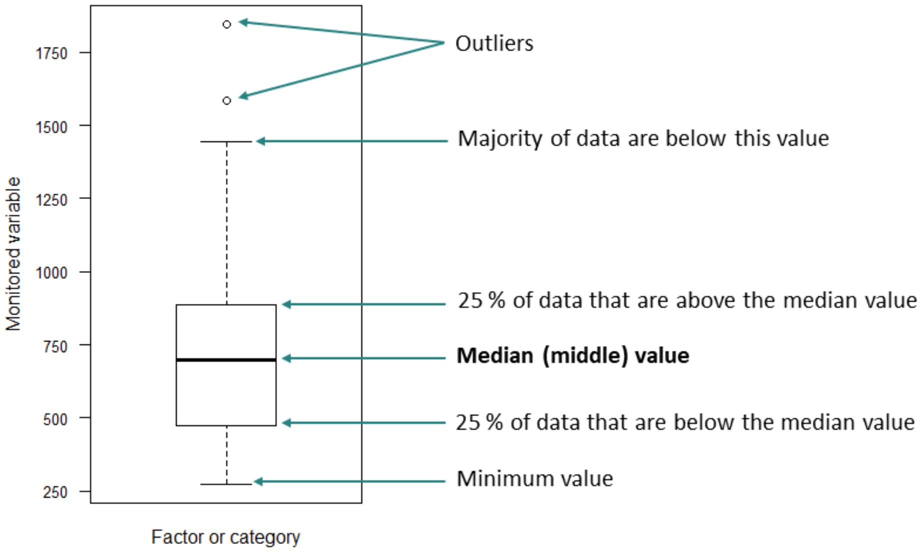

Figure 8 Generic boxplot

The central 50% of the data are called the interquartile range. The dotted lines and horizontal bars indicate 25% of data above and below the interquartile range. Outliers are higher or lower than 1.5 times the interquartile range and may occur on either side of the median.

2.3 Modelling

Mixed regression models estimate the extent to which different values of explanatory variables are associated with different values of the response (monitoring) variable, while accounting for known variation in the data.

Explanatory variables

In order to determine the likely effect of ecological thinning over time, the following explanatory variables were included in all models:

- survey year (a fixed effect with four levels: 2015, 2017, 2018 and 2019)
- thinning treatment (a fixed effect with three levels: control, moderate and heavy)
- site quality (a fixed effect with two levels: Site Quality 1 and Site Quality 2)
- one or two random effects to account for known variation (see below).

Additional explanatory variables were also included in the model for tree growth rate; specifically:

- whether the plot was thinned after flooding (a fixed effect with two levels)
- diameter prior to thinning (continuous fixed effect).

All models included random effects across either site (where there was one estimate per 9 hectare plot) or plot nested within site (where there were multiple estimates per 9 hectare plot). Random effects account for the fact that measurements within a given site or plot may not be independent samples (i.e. they may be spatially auto-correlated), which could influence interpretation of explanatory variables and their significance.

Interactions

For most response variables, two combinations of explanatory variables were compared:

1. Response ~ treatment * survey year + site quality

   This model format calculated the extent to which the response variable differed among thinning treatments, whether those differences changed over time and whether site quality had an additive positive or negative effect across all of those differences.

2. Response ~ treatment * survey year * site quality

   This model format calculated the extent to which the response variable differed among thinning treatments, whether those differences changed over time, and whether any of those differences varied by site quality. That is, there was no assumption that the effect of thinning would be the same in the different site qualities or among years.

For some response variables, only one interaction was modelled:

3. Response ~ treatment * site quality

   This model format was used where only data from the current survey period was analysed, or where the response variable was change between 2015 and 2019.

Response variable family and link

Monitoring (response) variables can be continuous numbers, proportions, counts or categories. Each type of variable differs in terms of the likely spread of values, and the amount of variation expected to occur around each value.

Mixed regression is most useful in detecting the effects of thinning when the likely spread and variation (i.e. distribution) of response variable values are specified.

There are two features of regression models that are used to specify the distribution of the response variable: family and link.

The family specifies the expected relationship between the mean (average) value and the variance of the response variable.

The link function allows the relationship between the response variable and the explanatory variables to be something other than a simple linear form. It is similar to transforming the raw response variable data (for example, taking the log of each response value), but instead transforms the modelled average of the response. Other modelled values are predicted around the mean in accordance with their family characteristics.

In cases where there was uncertainty about which family and link function may have been appropriate, multiple models were run and their performance compared.

Frequentist and Bayesian models

Frequentist regression (generalised linear mixed effects models) give a single point estimate for each explanatory variable, by finding the value that minimises the amount of error in the data (called ordinary least squares).

In Bayesian regression modelling, a range of possible fits for each explanatory variable are explored. The result is a *distribution* for the explanatory variables that is proportional to the likelihood of the data. This allows the influence of each explanatory variable on the monitoring variable to be assessed while taking into account background variability. These distributions are called credible intervals.

Frequentist regression results can be re-sampled many times using bootstrapping procedures, also resulting in distributions of explanatory variables. These distributions are called confidence intervals. In cases where bootstrapping is computationally limited, confidence intervals may be calculated using alternative equations (e.g. Wald confidence intervals).

While the frequentist and Bayesian estimates are calculated differently, they both provide estimates of uncertainty around the relationship between each explanatory variable and the response variable.

When a credible or confidence interval for a model coefficient does not include zero, there is high confidence that the explanatory variable has had an effect on the response variable.

Frequentist models were used for most response variables, in conjunction with bootstrapping (1000 simulations) where possible. R packages were not available for bootstrapping beta distributions, and in these cases standard errors were reported. Bayesian models were used in most cases where the response variable was a category.

Model assumption checking and comparison

All models were assessed to determine whether they met assumptions of homoskedasticity, collinearity, and outliers. This information was used, in conjunction with the confidence or credible intervals, to estimate the level of confidence in the model.

Models with different interactions and/or different families were compared using corrected Akaike information criteria, model diagnostic plots (including Dunn Smyth residual tests) and model fit information.

Statistically significant effects are included in this report, but some additional and non-significant model results are not included.

Model reporting

Model results are shown as tables (Table 5) and figures. The figures show the estimated values on the original scale of the response variable, that is, the average or most likely modelled value of the response, given the data. The text that describes the magnitude of difference among thinning treatments, year and site quality refers to the estimated values. The figures also show the possible range of values that the response may take as bootstrapped confidence intervals, standard errors (where bootstrapping was not possible) or credible intervals (for Bayesian models).

Note that the figures and text descriptions are on the scale of the response, after removing any link function that had been applied in the model. As a result, a statistically significant effect may not appear so in the figure, with confidence intervals overlapping all means, particularly where there was a significant interaction but no significant main effects.

Table 5 Generic model results table

Response	Family	Link	Effect of time	Effect of thinning treatment	Effect of site quality	Confidence
The monitoring variable	A distribution that describes the spread and variation in response variable values	A function that moderates the relationship between response and explanatory variables	The magnitude of effects that are likely to be influential on the response, as indicated by bootstrapped confidence intervals, credible intervals or standard errors			A qualitative description of model fit and uncertainty

All model specifications and outputs, including model coefficients, significance values and (bootstrapped or Wald) confidence intervals for each parameter are included in Appendices B–H.

3. Results: Tree parameters

3.1 Tree growth rates

Key result	Growth rates were greater in thinned plots than control plots (by 0.7–2.8 mm per year) In thinned plots, smaller trees grew faster than larger trees by 1.5–3 mm per year Flooding prior to thinning increased tree growth rates Growth rates were about 1.7 mm per year higher in Site Quality 1 sites than Site Quality 2 sites

Data collection

Within each 9 hectare treatment plot, 30 trees with >10 centimetres dbh were randomly selected along a north–south transect in the centre of the plot. These 30 trees were permanently marked and surveyed for diameter at breast height to the nearest millimetre (mm) each survey.

Out of 1980 permanently marked trees, 14 have died since the 2015 surveys. Replacement trees were selected that were a similar diameter to the dead trees. Replacement trees were included in these analyses.

The annual growth rate (millimetre/year) was calculated for each tree from change in dbh between the first observation date (this was in 2015 prior to ecological thinning for all trees except the replacement trees) until the most recent observation date (in 2019–20). For multi-stemmed trees a single dbh value was assigned based on total stem area.

Data summary

Annual tree growth rates, not taking into account tree size or flooding, were generally similar among thinning treatment and control plots in Site Quality 1 sites (Figure 9). The most commonly recorded rates in Site Quality 1 sites were between 2 and 7 millimetres/year.

On drier sites (Site Quality 2), the most commonly recorded growth rates were slightly higher in thinned plots (about 4 millimetres/year) than control plots (about 2 millimetres/year).

Negative growth rates were recorded in all plot types, a result of shrinkage in *Eucalyptus camaldulensis* trees in dry hydroclimatic conditions.

There was considerable variation in annual tree growth rates for all tree sizes, but many of the lowest tree growth rates were recorded for larger trees (Figure 10). Also, the order in which flooding and thinning occurred influenced growth rates. For example, in Site Quality 2 plots that were heavily thinned there was one tree with growth >10 millimetres per year when thinning occurred before flooding, and nine trees with growth >10 millimetres per year when thinning occurred after flooding.

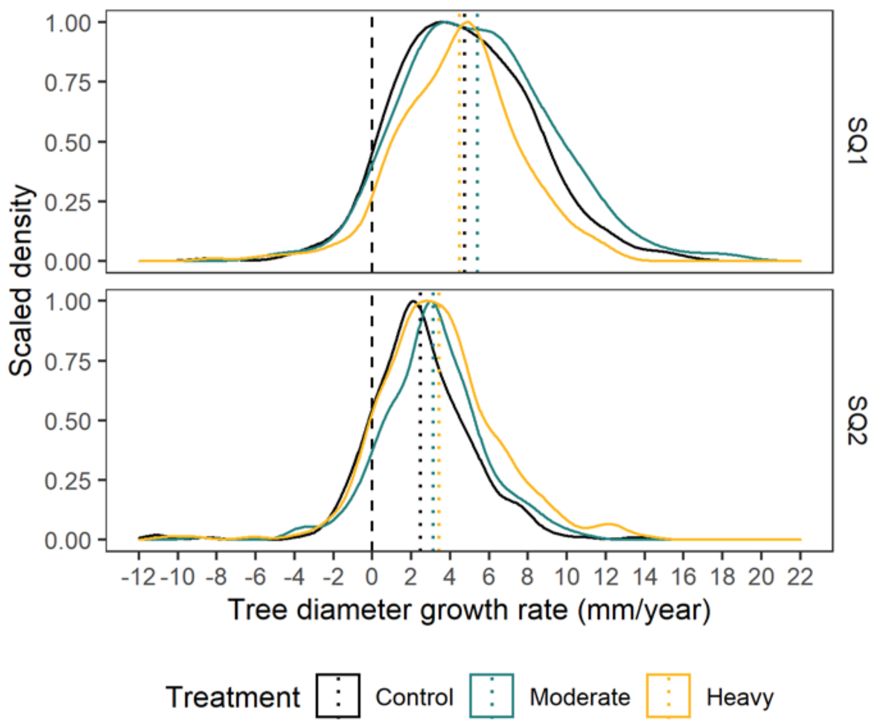

Figure 9 **Density plots and averages (dotted lines) of diameter growth rates of trees between 2015–16 and 2019–20 survey dates in millimetres per year, by ecological thinning treatment and site quality (SQ1 and SQ2)**

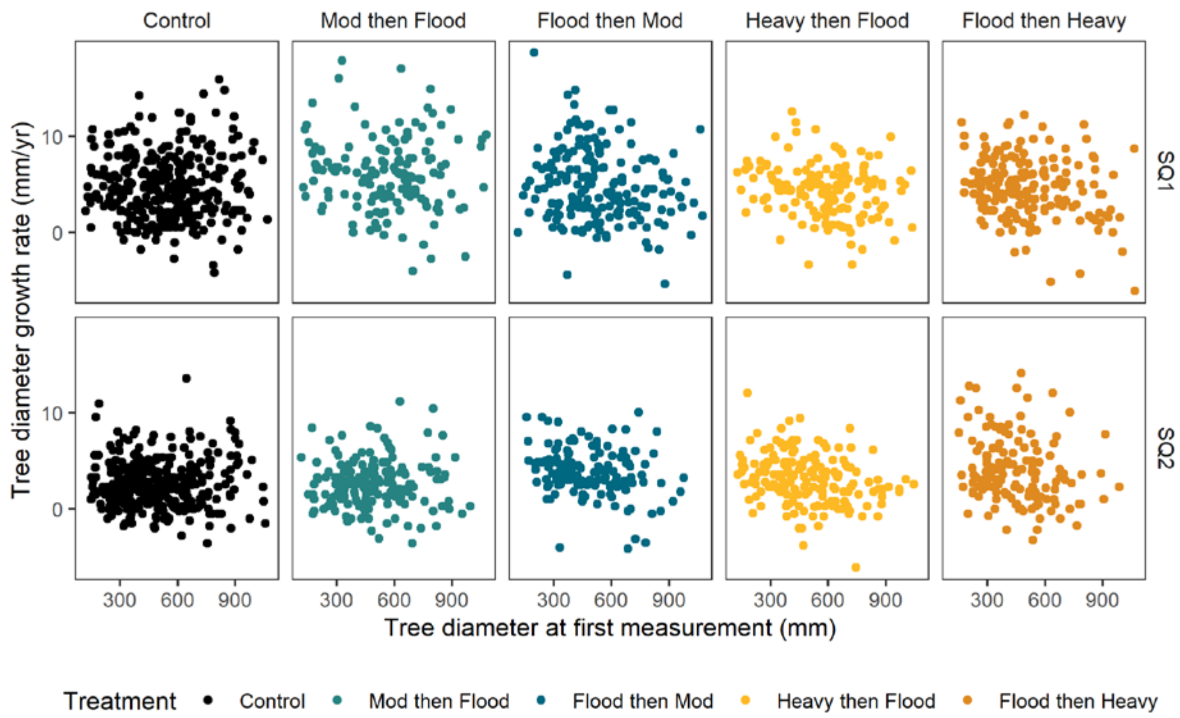

Figure 10 **Recorded tree diameter growth rate (millimetres per year) in relation to tree diameter at first measurement, by ecological thinning treatment (moderate thinning abbreviated to Mod) and flooding, and site quality (SQ1 and SQ2)**

Model results

The model indicated that growth rates were dependent on tree size in thinned plots, with the fastest growth rates occurring in the smallest trees (Table 6, Figure 11). In control plots, larger trees grew slightly faster in Site Quality 1 plots and trees of all sizes grew at roughly the same rate in Site Quality 2 sites.

Growth rates were faster on sites that were flooded prior to thinning, and fastest among small trees on sites that were flooded and then heavily thinned. Note that growth rates in the moderate thinning then flooding treatment was not significantly different from the control plots.

Table 6 Model summary for tree growth rate

Response	Family	Link	Effect of tree size	Effect of thinning and flooding	Effect of site quality	Confidence
Annual tree growth rate (mm per year)	Gaussian	None	Smaller trees grew 2.0–3.2 mm / year faster than large trees in thinned plots (except moderately thinned plots that then flooded).		Trees grew 1.7 mm / year faster on wetter Site Quality 1 sites	Moderate R^2 = 32.8% Residual checks indicated minor deviation from uniformity and some outliers
				Thinning increased growth rates by 0.7–3.0 mm per year, and this effect was stronger where flooding occurred prior to thinning.		

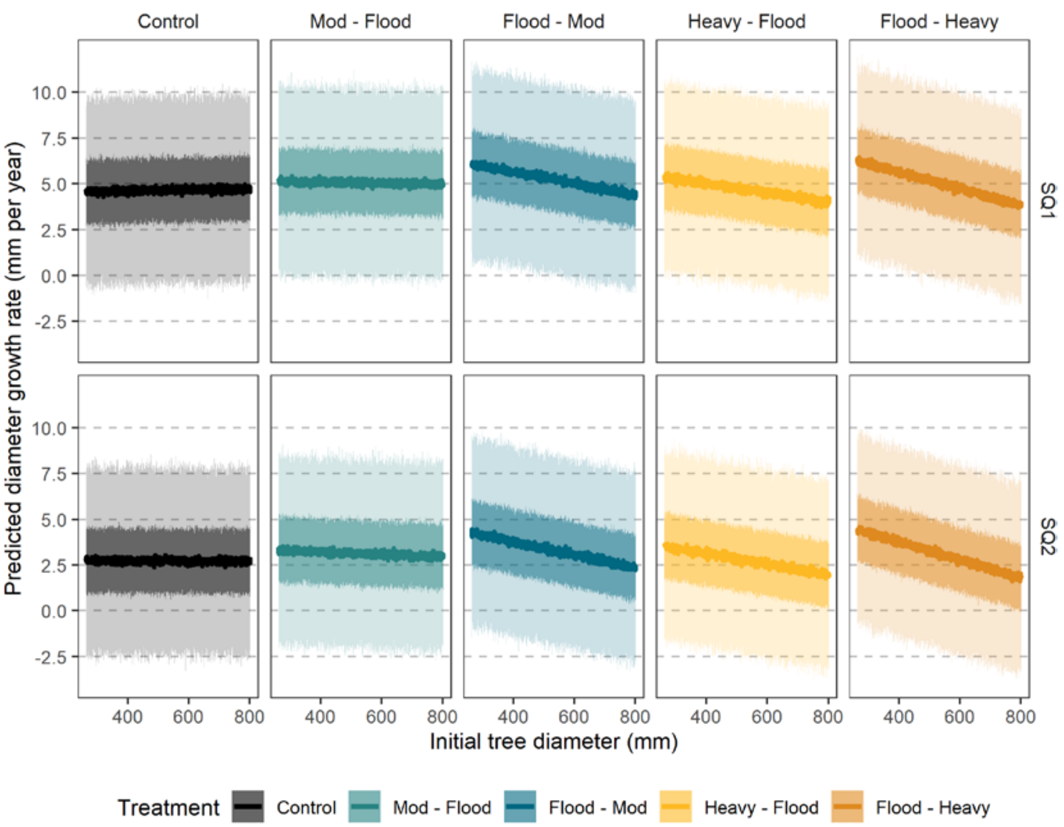

Figure 11 Modelled tree growth rates (millimetres per year between first and last survey dates) with bootstrapped 50% and 95% confidence intervals, by initial tree diameter (millimetres), sequence of ecological thinning treatment (moderate thinning abbreviated to Mod) and occurrence of flooding, and site quality (SQ1 and SQ2)

Table 7 Average modelled differences between tree diameter growth rates (millimetres per year) in trees that had an initial diameter of 20 centimetres and 80 centimetres diameter at breast height (dbh) for SQ1 and SQ2

Thinning treatment	SQ1			SQ2		
	20 cm initial dbh	80 cm initial dbh	Difference in rate	20 cm initial dbh	80 cm initial dbh	Difference in rate
Control	4.7	4.7	0.0	2.6	2.6	0.0
Mod then flood	5.3	5.1	+0.2	3.3	2.8	+0.5
Flood then mod	6.2	4.5	+1.8	4.6	2.4	+2.2
Heavy then flood	5.5	4.1	+1.4	3.7	1.9	+1.8
Flood then heavy	6.8	3.9	+2.9	4.7	1.9	+2.8

3.2 Tree mortality

Key result	Thinned plots had higher proportions of dead trees (10–11 per 100) than control plots (7 per 100) on average in 2019

Data collection

Dead trees were defined as those with no live foliage and included ringbarked trees.

Tree mortality was surveyed by assessing 50 trees with diameter at breast height ≥10 centimetres as live or dead, along a north–south transect in each 9 hectare treatment plot.

Data summary

In 2015, prior to ecological thinning, the distribution of proportion of dead trees among plots was similar for all treatment types (Figure 12).

In control plots, minor fluctuations in the proportion of trees that were dead were observed across survey periods (Figure 13).

In moderately thinned plots, the median proportion of dead trees temporarily increased after thinning in 2017 in Site Quality 1; but the increase was sustained in Site Quality 2 in all subsequent years.

In heavily thinned plots, an increase in the median proportion of dead trees was sustained in all post-thinning years in both site quality classes.

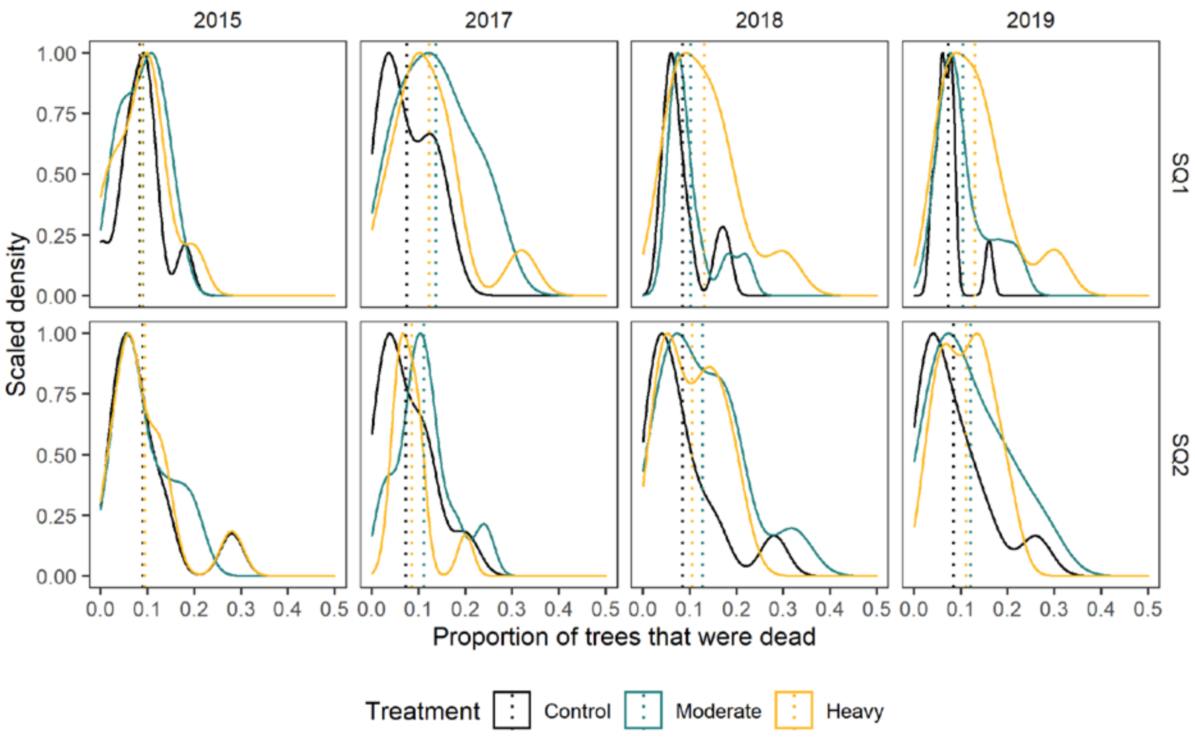

Figure 12 **Density plots and averages (dotted lines) of proportion of trees that were dead, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)**

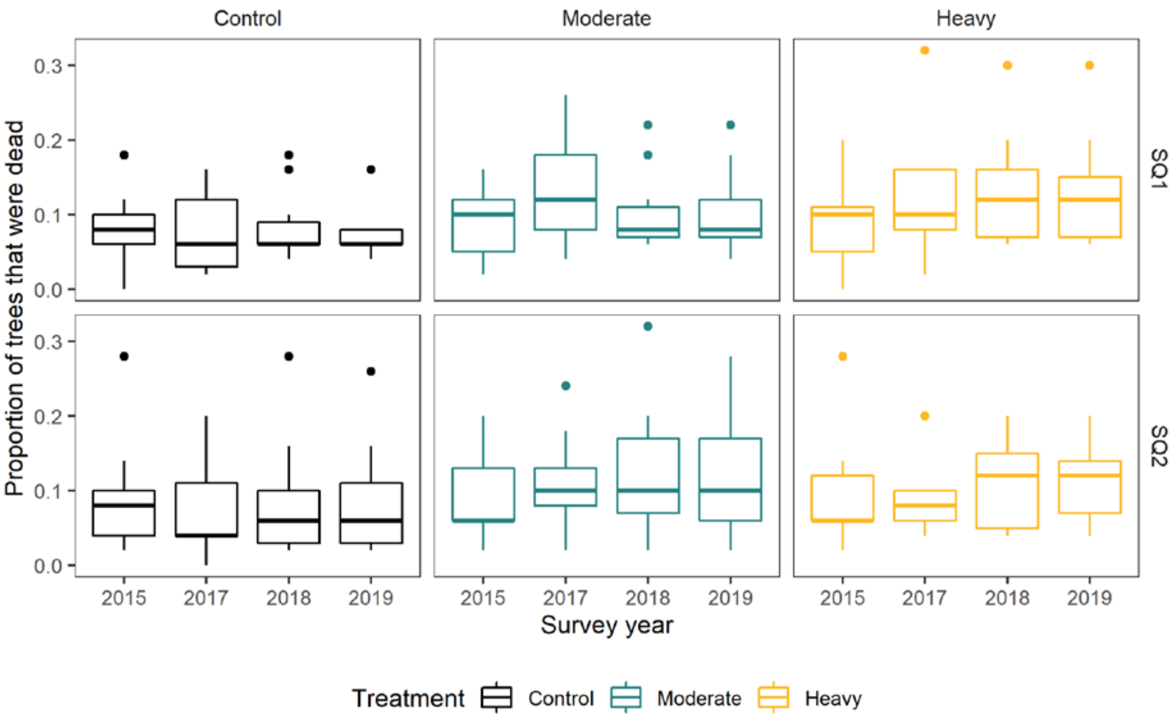

Figure 13 **Boxplots of proportion of trees that were dead, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)**

Model results

Tree mortality was analysed as the proportion of trees that were dead.

Modelling indicated that the proportion of trees that were dead was significantly higher in heavily thinned plots in both site quality classes in 2019 (not significantly higher in 2017 or 2018) (Table 8, Figure 14).

Modelling also suggested that the proportion of dead trees was likely higher for moderate treatment in 2019, though confidence was lower (bootstrapped confidence interval included zero).

Table 8 Model summary for proportion of trees that were dead

Response	Family	Link	Effect of time	Effect of thinning treatment	Effect of site quality	Confidence
Proportion of trees that were dead	Binomial	Log link	Controls remained around seven dead trees per 100 in all years; moderately thinned plots had 11 dead trees in 2017; moderately and heavily thinned had 10–11 dead trees in 2019		No difference	Moderate R^2 = 9.3% Residual checks were good

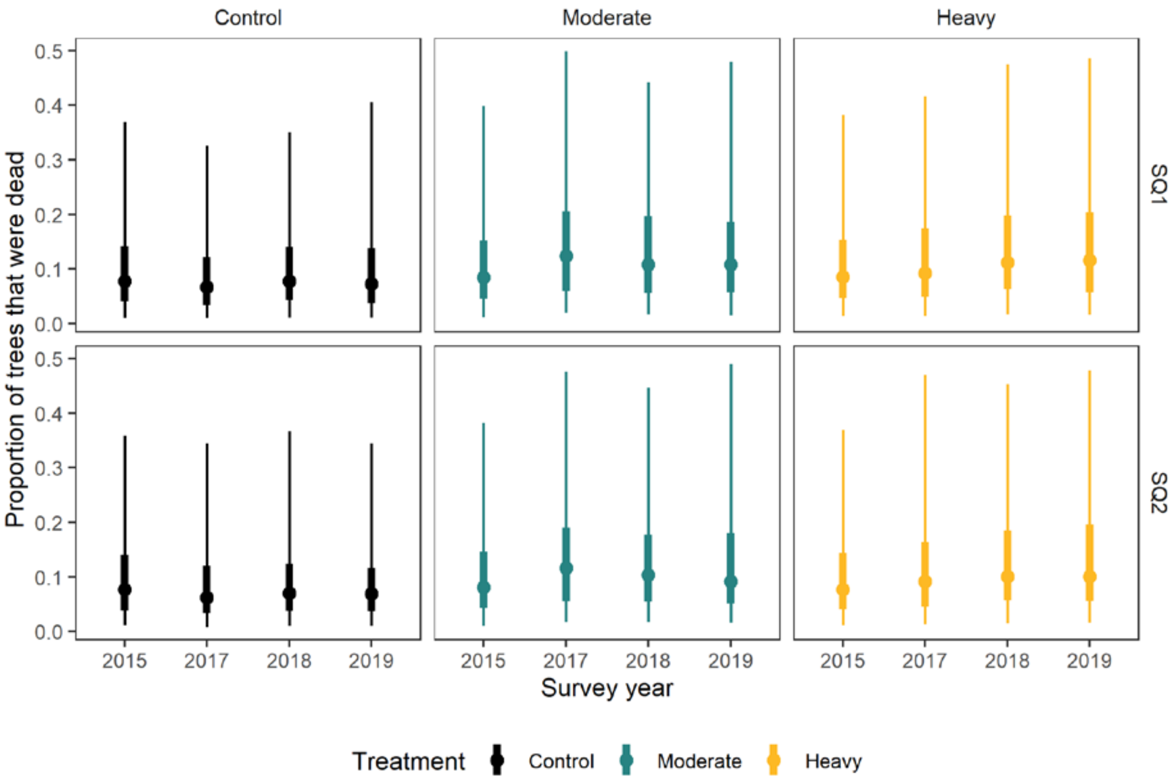

Figure 14 Modelled tree mortality (proportion of trees that were dead) with bootstrapped 50% and 95% confidence intervals, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

4. Results: Recruitment

4.1 Germinants

Key result	No effect of thinning was detected on the probability of germinants occurring Probability of germinants occurring was slightly higher in 2019 than in 2015 Probability of germinants occurring was lower in Site Quality 2 than Site Quality 1 over all years There was insufficient data to model germinant abundance

Data collection

Germinants were defined as individuals of *Eucalyptus camaldulensis* with cotyledons present.

Germinants were recorded in four quadrants of each 0.04 hectare subplot and summed for each 9 hectare plot.

Presence of germinants tends to be transient in the few weeks after floodwaters recede. If climatic conditions are too dry the germinants die and if climatic conditions are appropriate, they develop into seedlings.

Data summary

Germinant presence–absence

Germinants were absent from most 0.04 hectare plots in all years, including 93% of plots in 2019.

Across all survey years, germinants occurred on 2–10 subplots (out of a possible 66 in each treatment) in Site Quality 1 sites; and 0–4 subplots in Site Quality 2 sites (Figure 15).

In 2019, germinants were recorded on more control plots in Site Quality 1 than any other treatment type.

Germinant abundance

In the vast majority of 0.04 hectare plots with germinants present there were fewer than 10 individuals recorded (Figure 16), across all survey years. A total of 11 subplots since 2015 recorded between 50 and 600 germinants.

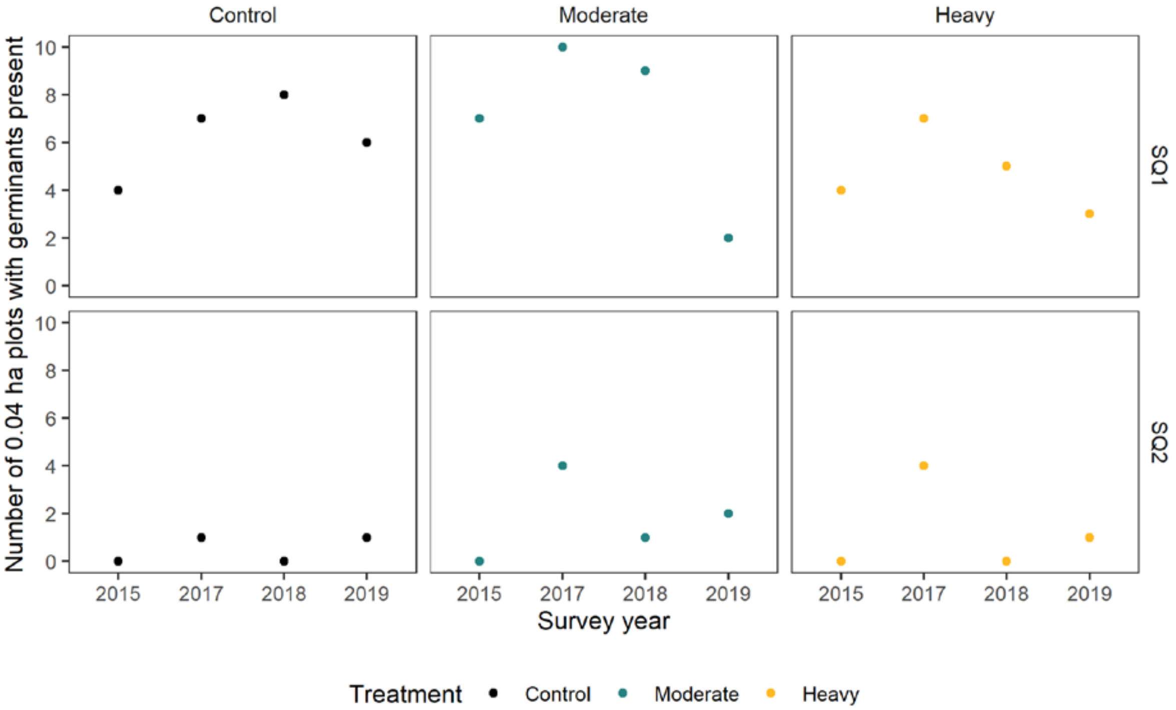

Figure 15 Number of 0.04 hectare subplots with germinants present, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

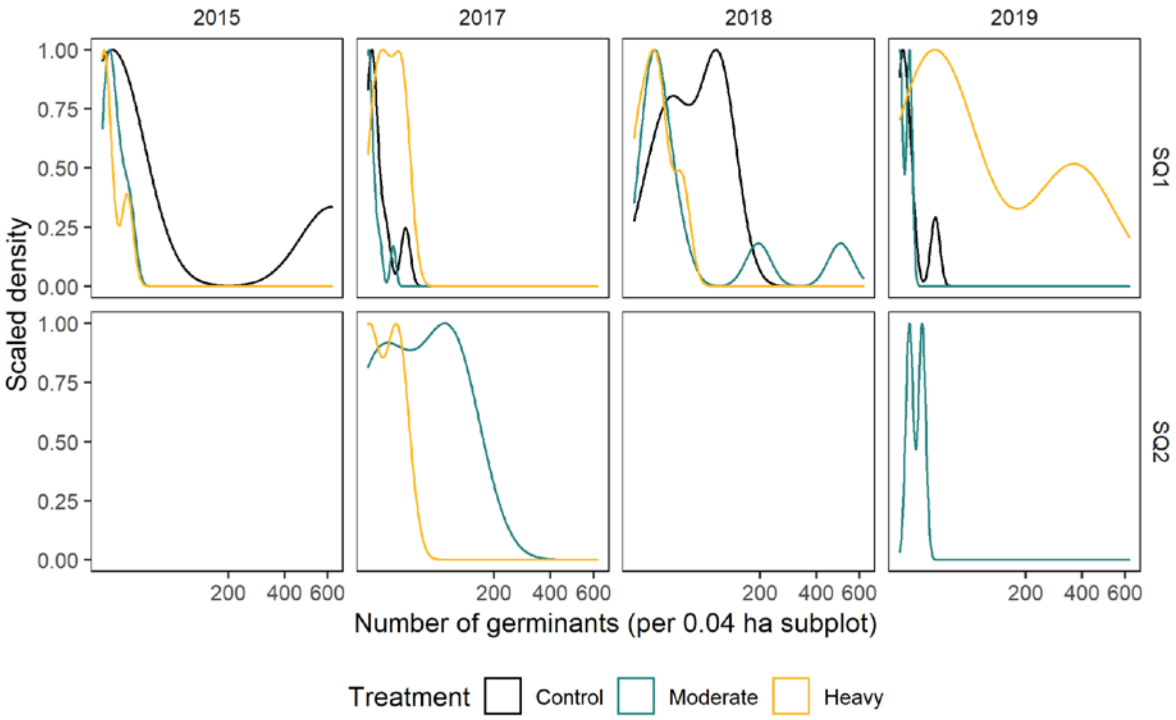

Figure 16 Density plots of germinant abundance (per 0.04 hectare subplot), showing only plots with germinants present, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

Blank panels and missing lines indicate fewer than two instances of germinants present.

Model results

Germinant presence–absence

There was a slight but uncertain increase in the probability of germinants occurring across all treatments in 2019 (Table 9, Figure 17).

In all survey years the probability of 9 hectare plots containing germinants was higher on wetter Site Quality 1 sites than drier Site Quality 2 sites.

Table 9 Model summary for presence of germinants on 9 hectare treatment plots

Response	Family	Link	Effect of time	Effect of thinning treatment	Effect of site quality	Confidence
Presence of germinants on 9 hectare treatment plots	Binomial	Logit	Slightly (0.83) higher probability in 2019 than 2015, but uncertain	No effect of thinning	Slightly (–0.08) lower probability of occurrence on drier Site Quality 2 sites	Moderate to high R^2 = 60.1% No strong deviations but some mid values overestimated, and some low values underestimated

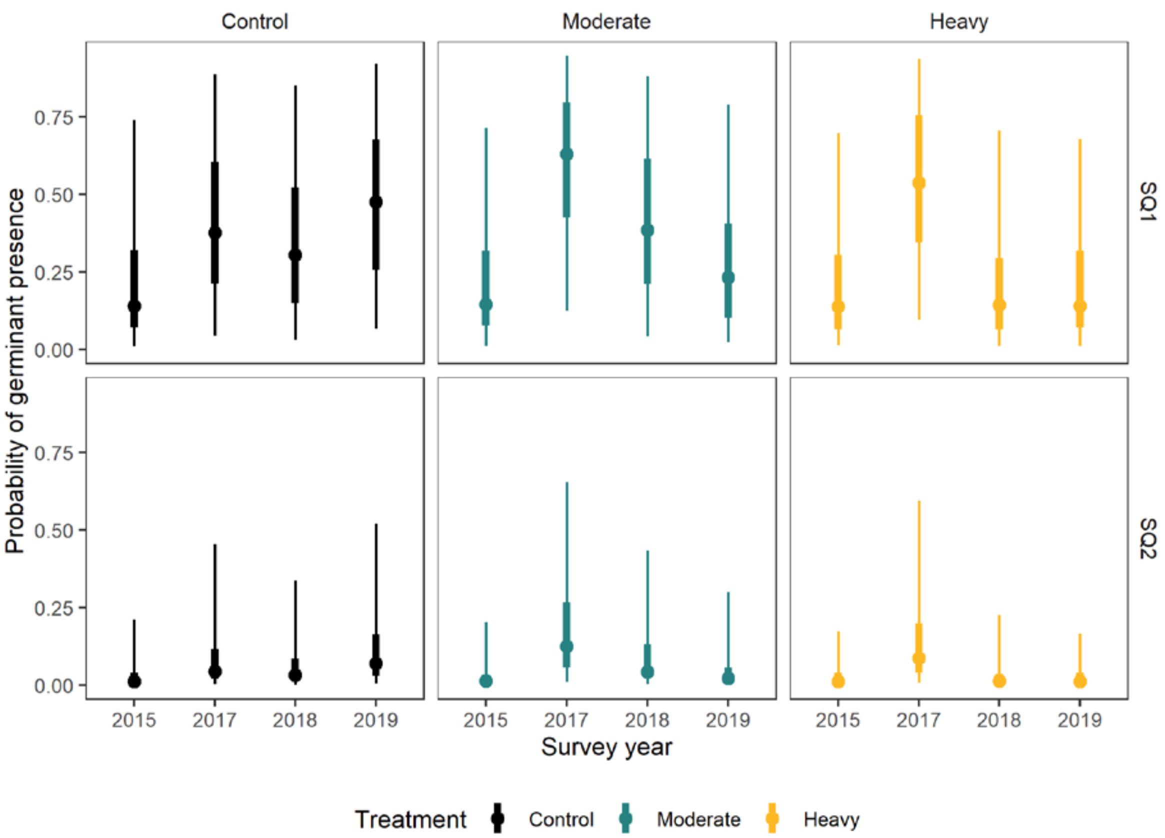

Figure 17 Modelled probability of germinant presence on 9 hectare treatment plots with bootstrapped 50% and 95% confidence intervals, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

Germinant abundance

There were insufficient data to model whether thinning treatment had an effect on abundance of germinants.

4.2 Seedlings

Key result	No effect of ecological thinning on the occurrence of seedlings
	Seedling abundance was higher in heavily thinned plots in 2019 (approximately 10 additional seedlings)

Data collection

Seedlings are defined as being less than 1.37 metres in height. Seedlings did not include coppiced stems that were seedling sized but emerging from cut stumps or pushed over stems. Seedlings were counted in each of the three 0.04 hectare subplots in the 9 hectare treatment plots.

Data summary

Seedlings were present in almost all (96%) 9 hectare plots.

Seedling abundance was higher in Site Quality 1 sites than Site Quality 2 sites in all years, in terms of both the median value and the frequency with which values more than 80 per subplot were recorded (Figure 18, Figure 19). The distribution of seedling abundance values among thinning treatments was very similar in 2019.

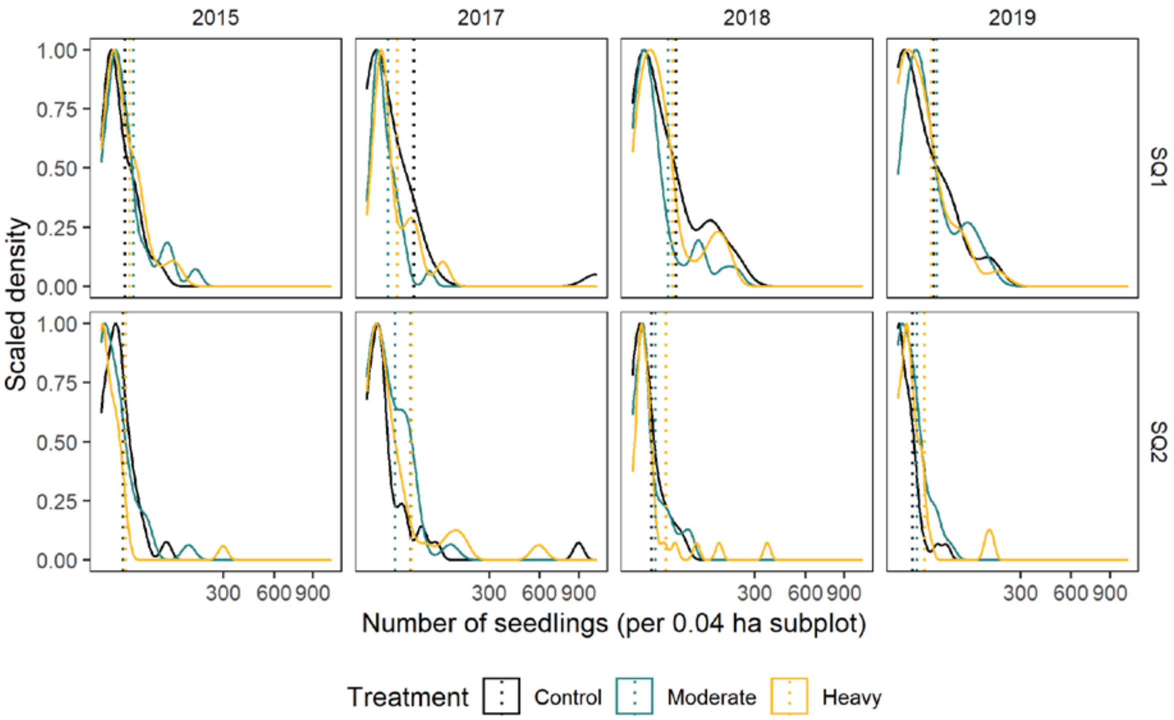

Figure 18 Density plots and averages (dotted lines) of seedling abundance per 0.04 hectare subplot, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

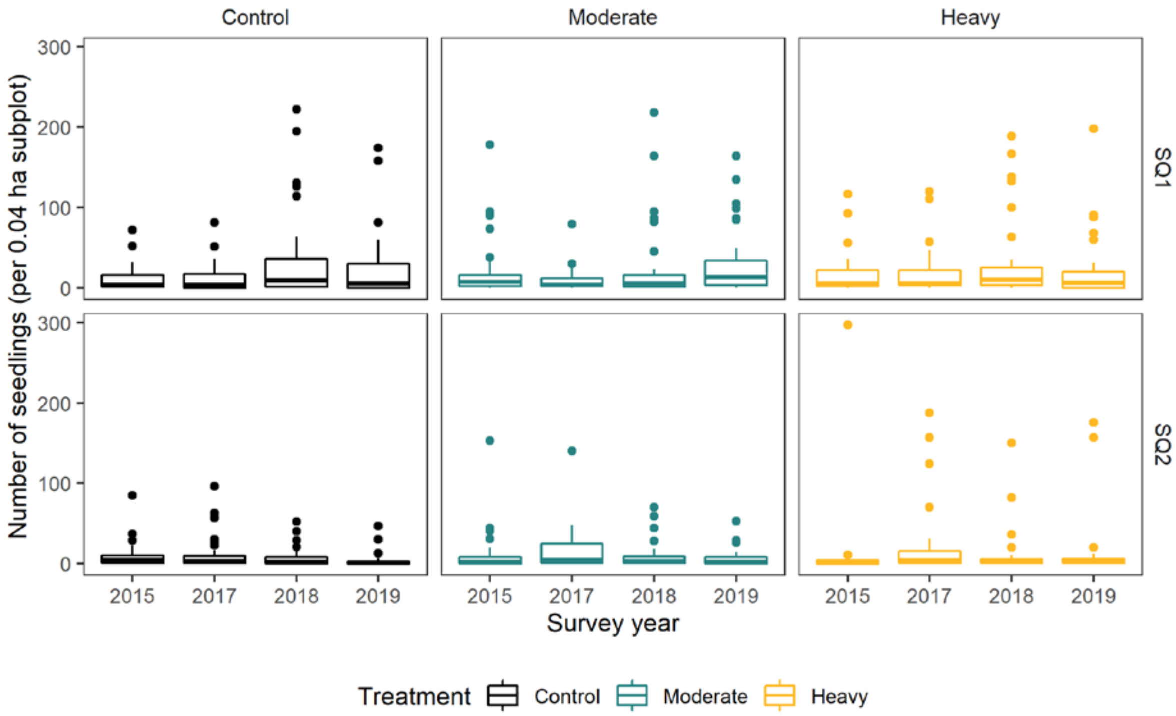

Figure 19 Boxplots of number of seedlings per 0.04 hectare subplot, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

Three values between 550 and 1000 were excluded from the plotted data.

Model results

Seedling presence was not modelled because they were almost always present.

A model of seedling abundance indicated that some three-way interactions were present, with differences among thinning treatments in the different site qualities over time (Table 10, Figure 20). In particular, seedling abundance was higher in thinned plots in Site Quality 2 in 2018, and in heavily thinned plots in Site Quality 2 in 2019. The magnitude of the increase was small with approximately 10 additional seedlings across three 0.04 hectare subplots in the heavily thinned plots in 2019.

Table 10 Model summary for abundance of seedlings per 9 hectare plot

Response	Family	Link	Effect of time	Effect of thinning treatment	Effect of site quality	Confidence
Count of seedlings per 9 hectare plot (log + 1 transformed)	Gaussian	None	Higher abundances across all thinning treatments in 2018			High R^2 = 52.7% No assumptions violated
			Heavily thinned plots on drier (Site Quality 2) sites had higher abundances of seedlings (10 additional seedlings in three 0.04 ha subplots) than control or moderately thinned plots in 2019 Moderately and heavily thinned plots in Site Quality 2 also had higher seedling abundances in 2018; as did moderately thinned in Site Quality 2 in 2017			

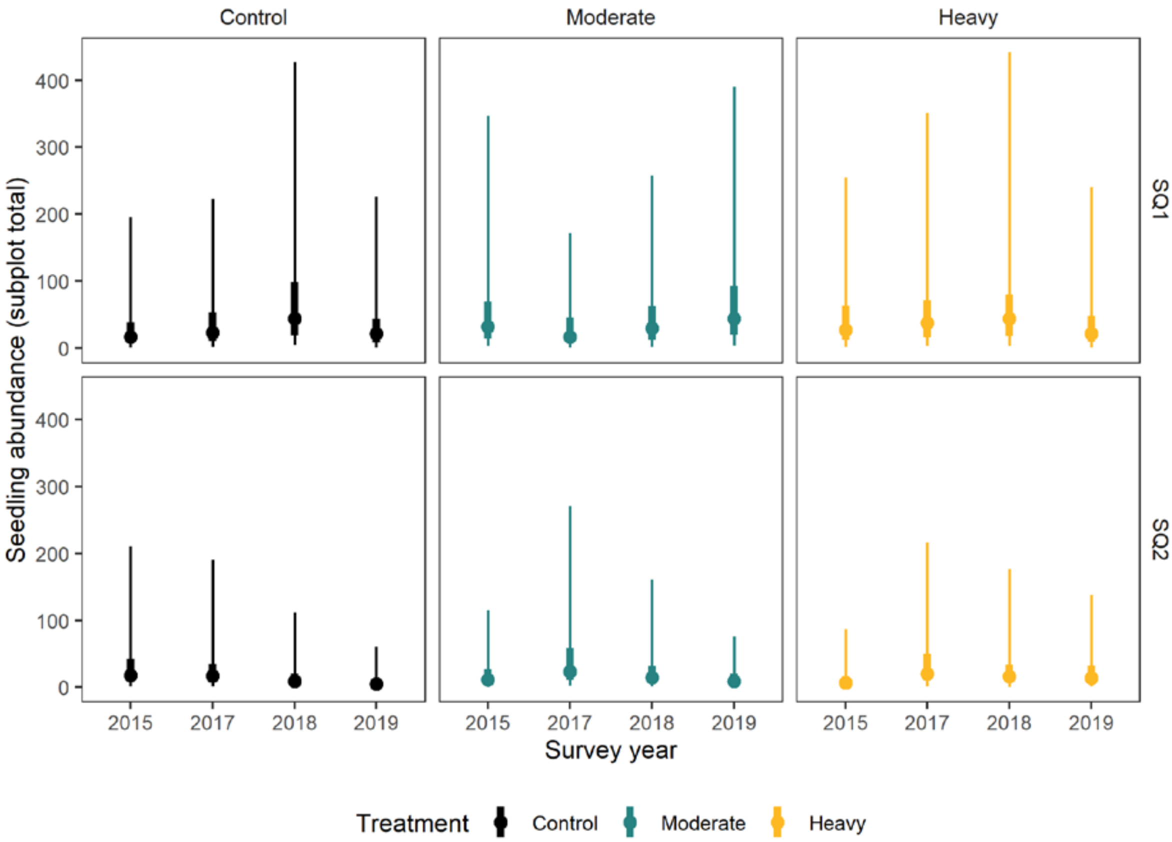

Figure 20 Modelled seedling abundance in 9 hectare plots (totalled across three 0.04 hectare subplots) with bootstrapped 50% and 95% confidence intervals, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

4.3 Saplings

Key result	Fewer saplings occurred in thinned plots than control plots in all post-thinning years

Data collection

Saplings are defined as being greater than 1.37 metres in height with a diameter at breast height of less than 10 centimetres.

Saplings were removed as part of the thinning operations.

Data summary

Saplings were present in almost all 9 hectare plots in all years, 94% of plots in total. Saplings were therefore very widespread and an effect of ecological thinning on sapling occurrence was not evident. Sapling occurrence was therefore not modelled.

Sapling abundance varied substantially, with median densities of averages of approximately: 10–20 saplings per 0.04 hectare plot in control plots; 5–10 in moderately thinned plots; and 2–10 in heavily thinned plots (Figure 21, Figure 22). A maximum of 150 saplings per 0.04 hectares was recorded. The occurrence of saplings decreased as a direct result of thinning operations and remained lower than control plots in 2019.

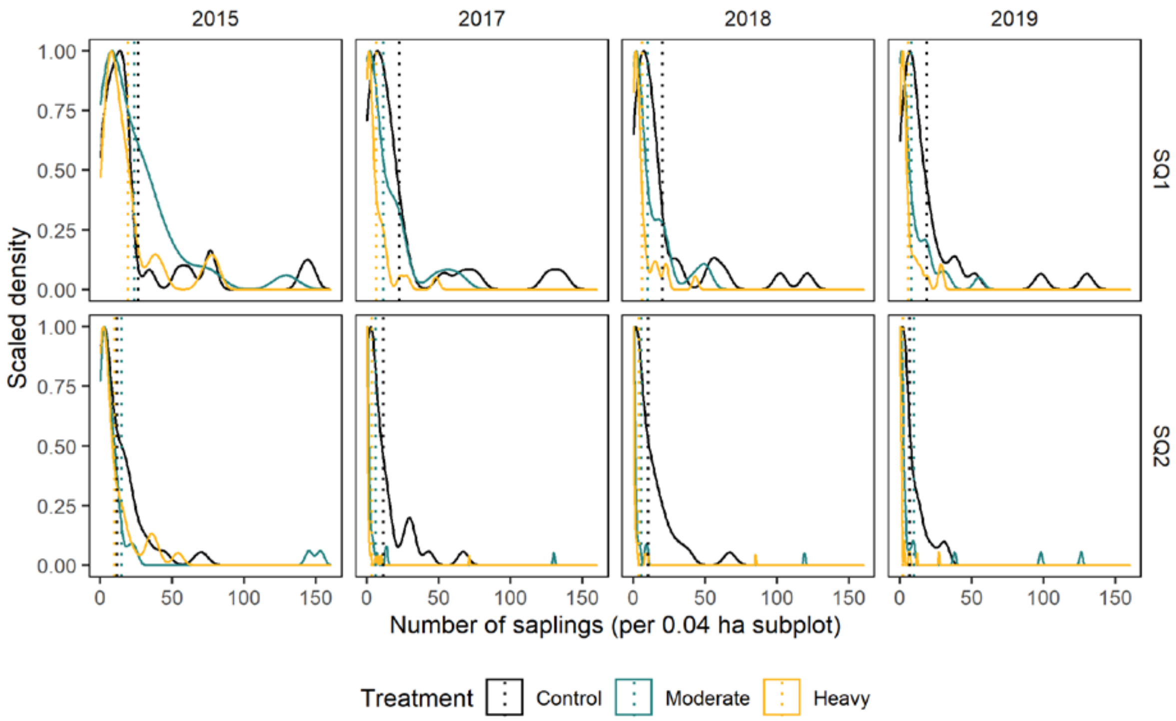

Figure 21 **Density plots and averages (dotted lines) of sapling abundance (per 0.04 hectare subplot), by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)**

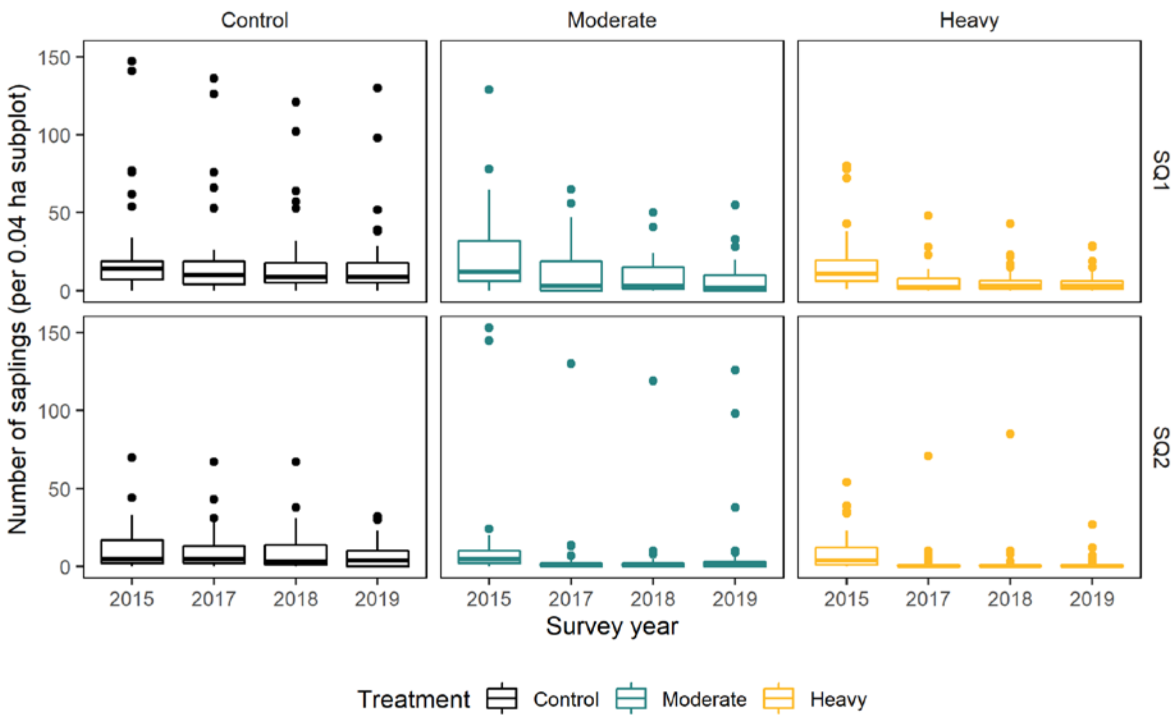

Figure 22 **Boxplots of sapling abundance (per 0.04 hectare subplot), by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)**

Model results

Sapling abundance was lower in moderately thinned (4–15 total of three 0.04 hectare subplots) and heavily thinned (3–10 total) plots than control plots (13–43 total) in all post-thinning years (Table 11, Figure 23). The abundance of saplings in heavily thinned plots was therefore slightly lower than the abundance in moderately thinned plots.

Sapling abundance was also consistently lower in drier Site Quality 2 sites than wetter Site Quality 1 sites.

Over time, sapling abundance had declined in control plots (from 54 to 34 on SQ1 and from 20 to 13 on SQ2 total of three 0.04 hectare subplots) but the change was not statistically significant. Over the post-thinning years, abundance in thinned plots was relatively stable.

Table 11 Model summary for count of saplings

Response	Family	Link	Effect of time	Effect of thinning treatment	Effect of site quality	Confidence
Count of saplings per 9 hectare plot (log + 1 transformed)	Gaussian	None	Lower in thinned plots in all years after 2015		Lower in Site Quality 2 sites	Moderate R^2 = 66.1% Some uncertainty about fit at high values

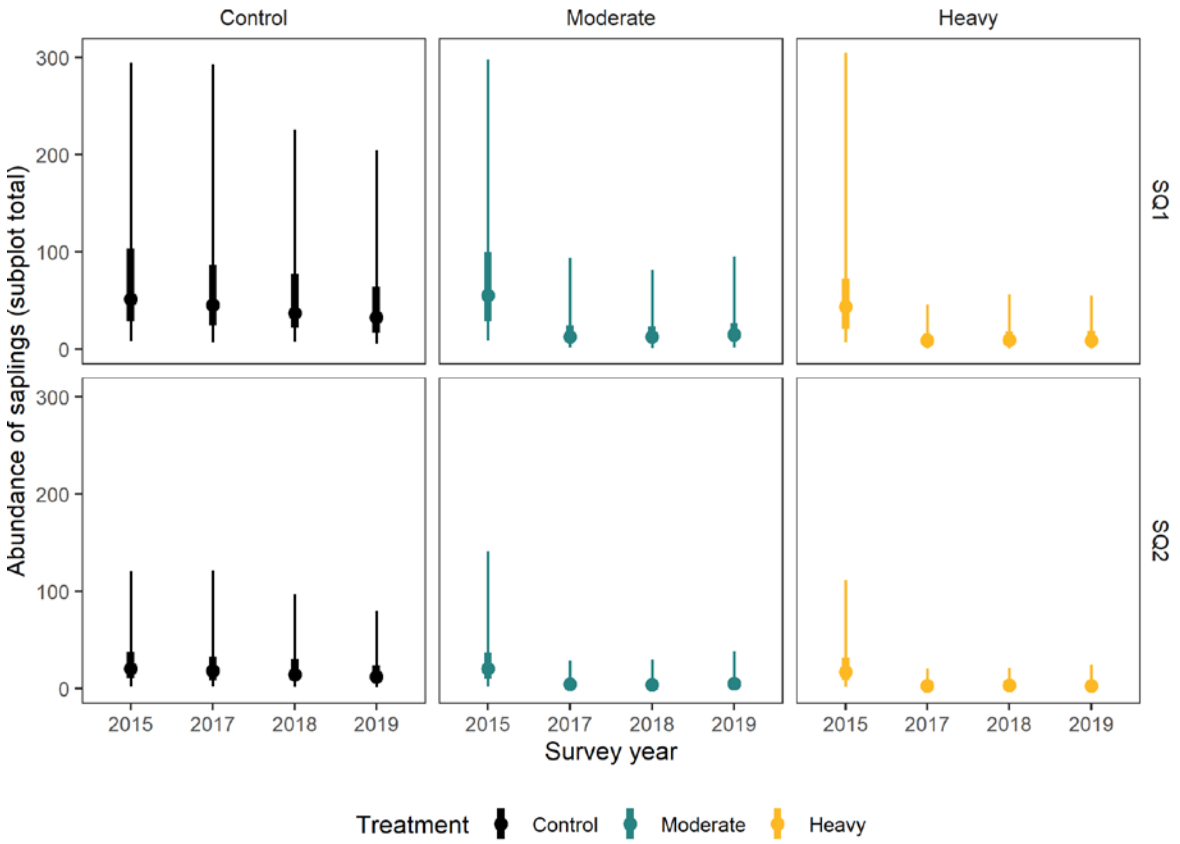

Figure 23 Modelled sapling abundance per 9 hectare plot (total of three 0.04 hectare subplots) with bootstrapped 50% and 95% confidence intervals, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

5. Results: Canopy condition

5.1 Average crown extent

Key result	Average crown extent was 3–4% lower in control plots than thinned plots in Site Quality 2 in 2019–20, not significant when bootstrapped

Data collection

Within each 9 hectare treatment plot, 30 trees with >10 centimetres dbh were randomly selected along a north–south transect in the centre of the plot. These 30 trees are permanently marked and are repeatedly measured for a range of parameters, including tree crown extent.

Crown extent is defined as the percentage of the potential crown that contains live foliage, including epicormic growth. The potential crown is estimated from the existing branching structure. Crown extent is sometimes referred to as 'crown vigour' in relevant literature. It was visually estimated to the nearest 5% for each of the 30 trees per plot.

Data summary

Over all survey periods, average crown extent per 9 hectare plot showed an upward trend on many plots, but some plots fluctuated over time possibly in response to flooding cycles and/or epicormic growth (Figure 24).

Over time, average values tended to be higher on wetter Site Quality 1 sites than drier Site Quality 2 sites.

In 2019, the most commonly recorded values of crown extent were similar among thinned and control plots in Site Quality 1 (Figure 25).

In 2019, the magnitude of difference between control and thinned plots was greater on drier Site Quality 2 sites.

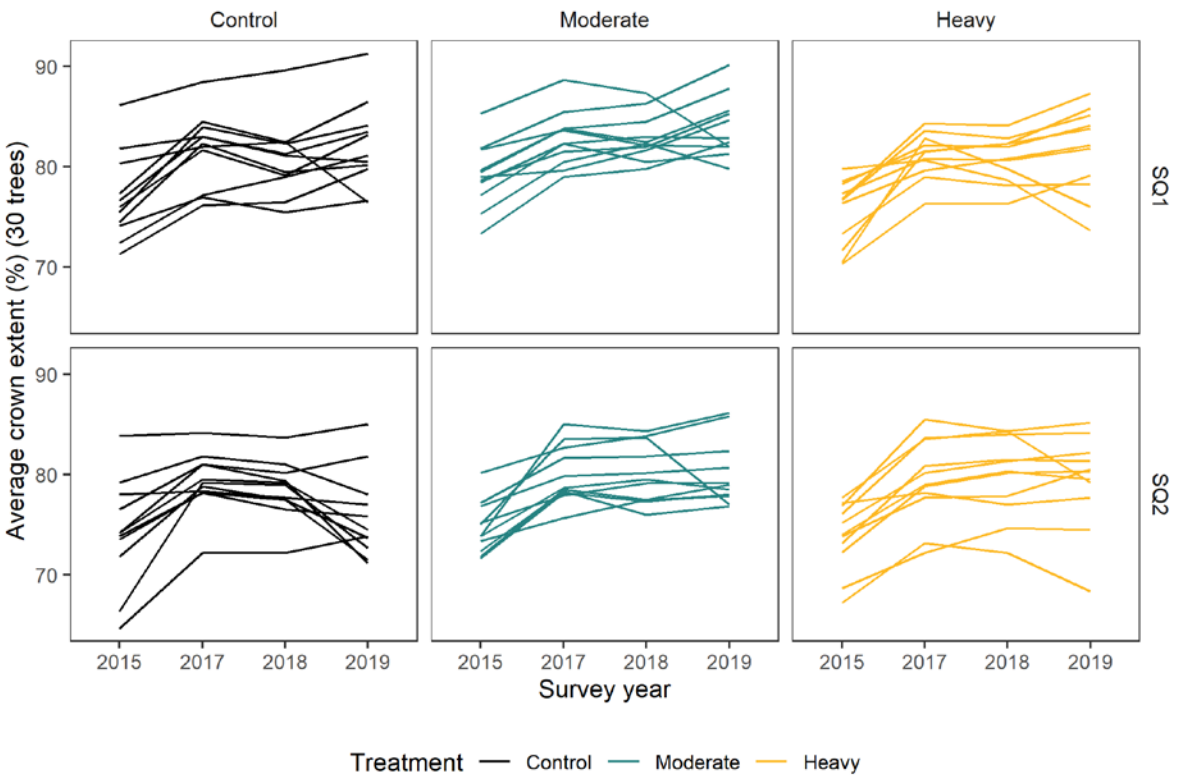

Figure 24 **Average crown extent (for 30 trees in each 9 hectare plot) trends over time, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)**

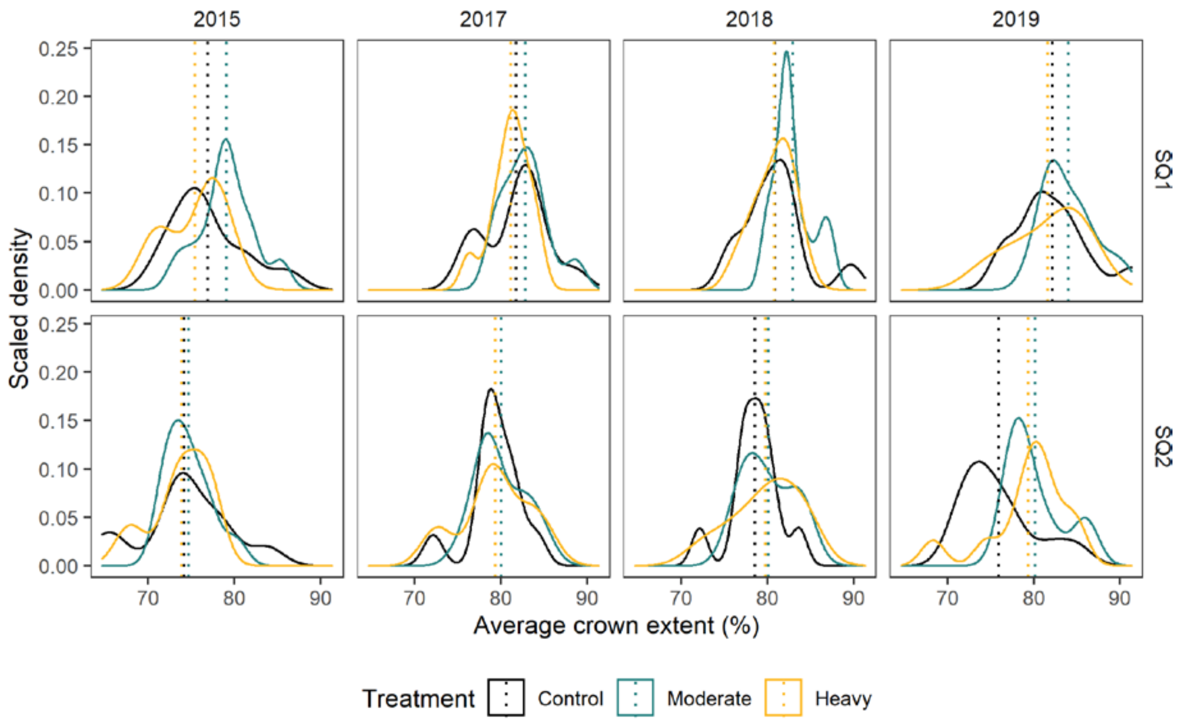

Figure 25 **Density plots and averages (dotted lines) of mean crown extent, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)**

Model results

A gaussian model was run to determine whether average crown extent differed among control and thinned plots over time, and whether any differences depended on site quality. Modelling indicated that three-way effects were present (Table 12, Figure 26).

In Site Quality 1, there was no evidence for substantial differences between control and thinned plots over time. In 2019, average modelled crown extent was between 82 and 84%.

In Site Quality 2, average crown extent was approximately 4% lower in control plots than thinned plots (75.8% in control plots, 79.8% in moderately thinned plots and 79.5% in heavily thinned plots). The difference between control and thinned plots in Site Quality 2 in 2019 was not statistically significant when bootstrapped.

Table 12 Model summary for average crown extent

Response	Family	Link	Effect of time	Effect of thinning treatment	Effect of site quality	Confidence
Average crown extent	Gaussian	None (no link)	Significantly lower (4–5%) in 2015	4% higher on moderate plots than control plots in Site Quality 2 in 2019 – not significant when bootstrapped	Significantly lower (2.5%) in Site Quality 2 (interval just includes zero when bootstrapped)	High R^2 = 61% Met all assumptions

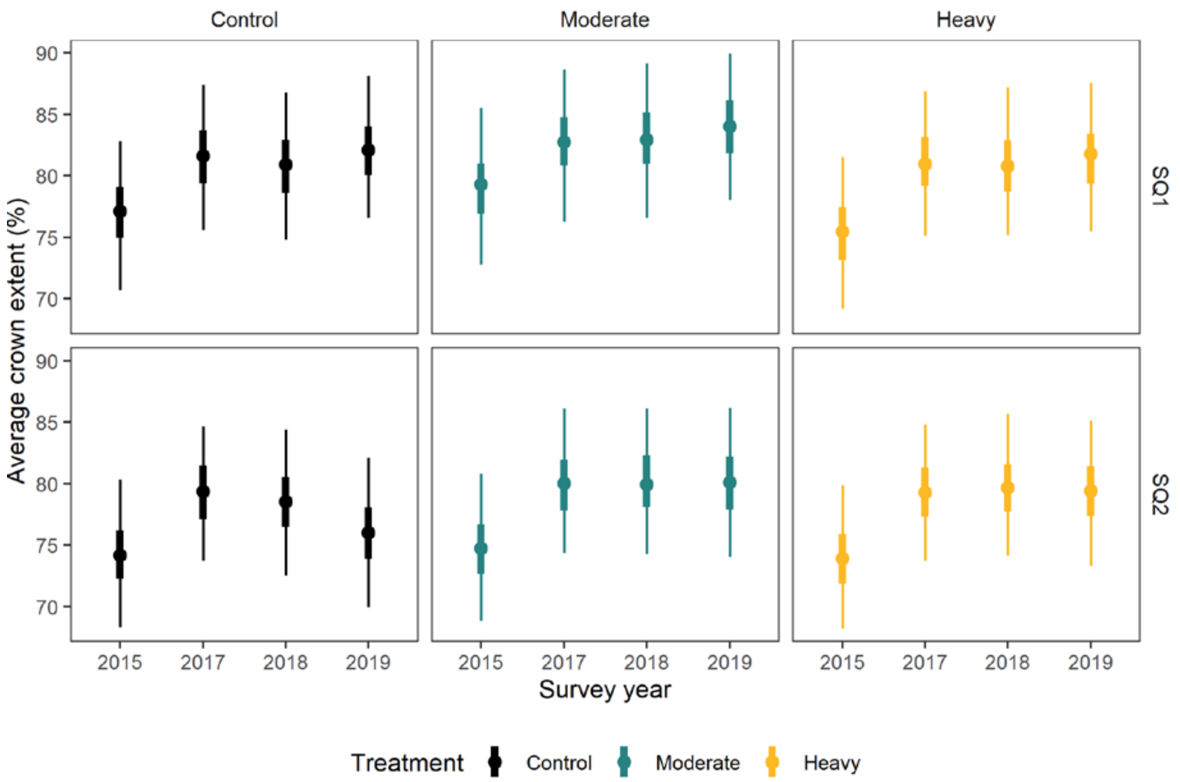

Figure 26 Modelled average crown extent (%) among 30 trees per 9 hectare plot with bootstrapped 50% and 95% confidence intervals, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

5.2 Recent change in crown extent

Key result	There were approximately 10–15% more trees (3–4.5 out of 30 trees) with recent decline in crown extent in control plots in Site Quality 2 than in thinned plots in 2019

Data collection

Data collection for tree crown extent is described above.

Given the previous model result that crown extent was lower in control plots in 2019, the change in crown extent between the two most recent surveys (2018 and 2019) was calculated for each tree.

Recent change was categorised as decline, stable or increase, and the proportion of trees in each category was calculated.

Data summary

The proportion of trees with recent declining, stable or increasing crown extent was similar across the thinning treatments in Site Quality 1 (Figure 27, Figure 28): however, the proportion of trees with decline was higher in control plots than thinned plots in Site Quality 2.

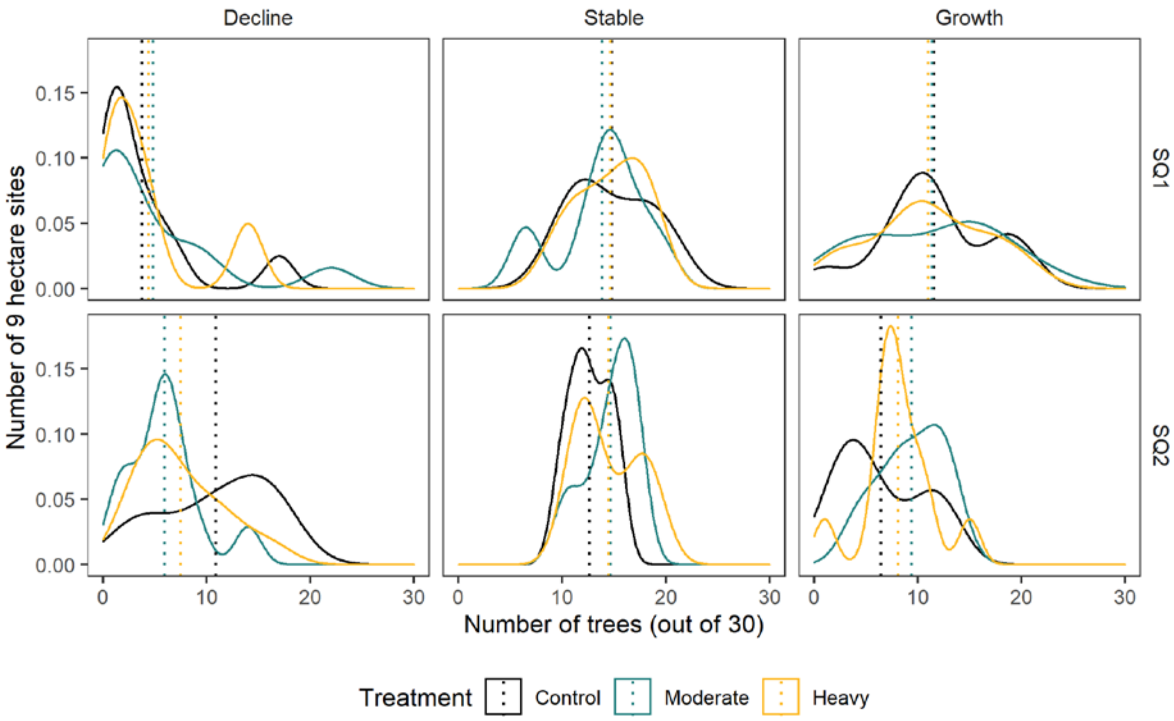

Figure 27 Density plots and averages (dotted lines) of numbers of trees with declining, stable or increasing crown extent between the 2018 and 2019 surveys, by ecological thinning treatment and site quality (SQ1 and SQ2)

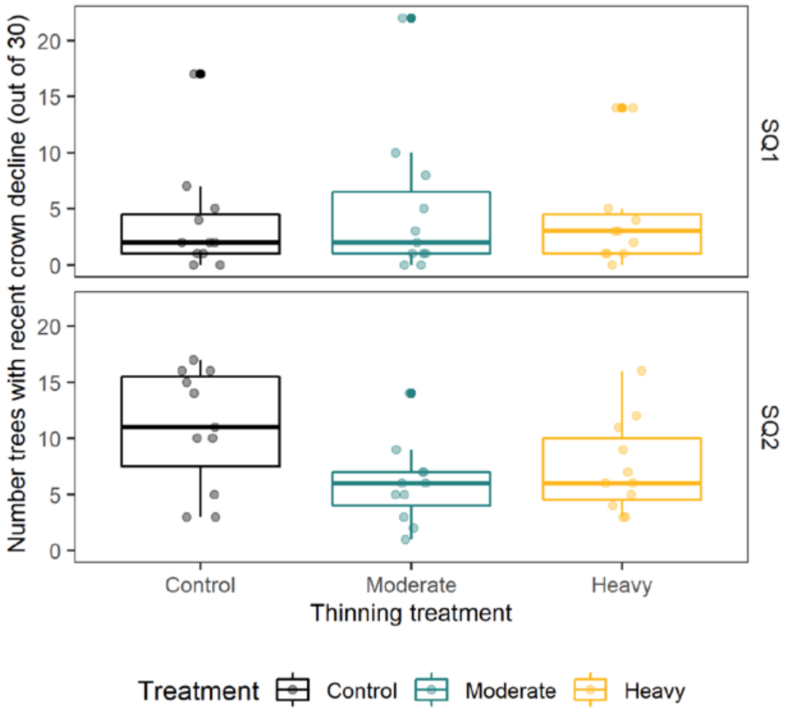

Figure 28 Boxplots of number of trees with recent decline in crown extent between the 2018 and 2019 surveys, by ecological thinning treatment and site quality (SQ1 and SQ2)

Model results

A binomial model was run to determine whether the proportion of trees with recent decline in crown extent was greater in control plots than thinned plots (Table 13).

There were no differences among control and thinned plots in wetter Site Quality 1 sites, with approximately 8–11% of trees with recent crown decline (Figure 29).

In drier Site Quality 2 sites there were substantially more trees in control plots with recent decline in crown extent (33%) than on moderate (18%) or heavily (23%) thinned plots. When expressed as number of trees out of the 30 (the number sampled in each 9 hectare plot), this equates to approximately 10 trees in control plots, 4.5 trees in moderately thinned plots and three trees in heavily thinned plots.

Table 13 Model summary for proportion of trees with recent decline in crown extent

Response	Family	Link	Effect of thinning treatment	Effect of site quality	Confidence
Proportion of trees with recent decline in crown extent	Binomial	Logit		Greater decline in Site Quality 2	Moderate R^2 = 27% Some overdispersion apparent
			More trees with decline in control plots (10–15%) than thinned plots in Site Quality 2		

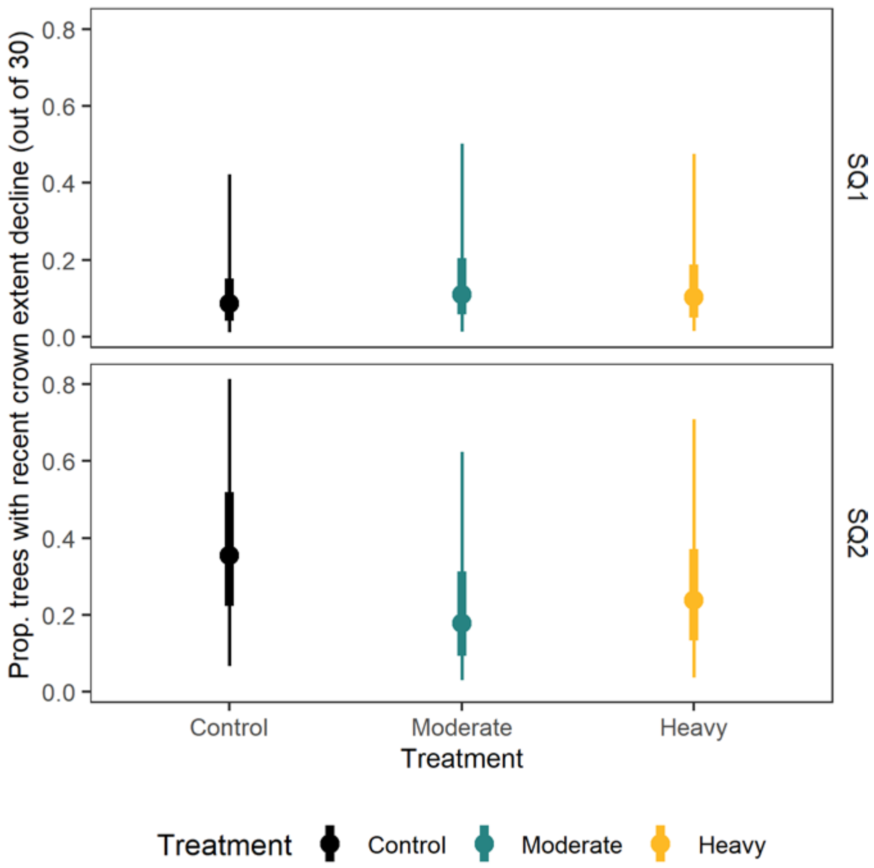

Figure 29 Modelled proportion of trees with crown extent decline between 2018 and 2019 with bootstrapped 50% and 95% confidence intervals, by ecological thinning treatment and site quality (SQ1 and SQ2)

5.3 Magnitude of recent decline in crown extent

Key result	There was no effect of thinning treatment on magnitude of recent decline in crown extent (probability >80% of declining one 5% category)

Data collection

Crown extent data collection is described above.

Here, only the trees that declined in crown extent between the two most recent surveys (2018 and 2019) were analysed.

To determine the magnitude of recent decline in crown extent, the difference in crown extent between the two survey periods was calculated.

Because crown extent is estimated to the nearest 5%, the data resembles categories, with each category consisting of a 5% increment.

Data summary

The recorded data indicated that the most common magnitude of decline was 5% (one category) for all thinning treatments in both site qualities (Figure 30). However, some greater magnitudes of decline were recorded in drier Site Quality 2 sites, particularly in control plots.

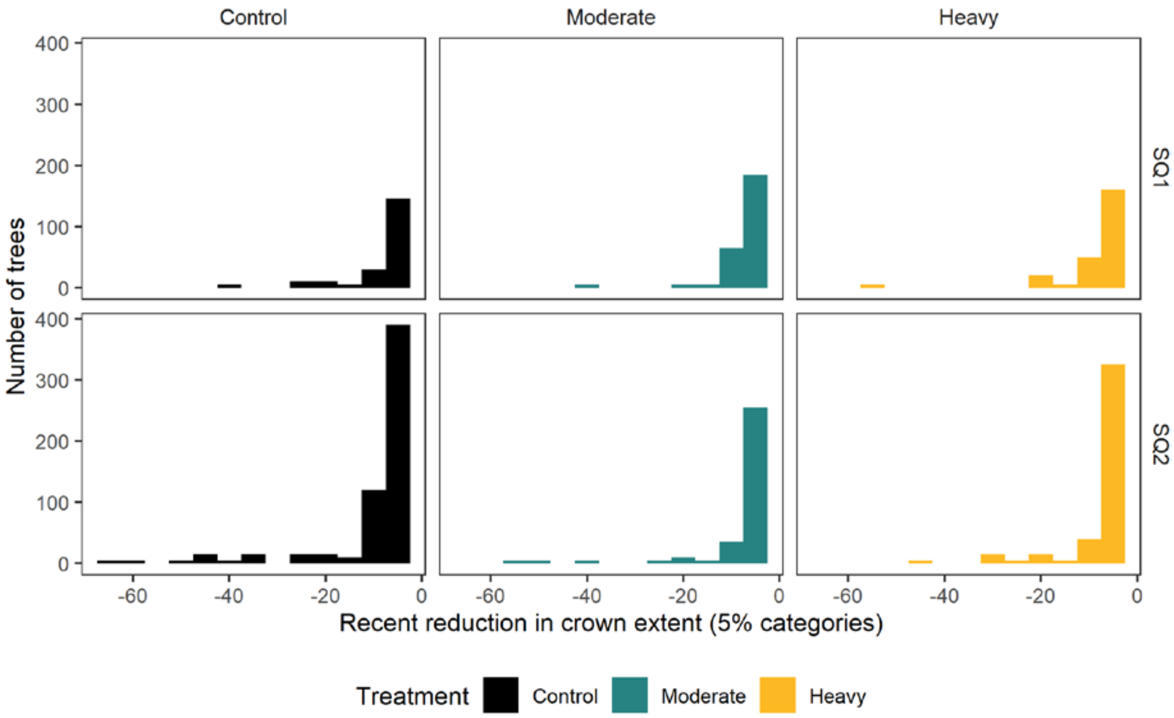

Figure 30 Magnitude of recent reduction in crown extent, by ecological thinning treatment and site quality (SQ1 and SQ2)

Model results

A Bayesian cumulative ordinal model was run to determine the probability of changing crown extent categories (Table 14).

In all treatments, the probability was highest (approximately 80% probability) for moving one 5% category between 2018 and 2019 (Figure 31).

The probability of crown extent declining by 10% (two categories) was slightly higher for control plots on drier Site Quality 2 sites but was still less than 10% probability.

There was no evidence for an effect of thinning treatment on the magnitude of recent decline in crown extent.

Table 14 Model summary for probability of magnitude of recent reduction in crown extent

Response	Family	Link	Effect of thinning treatment	Effect of site quality	Confidence
Probability of crown reduction in 5% categories	Cumulative ordinal	Logit	No effect of thinning treatment	No effect of site quality	Moderate

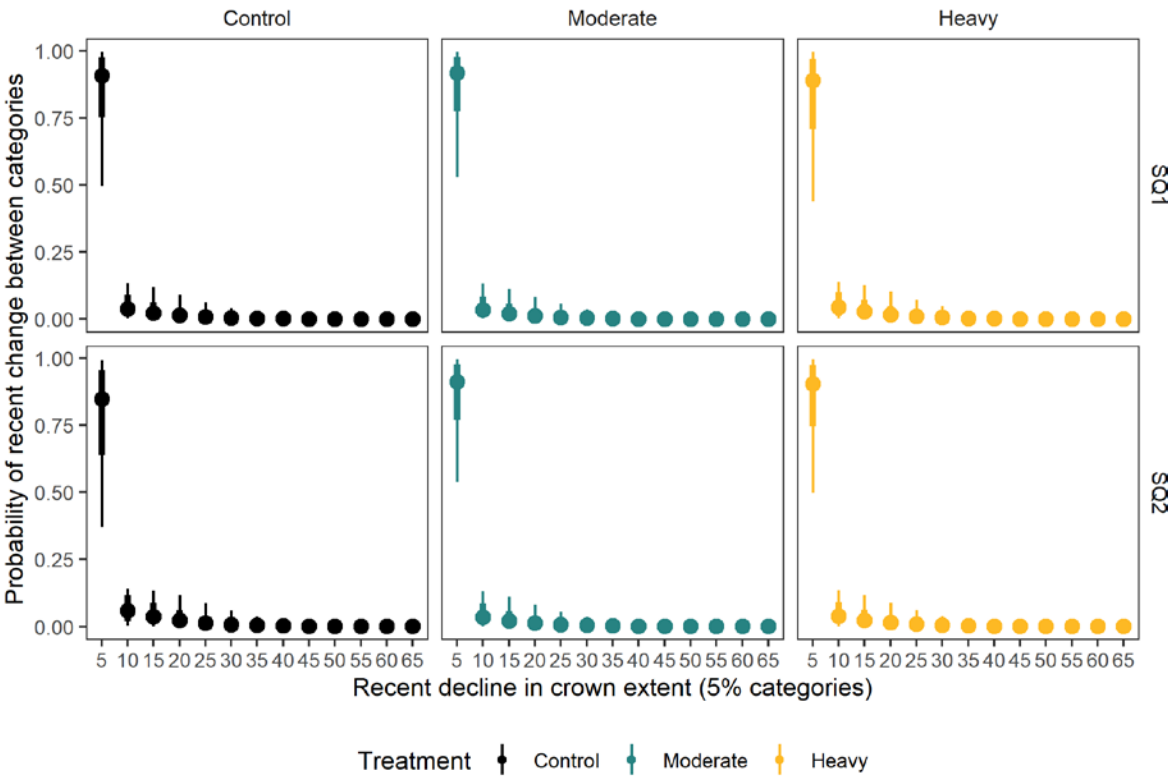

Figure 31 Modelled probability of change between 5% crown extent categories from 2018 to 2019 with bootstrapped 50% and 95% confidence intervals, by ecological thinning treatment and site quality (SQ1 and SQ2)

5.4 Visually assessed live canopy cover

Key result	Average live canopy cover (visually assessed) was 2% lower in heavily thinned plots in Site Quality 1 than control or moderately thinned plots in 2019

Data collection

Canopy cover is an on-ground estimate of the projective foliage cover of the trees in a stand. Canopy cover was visually estimated as a percentage by two observers independently, who then conferred to record one estimate. Estimates in each of the three 0.04 hectare subplots were averaged for the 9 hectare plot.

Dead canopy cover was also estimated (described in the section below).

Data summary

The distribution of live canopy cover estimates has varied over time among treatments (Figure 32). Lower values (<10%) were more commonly recorded in 2019.

Average live canopy cover has declined over time on all treatments in both site qualities (Figure 33).

In wetter Site Quality 1 sites, live canopy cover estimates tended to be higher in control plots than thinned plots in 2019. In drier Site Quality 2 sites, live canopy cover estimates were similar across control and thinned plots in 2019.

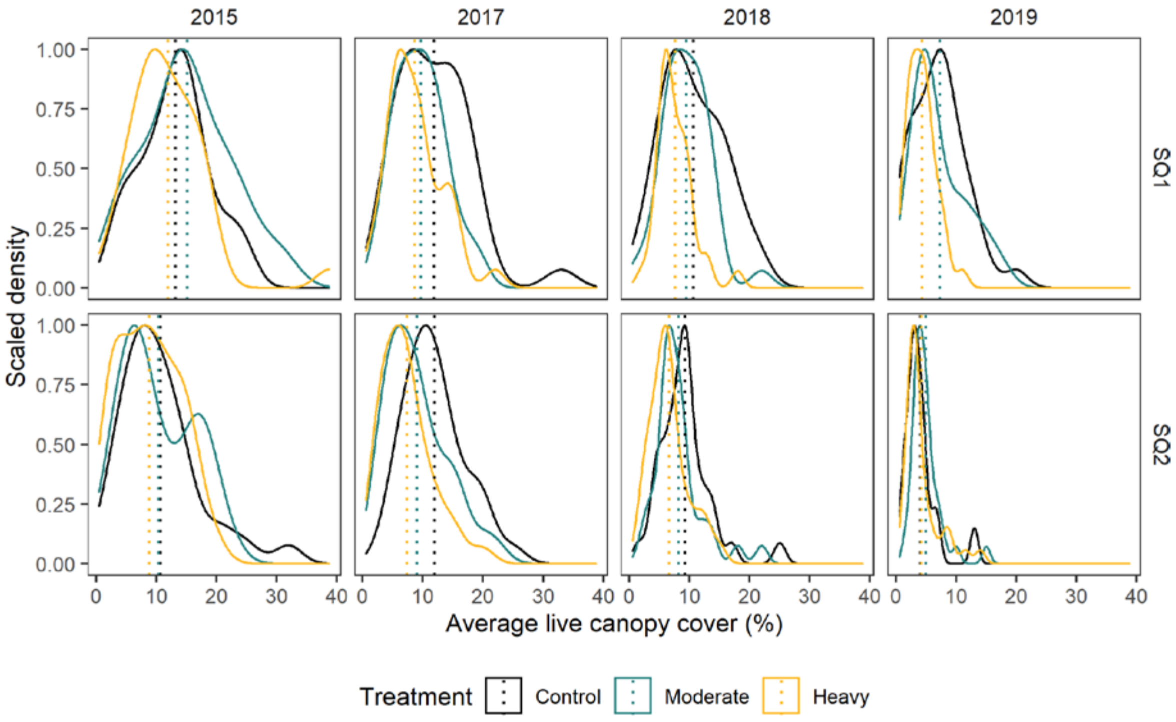

Figure 32 Density plots and averages (dotted lines) of live canopy cover (%, average per 9 hectare plot), visually assessed, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

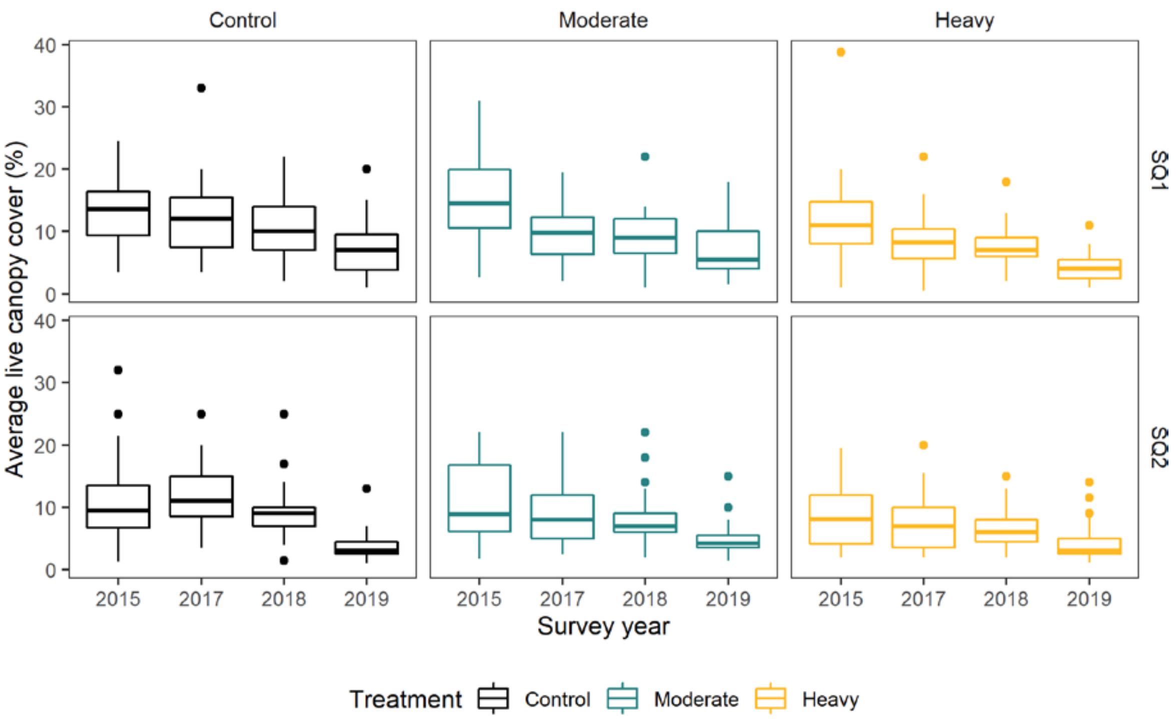

Figure 33 Boxplots of live canopy cover (%, average per 9 hectare plot), visually assessed, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

Model results

A beta model was run to determine whether the proportion (percentage) of live canopy cover differed by thinning treatment over time, and whether differences depended on site quality (Table 15).

Modelling indicated that live canopy cover was significantly lower in 2018 and 2019 than 2015 (Figure 34). In wetter Site Quality 1 sites, canopy cover has declined from about 11.5–15% in 2015 to 4.5–7% in 2019. In drier Site Quality 2 sites, the decline has been from about 8–10% in 2015 to 4–5% in 2019.

Differences between control and thinned plots are slight in 2019. In Site Quality 1 sites, canopy cover in heavily thinned plots is about 4.5% and in control and moderately thinned it is around 7%. Non-bootstrapped confidence intervals (standard errors) indicate that this magnitude is marginally significant.

In Site Quality 2 sites, cover was 4–5% for all treatments in 2019.

Table 15 Model summary for mean live canopy cover, visually assessed

Response	Family	Link	Effect of year	Effect of thinning treatment	Effect of site quality	Confidence
Live canopy cover	Beta	Logit	Lower in 2019 (4–7%) and 2018 (1–4%) than 2015		Lower in Site Quality 2 (<1%)	Moderate–High Some uncertainty about fit at high values
			Lower in moderately thinned in 2017 and 2018			
			Lower in heavily thinned, except for heavily thinned in Site Quality 2 in 2019			

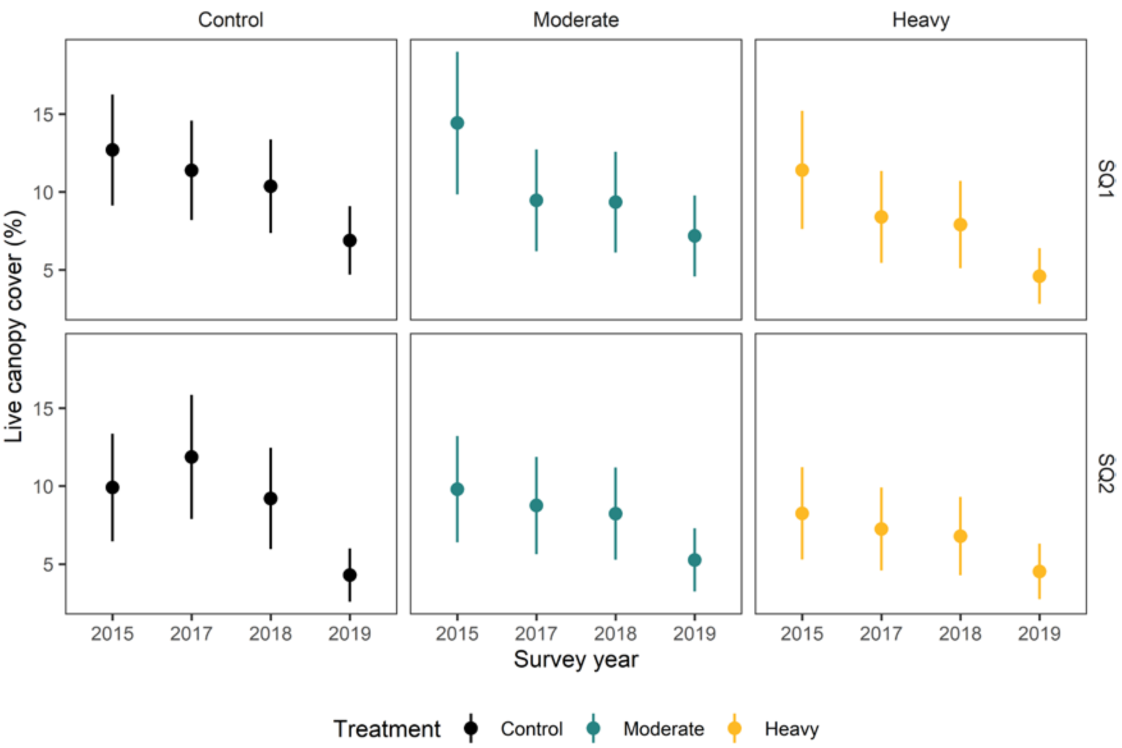

Figure 34 Modelled visually assessed live canopy cover (%, average per 9 hectare plot) with standard errors, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

5.5 Visually assessed dead canopy cover

Key result	No difference between control and thinned plots for dead canopy cover (visually assessed)

Data collection

Tree crown extent (described above) is an estimate of foliage on individual trees.

Canopy cover is an on-ground estimate of the projective foliage cover of the trees in a stand. Canopy cover was visually estimated as a percentage in each of the three 0.04 hectare subplots on each 9 hectare plot. The average of the three 0.04 hectare plots in each 9 hectare plot is reported here.

Dead canopy cover is comprised of dead leaves attached to live trees. In 2015 observers provided variable estimates of values <1%; in subsequent surveys observers used a standardised value of 0.5%.

Data summary

In all years and all thinning treatments, the most commonly recorded value of dead canopy cover was <1% (Figure 35, Figure 36).

In 2019, a higher proportion of plots recorded averages of 1% or 1.5% dead than in previous years.

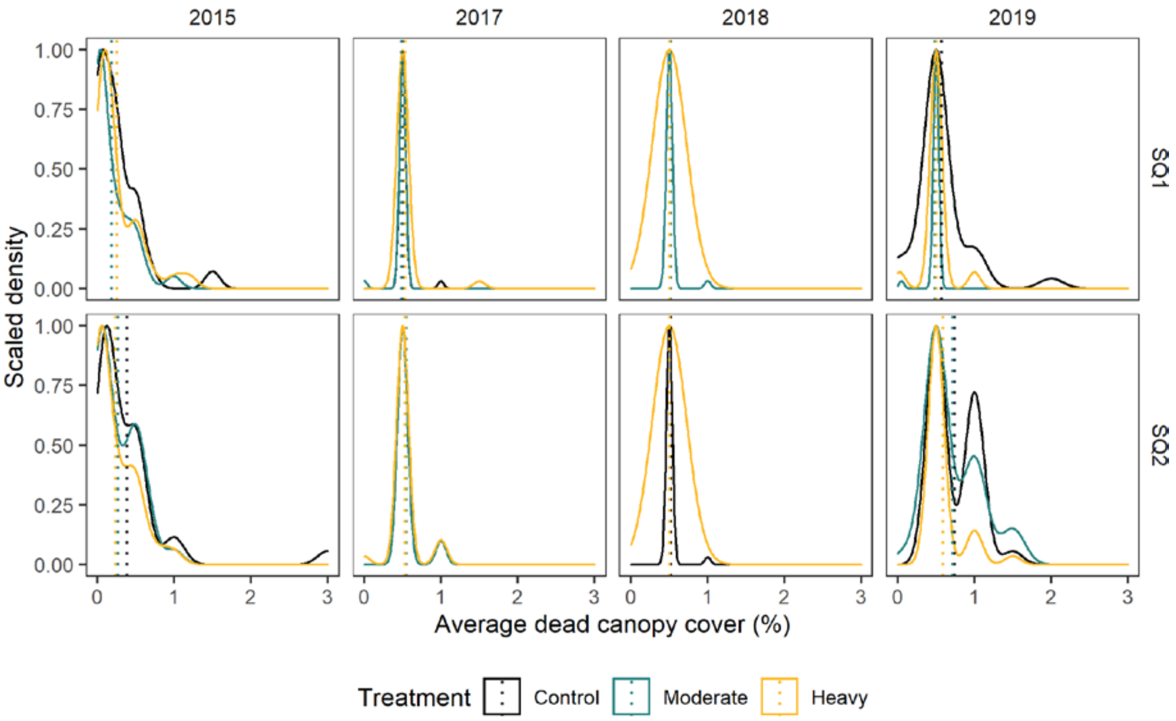

Figure 35 Density plots and averages (dotted lines) of average dead canopy cover (%, visually assessed), by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

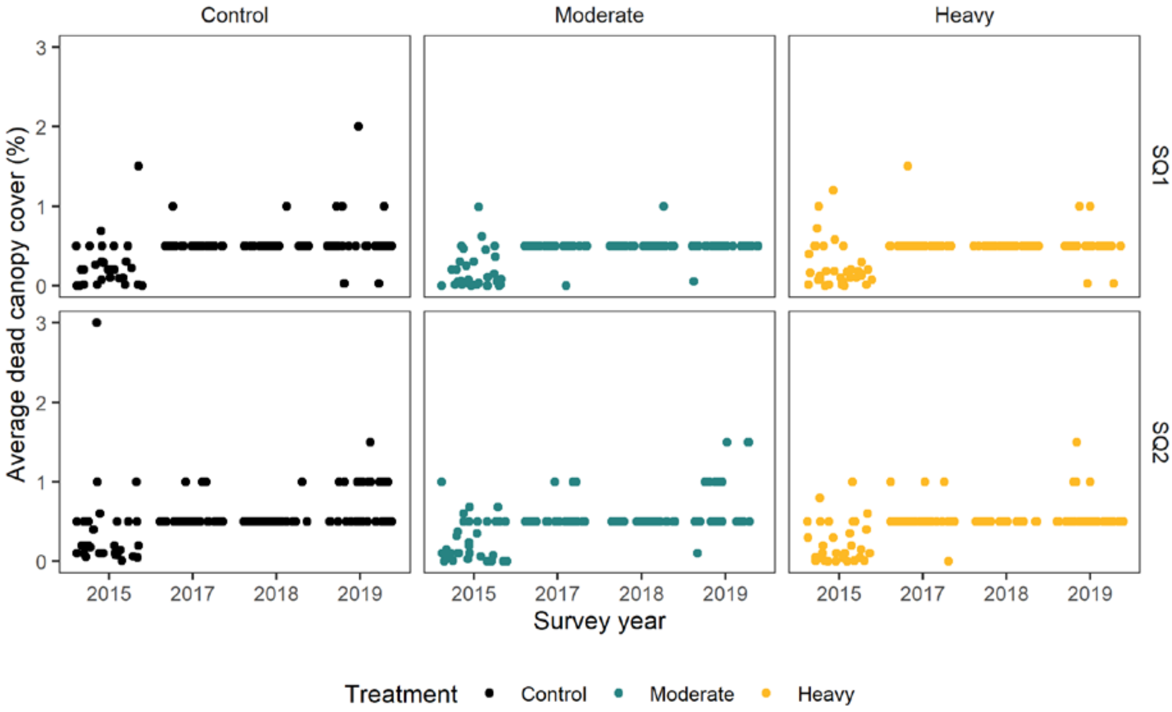

Figure 36 Scatter plots of average dead canopy cover (%, visually assessed), by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

Model results

No model was run because there is no ecological difference between 0.5% dead and 1% dead canopy cover.

5.6 Remotely sensed canopy cover

Key result	The magnitude of decline in FPC was greater in control plots (approximately 0.13–0.14) than thinned plots (approximately 0.07–0.09) FPC was higher on wetter Site Quality 1 sites than drier Site Quality 2 sites throughout the period

Data collection

The Landsat satellite provides remotely sensed images at 30 metres resolution at 16-day intervals. Foliage projective cover (FPC) (Scarth et al. 2008) is a measure of canopy density derived from Landsat images that describes the percentage of ground area occupied by the vertical projection of green foliage of woody vegetation greater than two metres in height.

FPC data were extracted from Landsat images on each cloud-free date between August 2017 (when thinning was complete on all treatment sites) and March 2020. This time period allowed investigation of FPC trends in control and treatment plots after thinning was implemented. Multiple pixels (30 x 30 metres) were available per 9 hectare plot for each date, from which the median FPC was calculated for each 9 hectare plot.

Data summary

After thinning was implemented (in August 2017), median FPC values were highest for control plots. All sites had been flooded in the previous year (Figure 4) and FPC was lower in thinned plots that had had a portion of their canopy removed.

Dry hydroclimatic conditions occurred over the study period (Figure 4, Figure 6).

Model results

A gaussian time series model was run to determine whether the trend in FPC over time differed among thinned and control plots (Table 16). A spherical correlation component was included in the model to account for temporal autocorrelation among plots.

FPC declined significantly on all treatments between August 2017 and March 2020 (Figure 37).

The magnitude of decline over the period was greater for control plots (approximately 0.13–0.14 decline) than thinned plots (approximately 0.07–0.09 decline), and this difference was statistically significant.

At the end of the survey period, FPC values were similar among control and moderately thinned plots (0.35–0.36 on wetter Site Quality 1 and 0.25 on drier Site Quality 2), and slightly lower for heavily thinned plots (0.31 in Site Quality 1 and 0.21 in Site Quality 2).

FPC was consistently higher on wetter Site Quality 1 sites than drier Site Quality 2 sites throughout the period. Additionally, FPC was more variable among plots in the wetter Site Quality 1.

Seasonality in FPC was apparent in the model and a seasonal variable (cosine of time) was a significant predictor.

Table 16 Model summary for foliage projective cover

Response	Family	Link	Effect of year	Effect of thinning treatment	Effect of site quality	Confidence
FPC time series from Aug. 2017 to Mar. 2020	Gaussian. Spherical correlation (to account for autocorrelation among plots)	None	Significant decline over time	Significantly greater decline for control plots (0.13–0.14) than thinned plots (0.07–0.09)	Significantly lower on Site Quality 2	Moderate – High R^2 = 73%

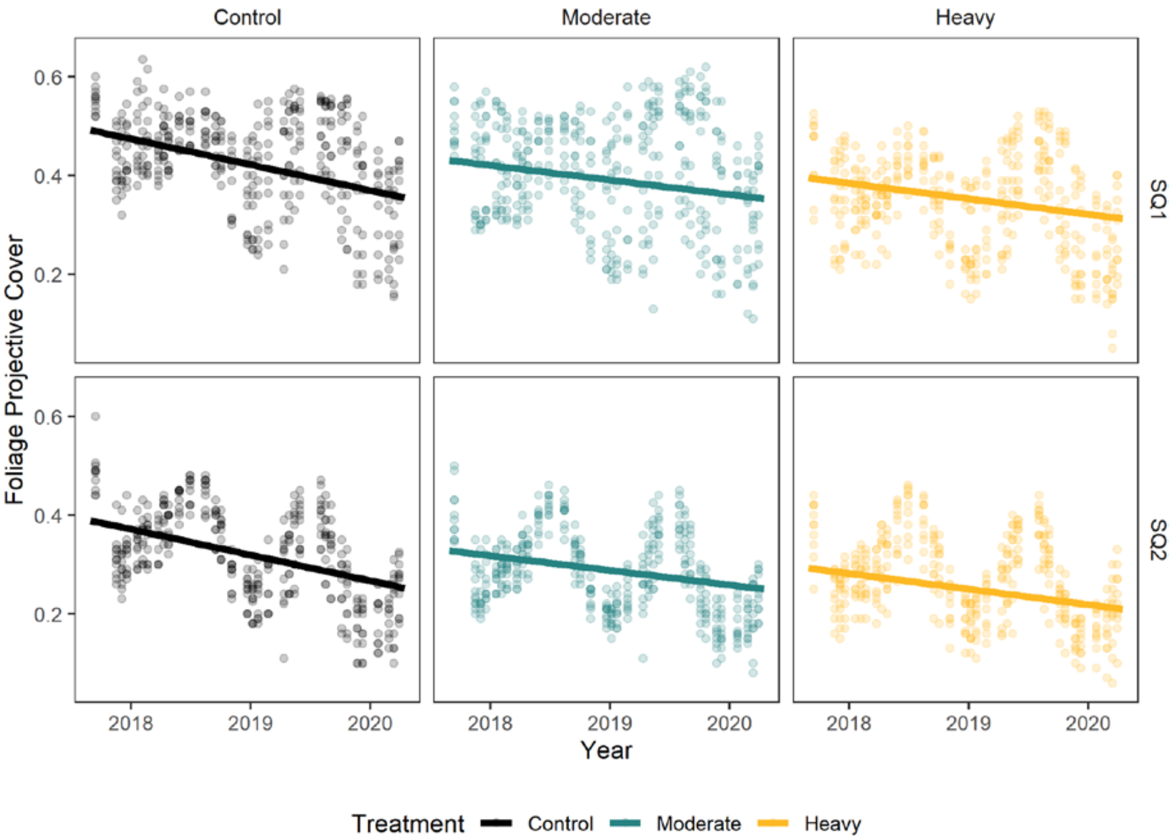

Figure 37 Median foliage projective cover (FPC) derived from Landsat (points) and modelled change over time (lines) for post-thinning dates, by ecological thinning treatment and site quality (SQ1 and SQ2)

5.7 Plant area index

Key result	Average plant area index was 0.2–0.4 higher in control plots than thinned plots in Site Quality 1 and 0.2 higher than heavily thinned plots in Site Quality 2

Data collection

Plant area index is a measurement of the area of leaves and stems relative to a unit of sky. It provides an objective estimate of tree canopy cover.

Plant area index was calculated from hemispherical photos taken in May 2019 (Bennetts & Jolly 2019). Digital hemispherical photographs were taken using a circular fisheye lens from five fixed positions in each 9 hectare treatment plot. Photographs were taken during specific light and wind conditions, and multiple photographs were taken at each position to ensure the highest contrast between the sky and trees. Photographs were then analysed using Multispec and Winphot to generate an estimate of plant area index for each photograph.

Data summary

All treatment types had a relatively broad range of commonly occurring average plant area index values (Figure 38, Figure 39).

Control plots tended to have a higher average plant area index than thinned plots, with a greater magnitude of difference on wetter Site Quality 1 sites.

Moderately thinned plots tended to have a higher plant area index than heavily thinned plots.

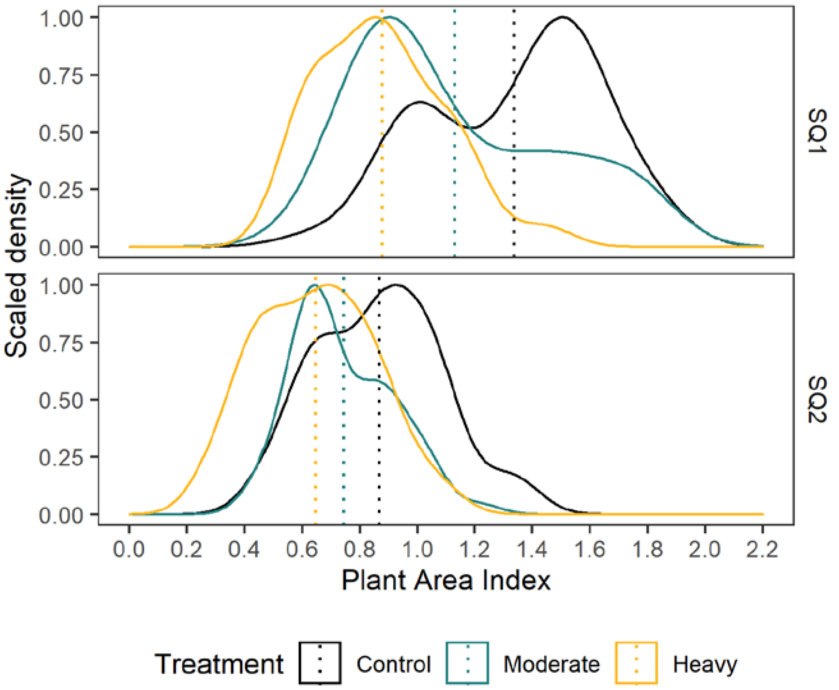

Figure 38 Density plots and averages (dotted lines) of average plant area index per 9 hectare plot in 2019, by ecological thinning treatment and site quality (SQ1 and SQ2)

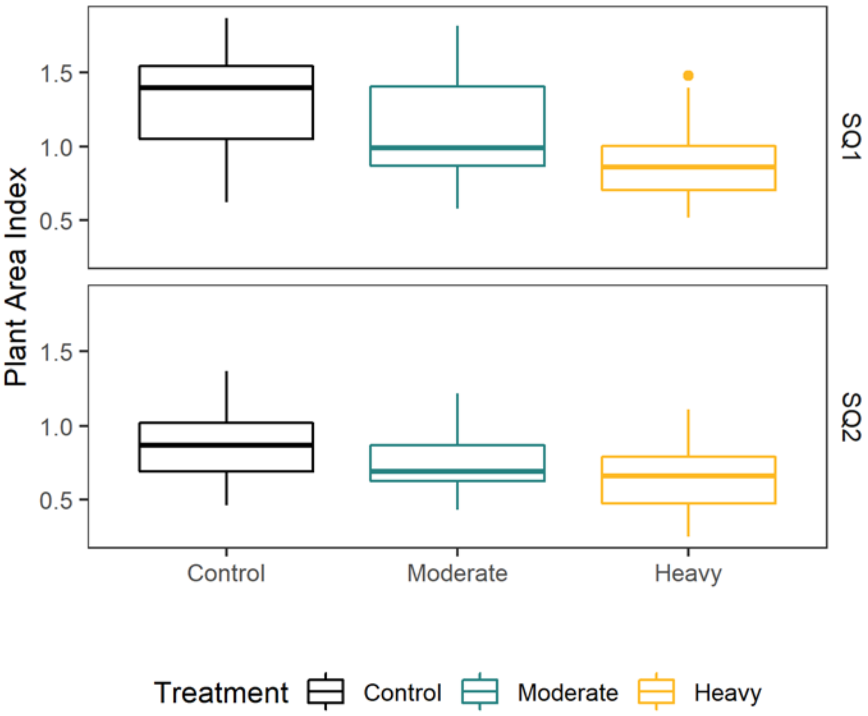

Figure 39 Boxplots of average plant area index per 9 hectare plot in 2019, by ecological thinning treatment and site quality (SQ1 and SQ2)

Model results

A gaussian model was run to determine whether the differences between control and thinned plots were statistically significant (Table 17).

Differences among thinning treatments were all statistically significant with the exception of control plots and moderately thinned plots in Site Quality 2 (Figure 40).

The fitted values for average plant area index were 1.33 for control, 1.13 for moderate and 0.88 in wetter Site Quality 1 sites.

The fitted values for average plant area index were 0.87, 0.72 and 0.65 for control, moderately and heavily thinned plots respectively, in drier Site Quality 2 sites.

Table 17 Model summary for plant area index

Response	Family	Link	Effect of thinning treatment	Effect of site quality	Confidence
Average plant area index	Gaussian	None	0.20–0.45 higher in control plots than thinned plots (not statistically significant for control and moderately thinned plots in Site Quality 2)	0.47 lower in SQ2	High R^2 = 72.7%

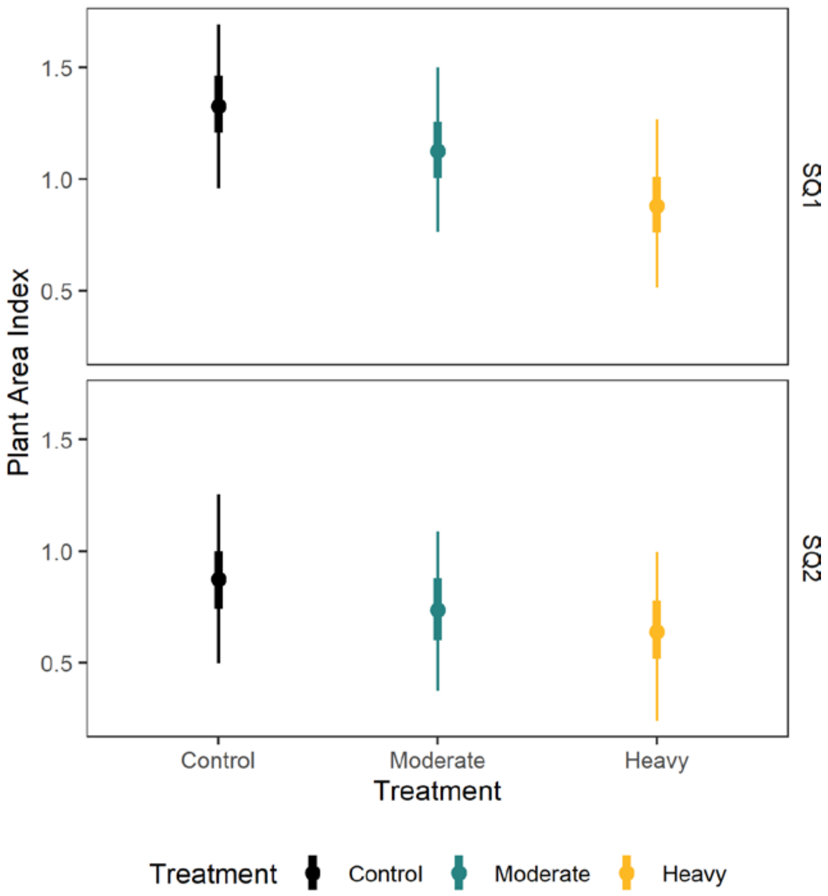

Figure 40 Modelled average plant area index per 9 hectare plot with bootstrapped 50% and 95% confidence intervals, by ecological thinning treatment and site quality (SQ1 and SQ2)

6. Results: Fuel hazard

Fuel hazard was assessed using the method of Hines et al. (2010). In this method, overall fuel hazard is determined from the assessment of four fuel hazard assessment components that are associated with vegetation strata from the forest floor to the canopy (Figure 41).

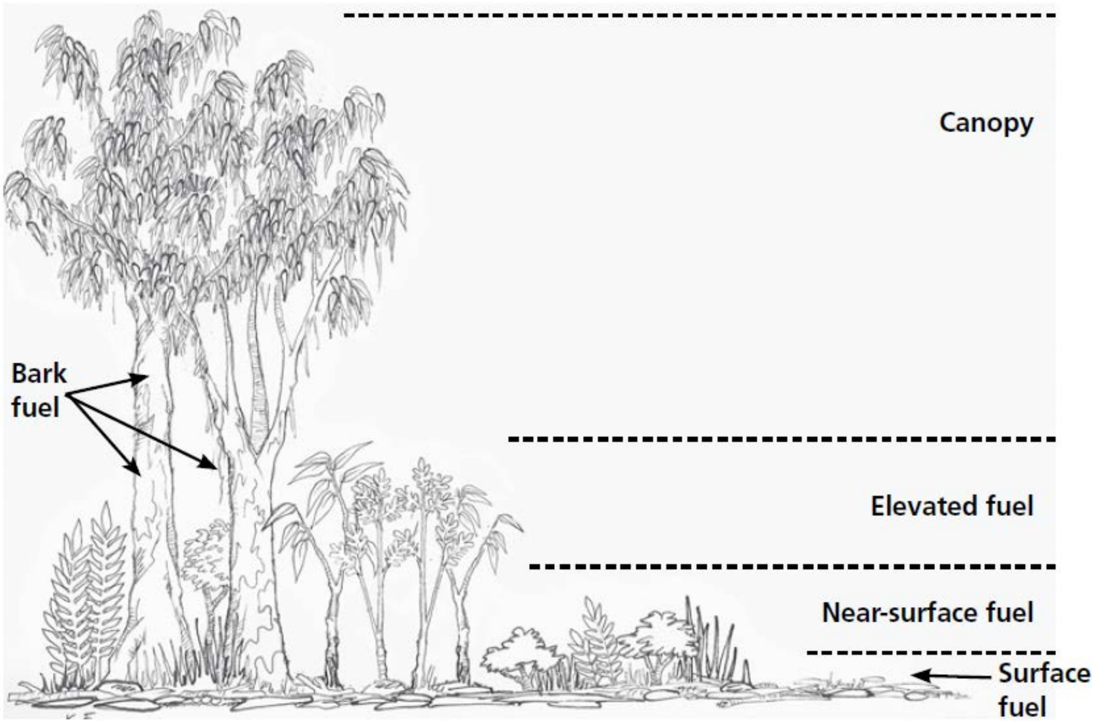

Figure 41 Fuel hazard assessment components (Hines et al. 2010)

The first component is *surface fuel hazard*, which is determined using estimates of litter cover and litter depth.

The second component is *near surface fuel hazard*, which is determined using estimates of live and dead ground vegetation cover.

These two components are combined into an overall surface fuel hazard category.

The third component is *elevated fuel hazard*, which is determined using estimates of live and dead elevated vegetation cover.

The fourth component is *bark fuel hazard* (all plots were in the low to moderate category).

All four components are combined into an *overall fuel hazard category*.

Results for overall fuel hazard are presented first, and then the other four components are presented in order below. The underpinning data (litter, vegetation cover, etc.) is reported prior to the hazard assessment for each component.

The Hines et al. (2010) method specifies subjective evaluation of categories for some aspects of fuel hazard assessment; for example, distinguishing between ‘Soil surface occasionally visible through litter bed’ or ‘Litter well connected. Little bare soil’. Where possible, these subjective assessments have been replaced with objective quantitative categories, detailed below.

6.1 Overall fuel hazard

Key result	No effect of ecological thinning on overall fuel hazard

Data collection

Data were collected from three 0.04 hectare subplots per 9 hectare treatment plot for all components of fuel hazard assessment in accordance with Hines et al. (2010).

Overall fuel hazard is determined from the hazard assessments of four components of fuel hazard: combined surface and near surface hazard category and the elevated fuel hazard category (Table 18). Bark hazard was in the low to moderate category on all plots. The analyses and results for all other components are described in following sections, below.

Overall fuel hazard is scored on a scale with five categories, from low to extreme (Table 18).

Table 18 Overall fuel hazard assessment categories (from Hines et al. 2010)
L = Low, M = Moderate, H = High, VH = Very High, E = Extreme

1	2	3 Combined surface and near surface fuel hazard				
Bark hazard	**Elevated fuel hazard**	**L**	**M**	**H**	**VH**	**E**
Low and moderate	L	L	M	M	H	H
	M	L	M	M	H	H
	H	L	M	H	VH	VH
	VH	VH	VH	VH	VH	VH
	E	E	E	E	E	E

Data summary

The proportion of 9 hectare plots in each of the overall fuel hazard categories is shown in the bottom row of each site quality panel in Figure 42.

In both site qualities all treatment types generally have very similar proportions of plots in the high and moderate categories, with slight increases in the proportion of plots in the high category over time. There are a few records of low and very high fire risk.

Figure 42 Proportion of 9 hectare treatment plots in each fuel hazard assessment category, by survey year and site quality (SQ1 and SQ2)

Model results

A Bayesian cumulative ordinal model was run to determine whether there were any differences among thinning treatments in the probability of being in any overall fuel hazard categories over time, and whether any differences depended on site quality (Table 19).

There was no evidence for difference in probability of being in a particular overall fire risk category among thinning treatments.

There was a higher probability (approximately 0.8) of being in the high category in 2018 and 2019 than 2015; with a corresponding decrease in the probability of being in the moderate category (Figure 43).

Table 19 Model summary for probability of being in each of the overall fuel hazard categories

Response	Family	Link	Effect of year	Effect of thinning treatment	Effect of site quality	Confidence
Probability of overall fuel hazard category	Ordinal categorical (continuation ratio)	Logit	Higher in 2018 and 2019 (more plots in the high category)	No effect of thinning	No effect of site quality	Low

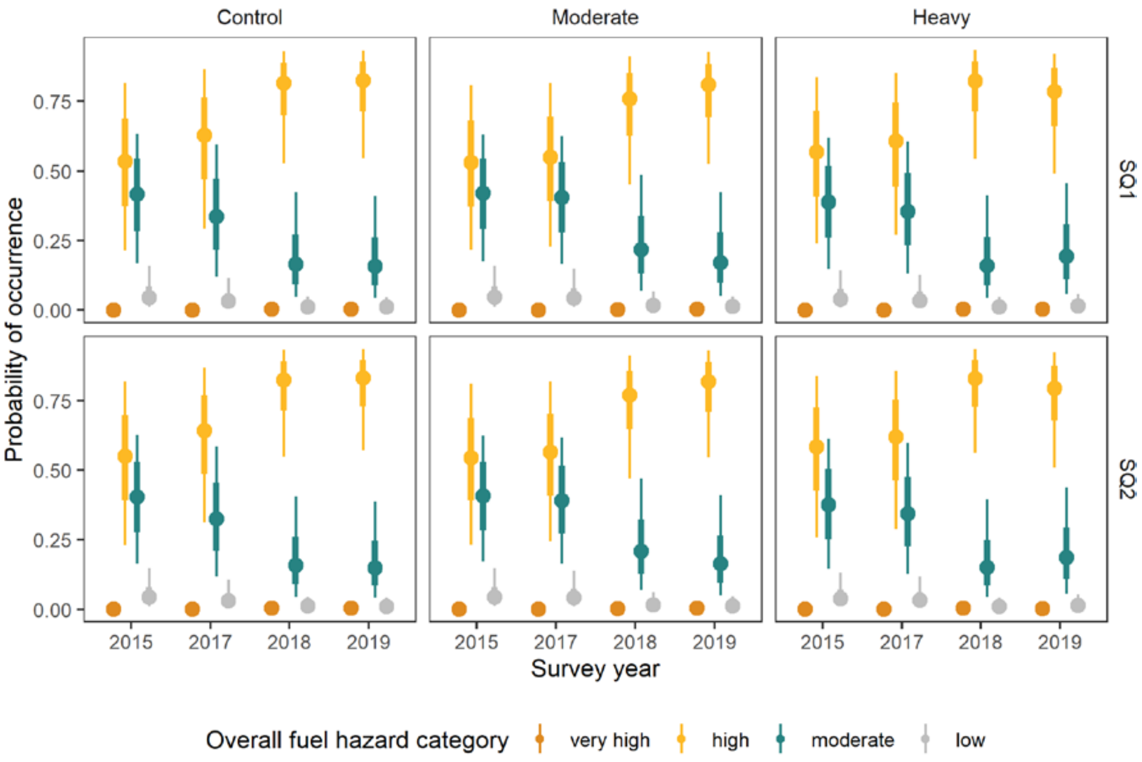

Figure 43 Modelled probability of being in each of the overall fuel hazard categories with 50% and 95% credible intervals, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

6.2 Surface fuel hazard: litter depth

Key result	No effects of ecological thinning on litter depth

Data collection

Litter was defined as any dead plant material that was separated from a live plant and included material <1 millimetre in diameter. Note that the definition of litter was refined between 2015 and 2018, which reduced uncertainty in observer estimates.

Litter depth was measured using the method of Hines et al. (2010). A metal ruler was inserted through the litter until it rested on the soil. A cardboard disc was held gently against the litter and used to mark the height of the litter on the ruler.

Litter depth was measured in 10 locations in each 0.04 hectare plot, giving 30 values per 9 hectare plot, which were averaged.

Data summary

The distributions of average litter depth values were very similar across treatments, years and site qualities (Figure 44, Figure 45). Average values were approximately 15–20 millimetres.

No trends in litter depth over time were apparent.

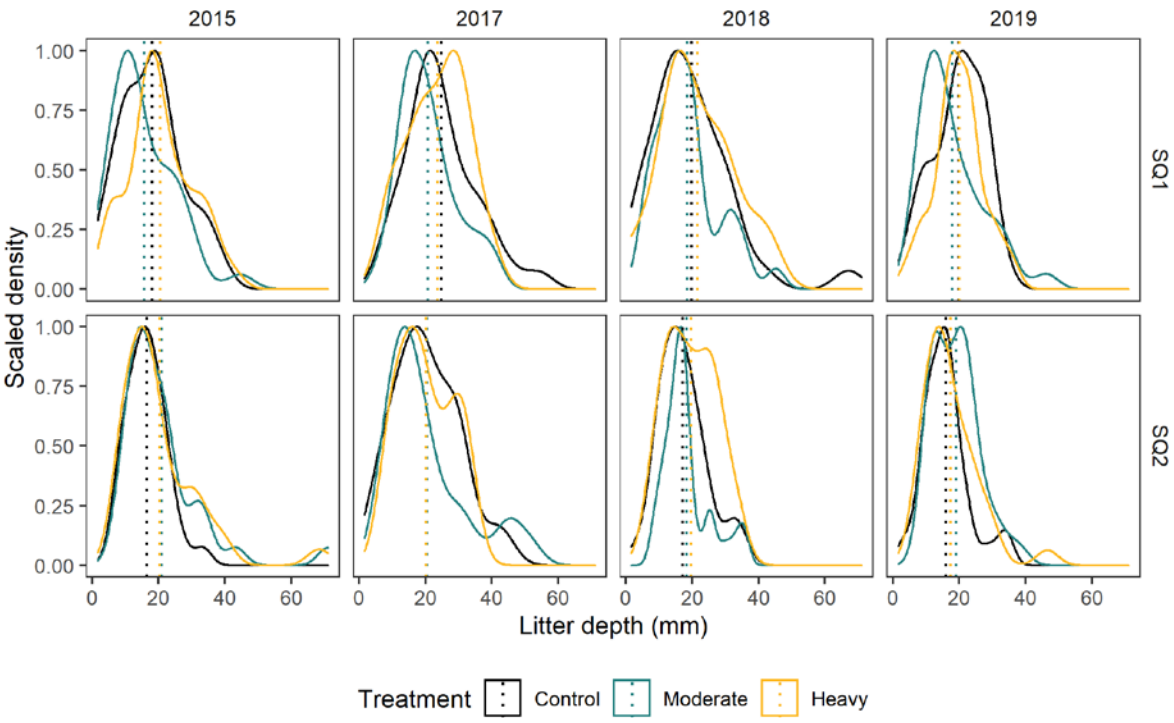

Figure 44 Density plots and averages (dotted lines) of litter depth (average per 9 hectare plot, in millimetres) by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

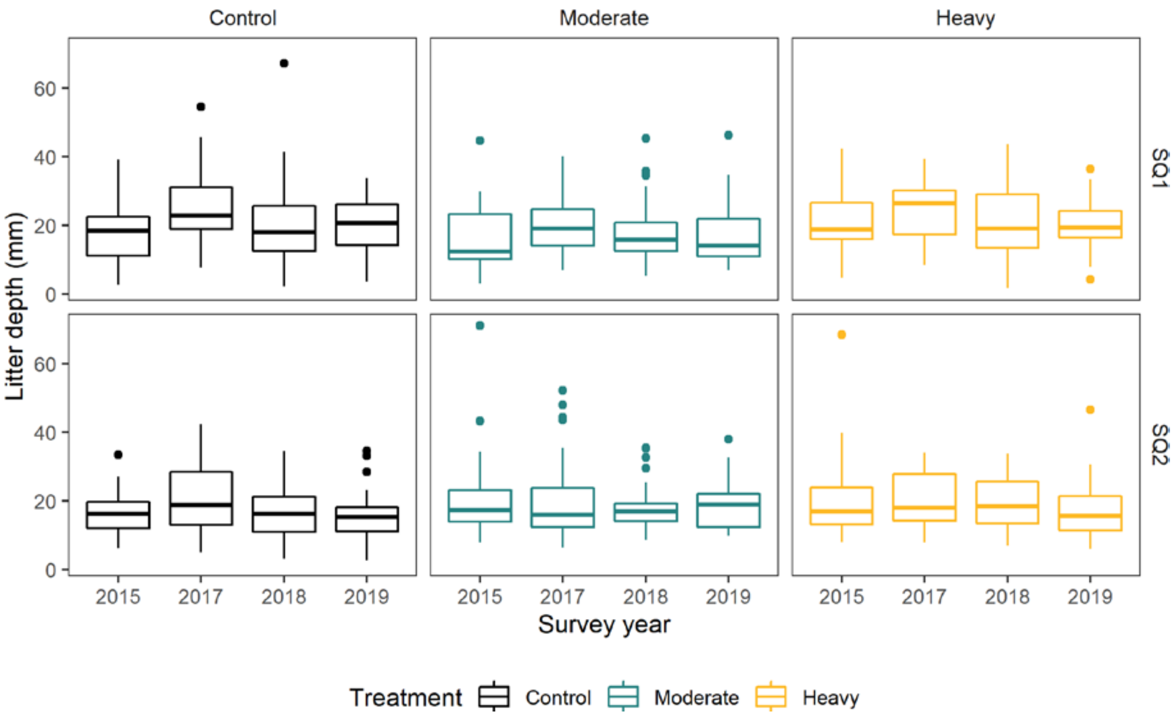

Figure 45 Boxplots of litter depth (average per 9 hectare plot, in millimetres), by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

Model results

A gaussian model was run to determine whether there were significant differences between control and thinned plots in average litter depth over time, and whether any differences depended on site quality (Table 20).

There was very weak evidence that values were elevated by approximately 1.5 millimetres in 2017, and 1 millimetre in moderately thinned plots in Site Quality 2 (Figure 46); however, these effects were not supported by bootstrapped confidence intervals.

Table 20 Model summary for litter depth

Response	Family	Link	Effect of year	Effect of thinning treatment	Effect of site quality	Confidence
Litter depth (mm) (log)	Gaussian	None	Slightly higher (1 mm) in 2017	Slightly higher (about 1 mm) in moderately thinned plots in Site Quality 2 (bootstrapped interval includes zero)		Moderate R^2 = 18.7% Slight deviation from uniformity

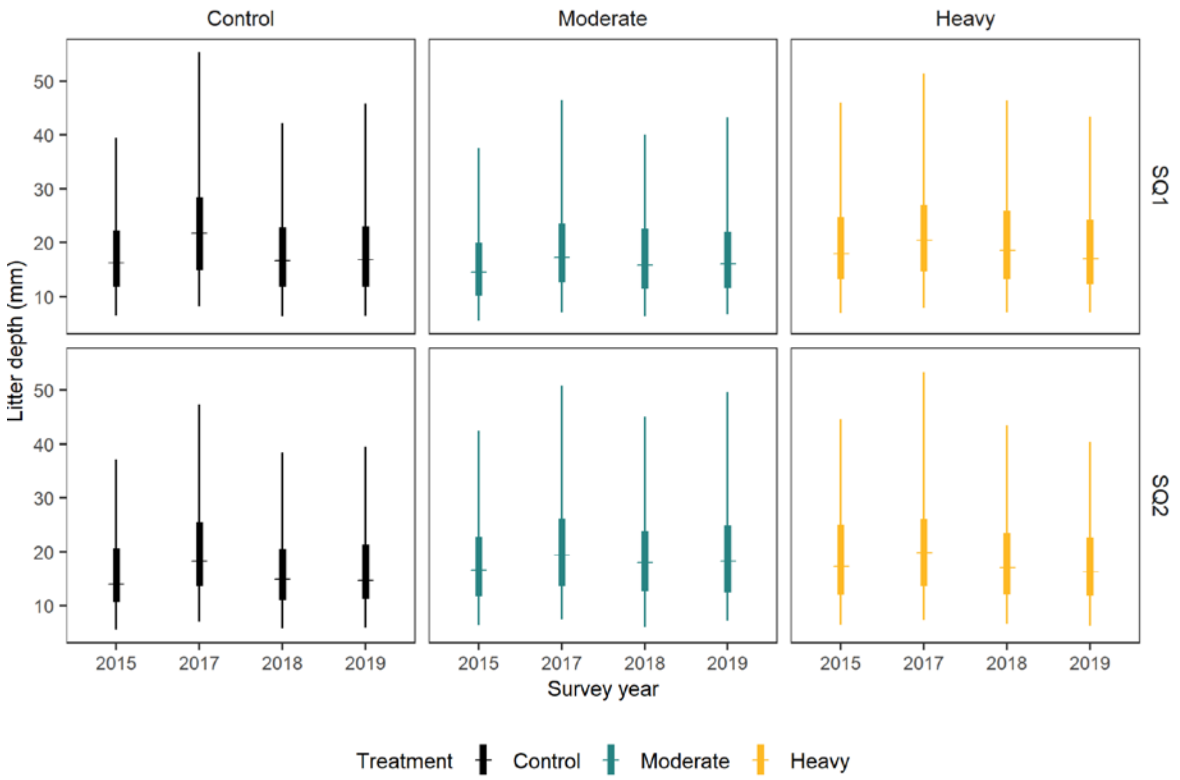

Figure 46 Modelled average litter depth (millimetres) with 50% and 95% bootstrapped confidence intervals, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

Plate 2 Two variants of litter in river red gum forest

Photos: Emma Gorrod.

6.3 Surface fuel hazard: litter cover

Key result	No effects of ecological thinning on litter cover

Data collection

Litter was defined as any dead plant material that was separated from a live plant and included material <1 millimetre in diameter. Note that the definition of litter was refined between 2015 and 2018, which reduced uncertainty in observer estimates.

Litter cover was visually estimated in three 0.04 hectare subplots in each 9 hectare treatment plot, and averaged.

Data summary

The coverage of litter increased on all treatments between 2015 and 2018 in both site quality classes and there were no differences among thinning treatments (Figure 47, Figure 48). This result is partly due to the refinement of the definition of leaf litter.

Litter cover estimates are most frequently 85–95% on all thinning treatments in both site qualities. There were few differences in the average and commonly recorded values of litter cover between 2018 and 2019, with the exception of slight increases in the median on drier Site Quality 2 control and heavily thinned plots (Figure 48).

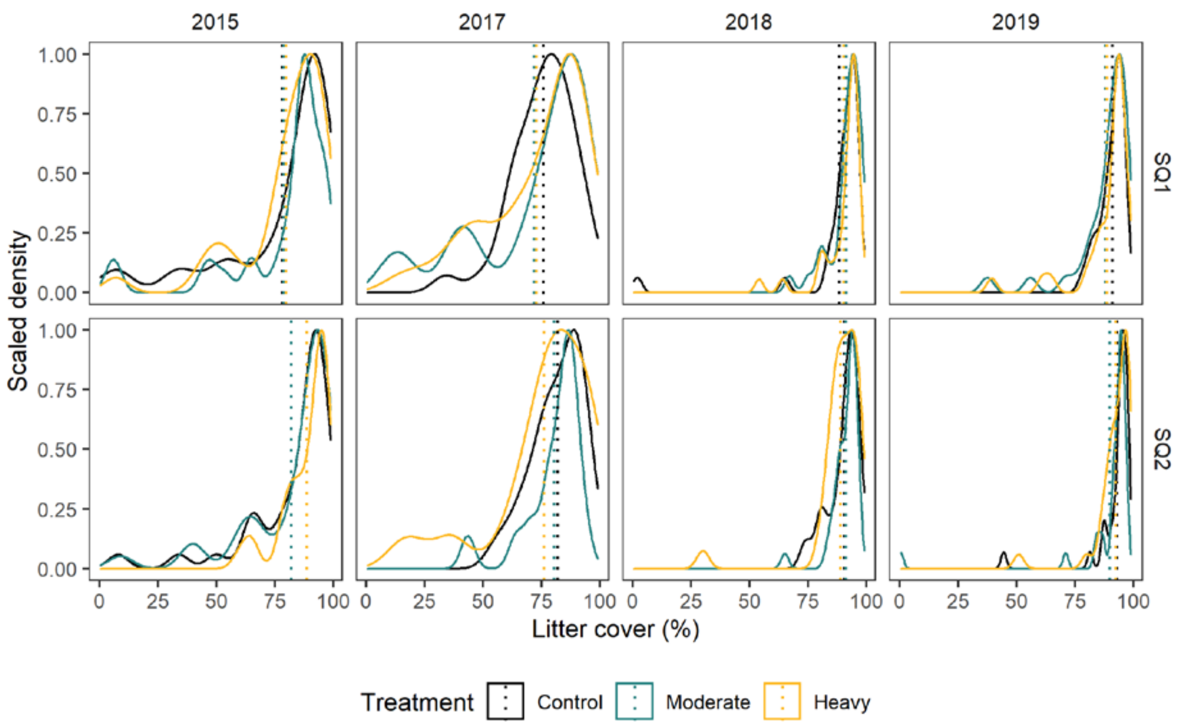

Figure 47 Density plots and averages (dotted lines) of litter cover (%, averaged per 9 hectare plot), by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

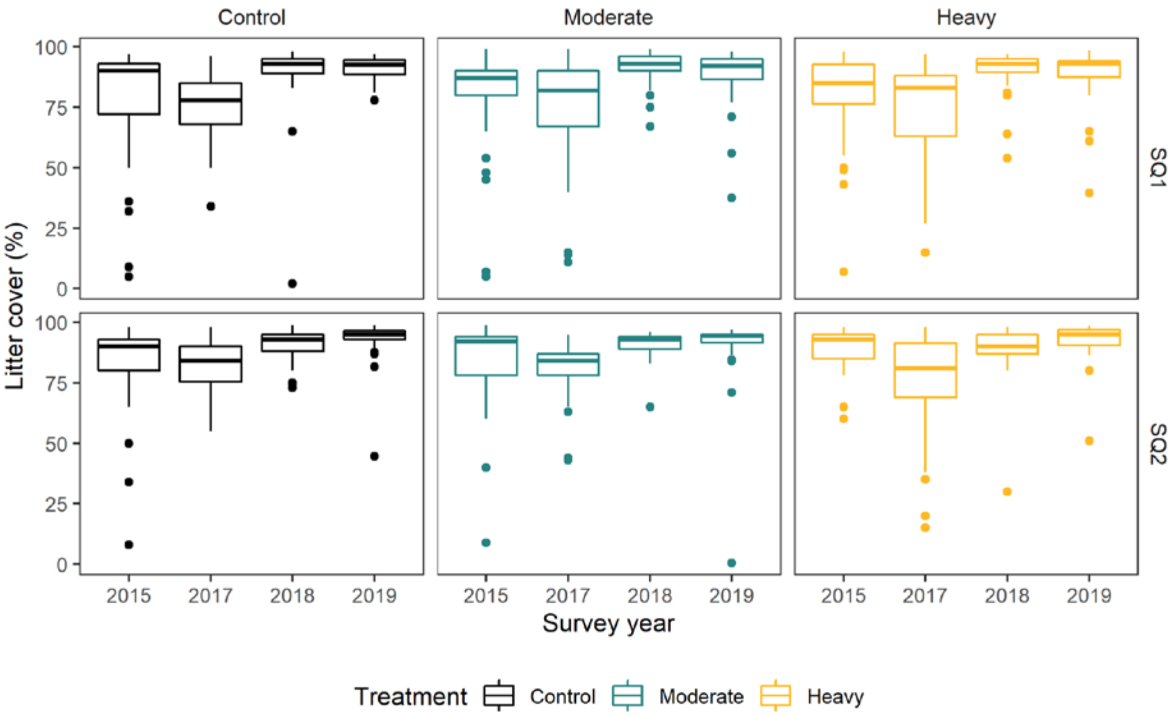

Figure 48 Boxplots of average litter cover (%) per 9 hectare plot, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

Model results

The percentage cover of litter was modelled using a beta regression (after trialling multiple transformations and error distributions) but model fit was poor (Table 21). Therefore, confidence in the modelled values was low.

No significant differences were detected among thinning treatments (Figure 49). Modelled litter cover in 2018 (78–91%) and 2019 (81–92%) was higher than 2015 (83–89%).

Table 21 Model summary for litter cover

Response	Family	Link	Effect of year	Effect of thinning treatment	Effect of site quality	Confidence
Litter cover %	Beta	Logit	Higher litter cover in 2018 and 2019 by <1%	No effect of thinning treatment	No effect of site quality	Low, failed assumptions of uniformity and dispersion

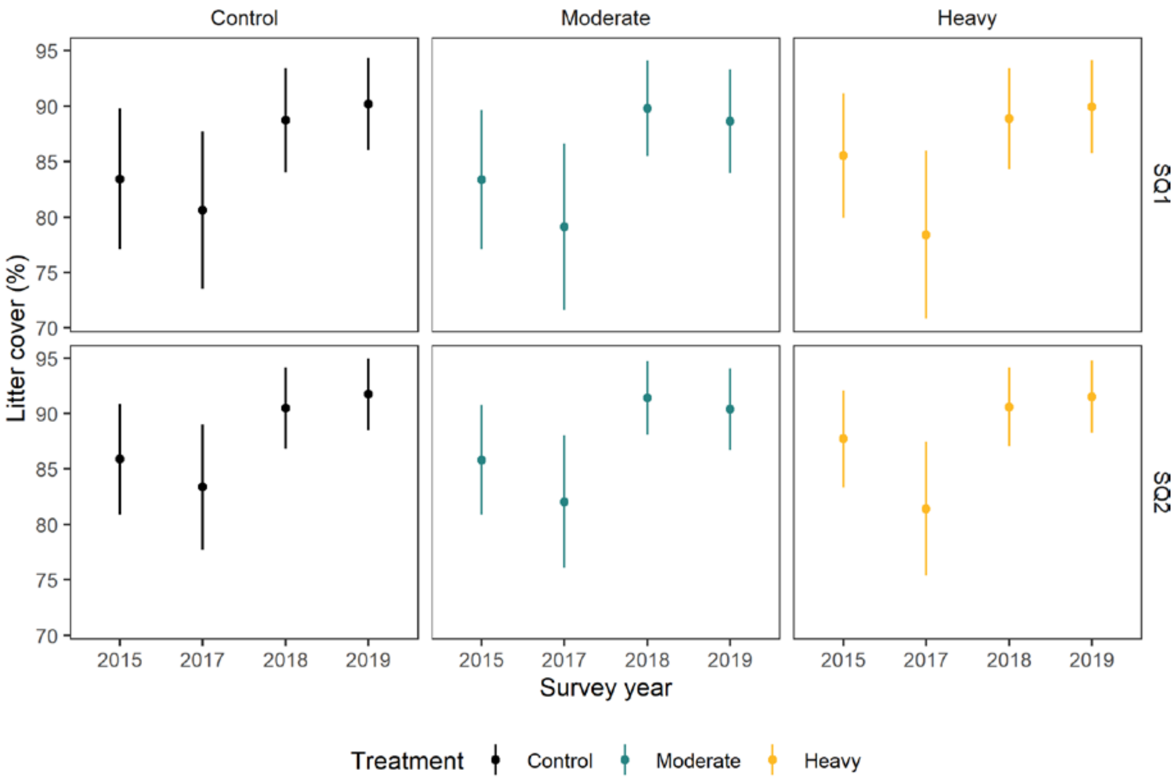

Figure 49 Modelled average litter cover (%), showing fit and standard errors, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

6.4 Surface fuel hazard assessment

Key result	No effects of ecological thinning on surface fuel hazard

Data collection

The surface fuel hazard category is determined based on litter depth and litter cover data (described in previous sections).

The categories for assessing surface fuel hazard defined by Hines et al. (2010) are not comprehensive (grey cells in Table 22). For instance, Hines et al. (2010) define surface fuel hazard as low when litter depth is <10 millimetres and litter cover <60%; and moderate when litter depth is 10–20 millimetres and litter cover is 60–80%. A category is not explicitly defined for sites with litter depth of <10 millimetres but litter cover >80%. Additional categories were therefore defined to enable objective classification of all data (white cells in Table 22).

Table 22 Surface fuel hazard assessment categories (adapted from Hines et al. 2010)

Grey cells are defined by Hines et al. (2010), white cells are additionally defined to enable classification of all data.

Litter height (mm)	Litter cover (%)				
	<60	60–80	80–90	>90	>95
<10	L	L	M	M	M
10–20	L	M	M	H	H
20–25	M	M	H	H	VH
25–30	M	H	H	VH	VH
30–35	H	H	VH	VH	VH
35–45	H	VH	VH	VH	E
>45	VH	VH	E	E	E

Data summary

In control plots, the proportion of plots among categories was almost the same as the previous year in both site qualities, but with no plots in the extreme category in Site Quality 1 and fewer plots in the very high category in SQ2 (Figure 42, above).

The proportion of moderately thinned plots in the extreme category reduced in Site Quality 1 between 2018 and 2019, but in Site Quality 2 the proportion in the very high category increased.

Fewer heavily thinned plots were in both the low and very high categories in Site Quality 1 in 2019 compared with 2018; while the proportion of plots among categories was almost identical for the two years in Site Quality 2.

Model results

A Bayesian ordinal regression was run to determine whether the probability of being in each surface fuel hazard category differed among thinning treatments over time, and whether differences depended on site quality (Table 23).

No effects of ecological thinning were detected (Figure 50). The probability of plots being in the very high category has increased over time in all treatments and both site qualities.

Table 23 Model summary for probability of being in each of the surface fuel hazard categories

Response	Family	Link	Effect of year	Effect of thinning treatment	Effect of site quality	Confidence
Probability of surface fuel hazard category	Ordinal categorical (continuation ratio)	Logit	Higher probability of being in the very high category in 2018	No effect of thinning	No effect of site quality	Moderate

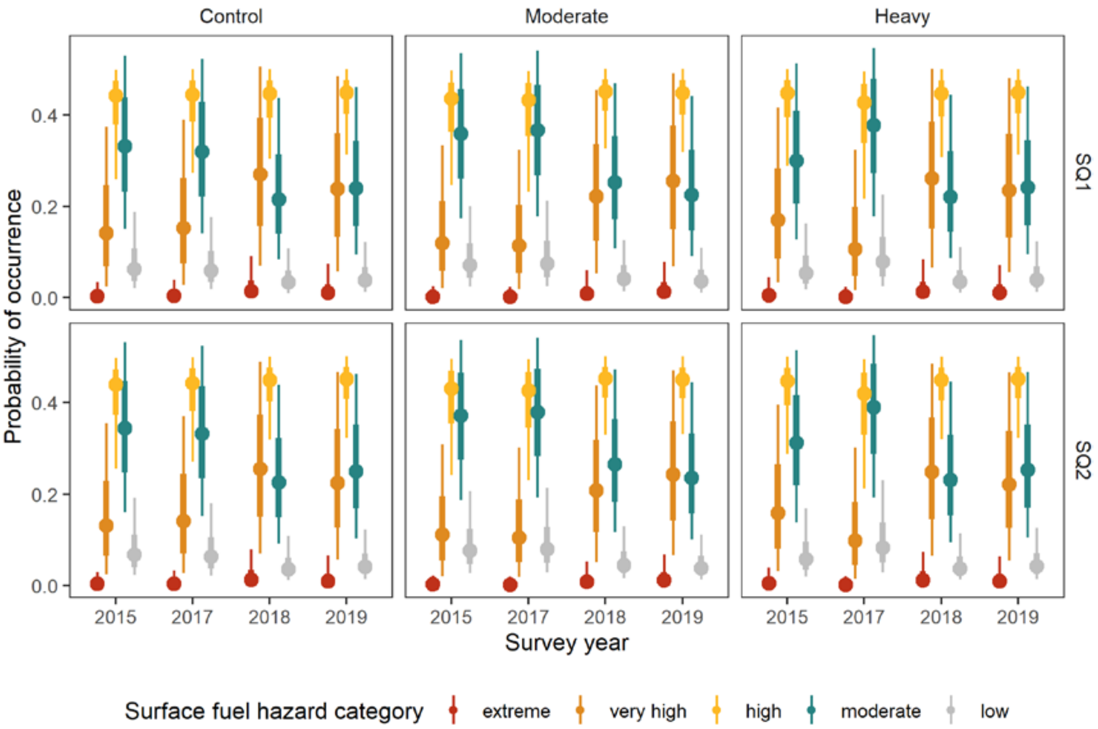

Figure 50 **Modelled probability of being in each of the surface fuel hazard categories with 50% and 95% credible intervals, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)**

6.5 Near surface fuel hazard: live near surface vegetation cover

Key result	No effect of thinning on live near surface vegetation cover

Data collection

Near surface vegetation is vegetation that is generally between 0 and 1.5 metres in height. Live and dead near surface vegetation cover are visually estimated independently by two observers who then confer to record one estimate for each. Estimates in three 0.04 hectare plots are averaged within each 9 hectare plot.

Data summary

For control and thinned plots, the most commonly recorded and average live near surface vegetation estimates have declined over time, likely a result of generally dry hydroclimatic conditions in 2018 and 2019 (Figure 51, Figure 52).

The distribution of live near surface cover values in 2019 was very similar among control and thinned plots, with a narrower peak in Site Quality 2.

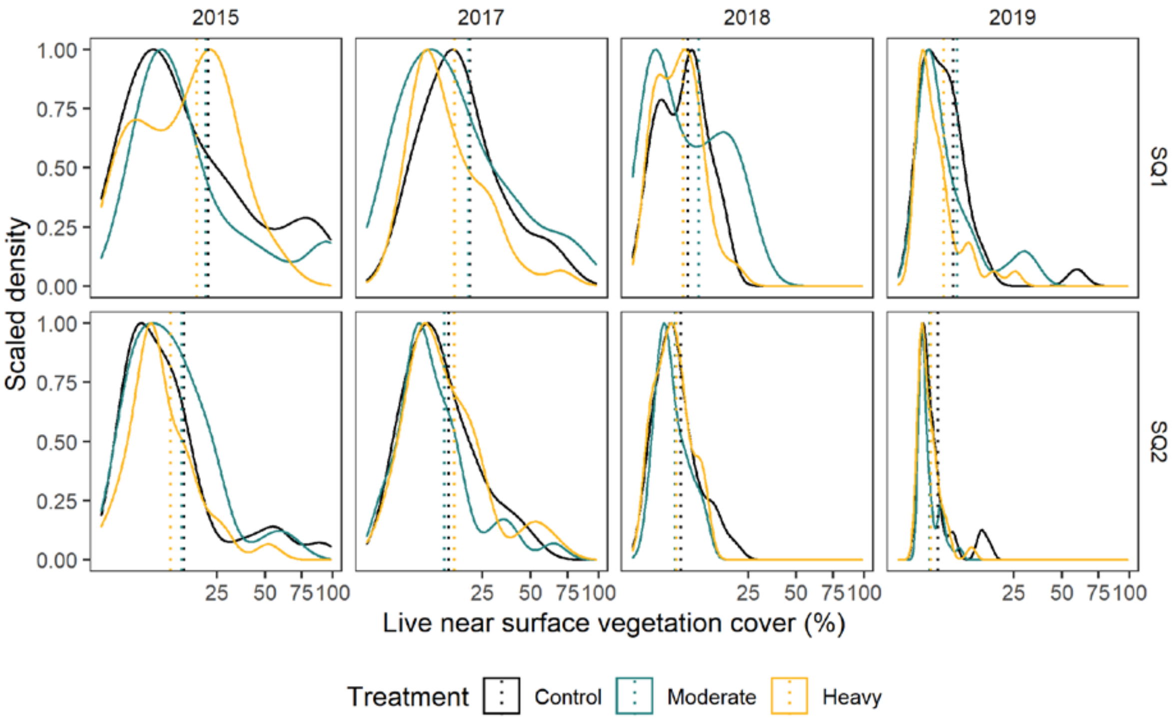

Figure 51 Density plots and averages (dotted lines) of live near surface vegetation cover (%), by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

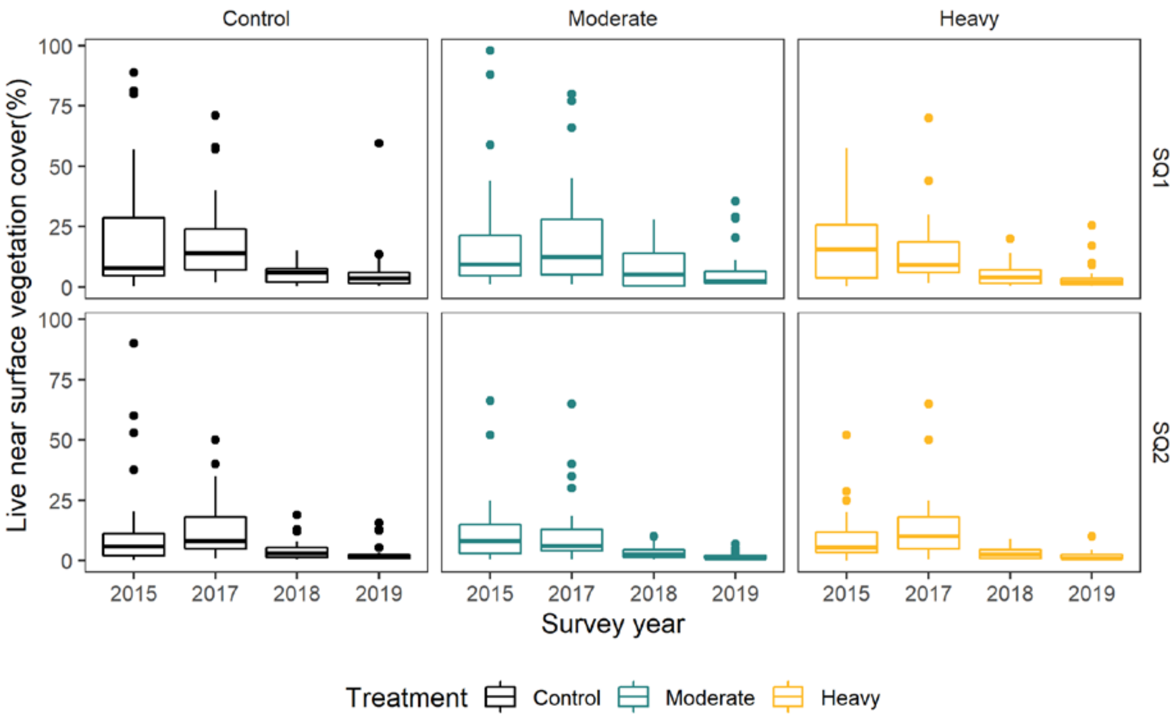

Figure 52 Boxplots of near surface live vegetation cover (%), by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

Model results

A gaussian model was run to determine whether there were differences in near surface live cover among thinning treatments over time, and whether any differences depended on site quality (Table 24, Figure 53).

No effect of thinning treatment was detected.

Live near surface vegetation was significantly lower in 2018 and 2019 than 2015.

Live near surface vegetation cover was very low on both site qualities in 2019: approximately 3% in Site Quality 1 sites and 3% in Site Quality 2 sites. This difference was statistically significant.

Table 24 Model summary for live near surface cover

Response	Family	Link	Effect of year	Effect of thinning treatment	Effect of site quality	Confidence
Near surface live cover (%) (log)	Gaussian	None	Lower (by about 5%) in 2018 and 2019 than 2015	No effect of thinning treatment	Slightly lower in Site Quality 2 (<1%)	Moderate – High R^2 = 42.9%

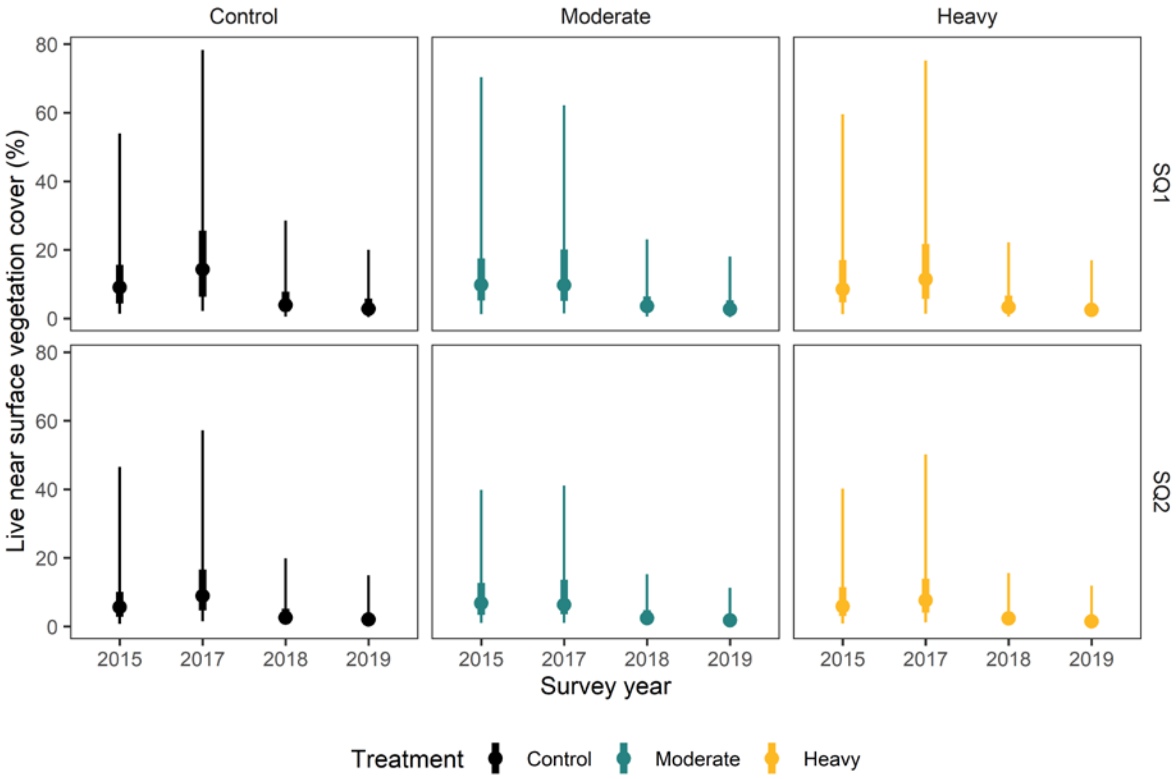

Figure 53 **Modelled live near surface vegetation cover (%, averaged for 9 hectare plot) with bootstrapped 50% and 95% confidence intervals, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)**

Plate 3 **Near surface vegetation in river red gum forest**
Photo: Emma Gorrod.

6.6 Near surface fuel hazard: dead near surface vegetation cover

Key result	No effect of thinning treatment on dead near surface vegetation cover

Data collection

Near surface vegetation is generally between 0 and 1 metre in height. Dead near surface vegetation is defined as dead material that is attached to a live plant. Dead near surface vegetation cover is visually estimated independently by two observers who then confer to record one estimate. Estimates in three 0.04 hectare plots are averaged within each 9 hectare plot.

Data summary

The distribution of recorded values for dead near surface vegetation was similar among control and thinned plots in 2019, in both site qualities (Figure 54, Figure 55).

In comparison to 2018, a slightly narrower range of values were recorded in 2019.

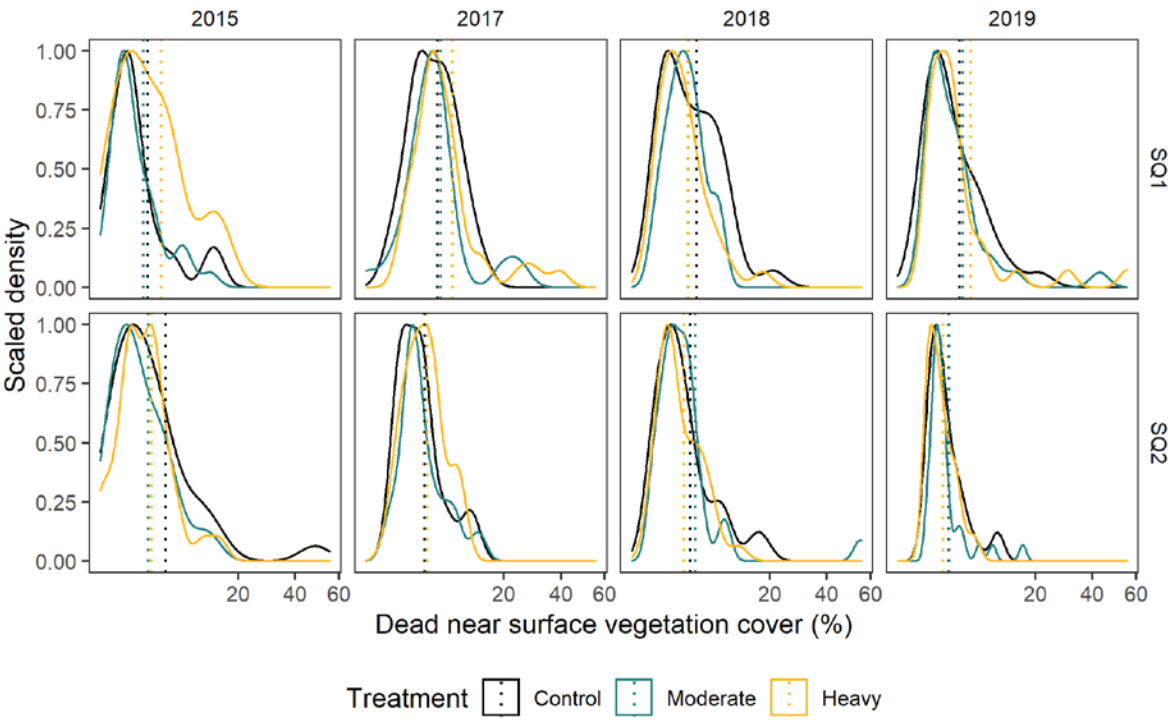

Figure 54 Density plots and averages (dotted lines) of dead near surface vegetation cover (%, averaged for 9 hectare plot), by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

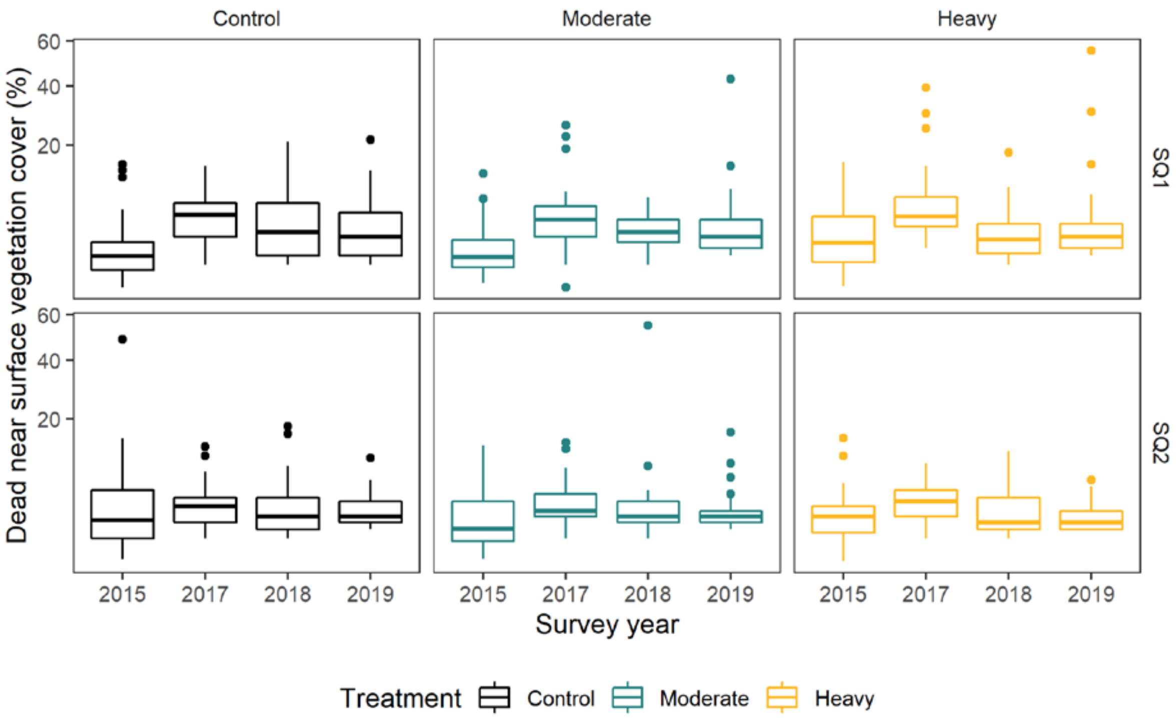

Figure 55 Boxplots of dead near surface vegetation cover (%), by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

Model results

A gaussian model was run for dead near surface vegetation cover (Table 25). The model did not meet all of the model assumptions, with high error for the lowest cover values.

Dead near surface cover in heavily thinned treatments in 2018 were identified as marginally significantly lower (<1%) in the initial model, but bootstrapping did not support the result as statistically significant. No other effects of thinning treatment were detected.

Dead near surface cover was higher in all post-thinning years than 2015 (Figure 56). This result was statistically significant, but the magnitude was small. Fitted values in 2015 were 1% on all treatments and in 2019 they were 2–2.5%.

Table 25 Model summary for dead near surface cover

Response	Family	Link	Effect of year	Effect of thinning treatment	Effect of site quality	Confidence
Dead near surface vegetation cover (%) (log)	Gaussian	None	Lower (<2%) in 2015	No effect	No effect of site quality	Moderate R^2 = 28.5% Failed uniformity assumption, and some outliers

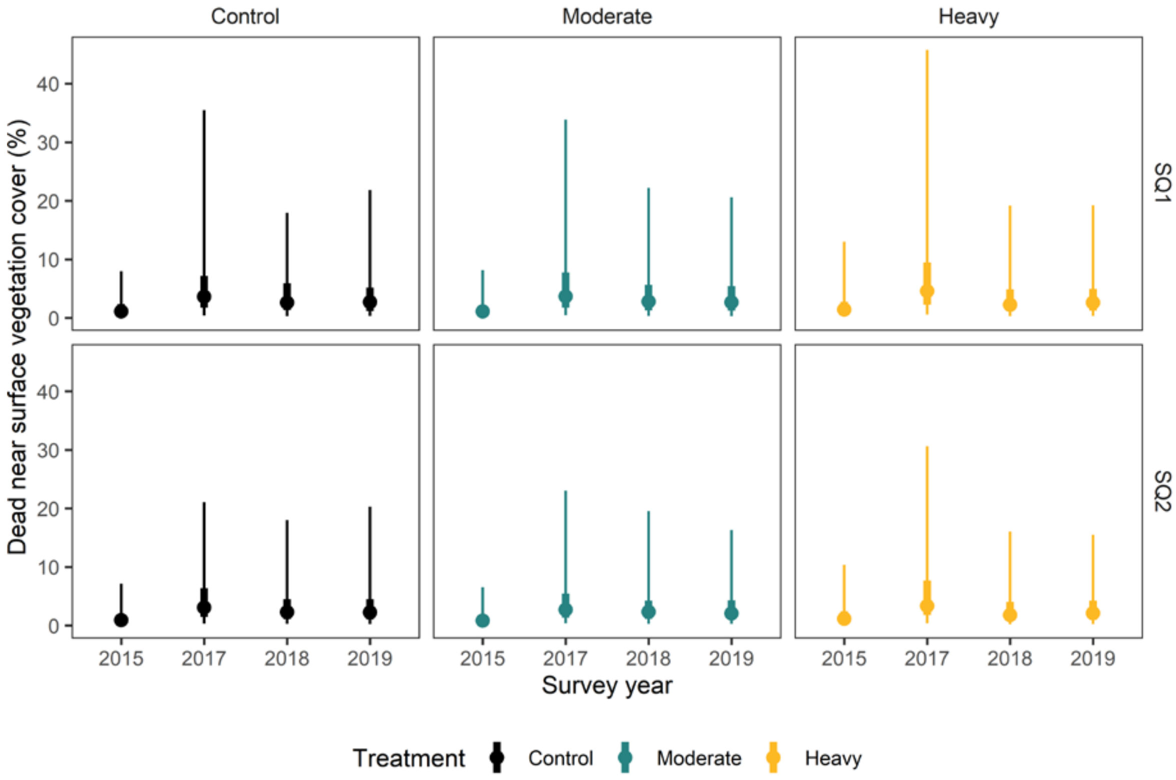

Figure 56 Modelled dead near surface vegetation cover (%, averaged for 9 hectare plot) with bootstrapped 50% and 95% confidence intervals, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

6.7 Near surface fuel assessment

Key result	Heavily thinned plots had a lower probability of being in the high category than other treatment types in 2019

Data collection

As described for surface fuel assessment, the near surface fuel assessment categories defined by Hines et al. (2010) are not comprehensive (grey cells in Table 26). Additional categories were defined to objectively allocate all data to a near surface fuel hazard category (white cells in Table 26).

Near surface fuel assessment is based on total near surface vegetation cover (i.e. live plus dead cover described in the previous two sections), and the proportion of total cover that is dead (i.e. dead cover divided by total cover).

Table 26 Near surface fuel assessment categories (adapted from Hines et al. 2010)
Grey cells are defined by Hines et al. (2010), white cells are additionally defined to enable classification of all data.

Proportion dead cover	Total near surface plant cover (%)				
	<10	10–20	20–40	40–60	>60
<10	L	M	M	M	M
10–20	L	M	M	H	H
20–30	L	H	H	H	VH
30–50	M	H	H	VH	VH
>50	M	H	H	VH	E

Data summary

The proportion of control plots in each near surface fuel assessment category moved in different directions for the different site qualities between 2018 and 2019: in Site Quality 1 more plots were in the moderate and fewer in the low category than last year; and in Site Quality 2 more plots were in the moderate and fewer in the high category than last year (Figure 42, above).

In both site qualities, more moderately thinned plots were in the moderate than high categories in 2019 than 2018, however, a small number of plots moved into the very high category in Site Quality 1.

More heavily thinned plots in Site Quality 1 were in the moderate category in 2019 than 2018 and a small number moved into the very high and extreme categories; and in Site Quality 2 almost all plots were in the moderate category in 2019.

Model results

A Bayesian ordinal categorical model was run to determine whether the probability of being in each near surface fuel hazard category differed among thinning treatments over time and whether any differences depended on site quality (Table 27).

Heavily thinned plots in 2019 had a slightly lower probability of being in the high category for near surface fuel assessment than moderately thinned or control plots (Figure 57). In 2019 all control and thinning treatments were most likely to be in the moderate near surface fuel hazard category.

Table 27 Model summary for near surface fuel hazard category

Response	Family	Link	Effect of year	Effect of thinning treatment	Effect of site quality	Confidence
Probability of each near surface fuel hazard category	Ordinal categorical (continuous ratio)	Logit	Lower probability of being in the high category in 2015	Lower probability of being in the high category in heavy treatment in 2019	No effect of site quality	Moderate

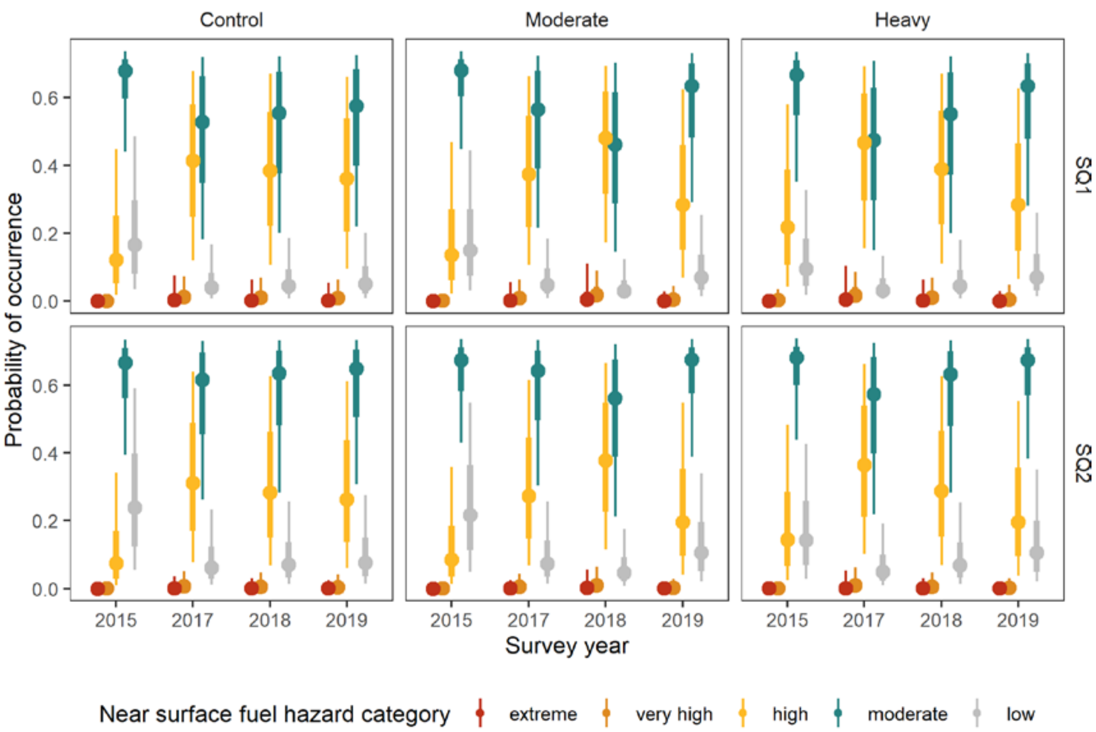

Figure 57 Modelled probability of being in each of the near surface fuel hazard categories with 50% and 95% credible intervals, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

6.8 Combined surface and near surface fuel hazard

Key result	No effect of ecological thinning on combined surface and near surface fuel hazard

Data collection

The surface and near surface fuel hazard categories are combined to determine a combined surface hazard category. All categories are defined by Hines et al. (2010) (Table 28).

Table 28 Combined surface and near surface fuel hazard assessment categories (from Hines et al. 2010)

Surface risk	Near surface risk				
	L	**M**	**H**	**VH**	**E**
L	L	L	M	H	VH
M	M	M	H	VH	E
H	H	VH	VH	VH	E
VH	VH	VH	E	E	E
E	E	E	E	E	E

Data summary

The proportion of control plots in different combined surface and near surface risk categories was very similar between 2018 and 2019 (Figure 42, above).

Fewer moderately thinned plots in Site Quality 1 were in the extreme category in 2019 than 2018 (with more in the very high and moderate categories); in Site Quality 2 more plots were in the very high category in 2019 than 2018 (with fewer in the extreme, high and moderate categories).

A higher proportion of heavily thinned plots in Site Quality 1 were in lower categories (more in the low and high categories); in Site Quality 2 a higher proportion were in higher categories in 2019 than 2018.

A small number of plots were allocated to the extreme category for combined surface and near surface fuel hazard in all years.

Model results

A Bayesian ordinal categorical model was run to determine whether the probability of being in each combined surface and near surface fuel hazard category differed among thinning treatments over time and whether any differences depended on site quality (Table 29).

There was no evidence of an effect of ecological thinning.

The probability of being in a higher category increased in 2018 and 2019 in comparison to 2015 (Figure 58). Across all years and treatments, the probability was highest for being in the very high category. The magnitude of the recent increase was slight (and the probability of being in the high category slightly declined).

Table 29 Model summary for combined surface fuel hazard

Response	Family	Link	Effect of year	Effect of thinning treatment	Effect of site quality	Confidence
Probability of each combined surface fuel hazard category	Ordinal categorical	Logit	Higher probability of being in the very high category in 2018 and 2019	No effect of thinning	No effect of site quality	Moderate

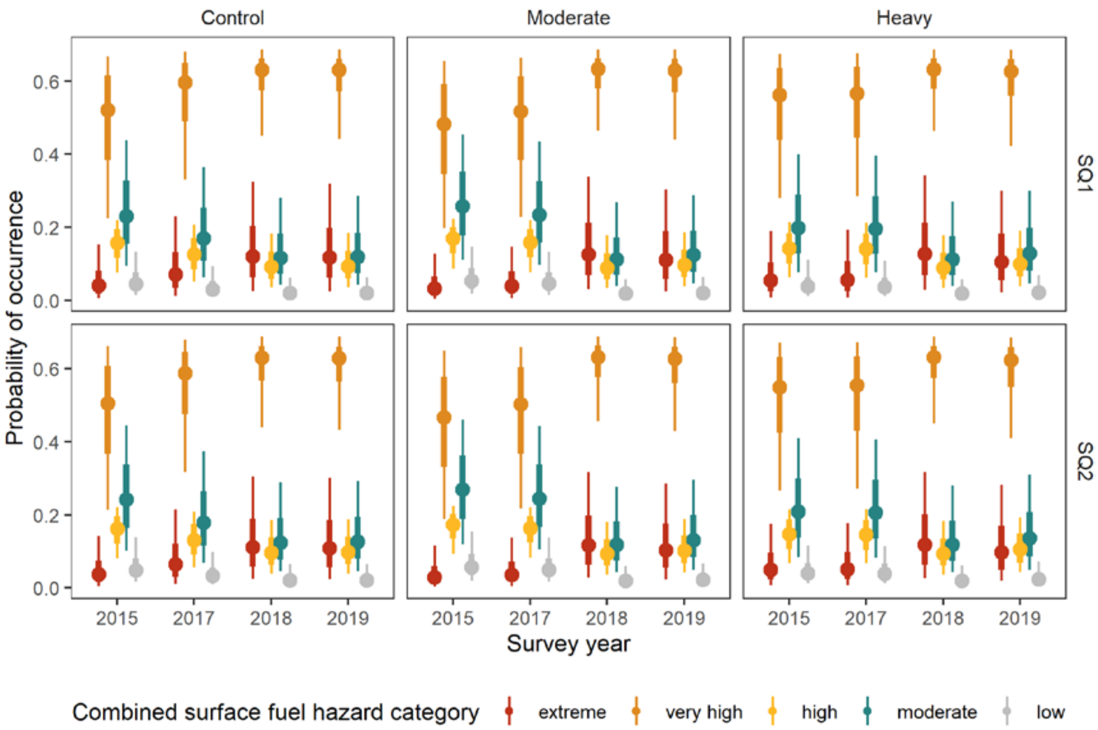

Figure 58 Modelled probability of being in each of the combined surface and near surface fuel hazard categories with 50% and 95% credible intervals, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

6.9 Elevated fuel hazard: live elevated vegetation cover

Key result	Live elevated vegetation cover was significantly lower in 2017 and 2018, but not in 2019

Data collection

Live elevated vegetation cover is assessed by visual estimation in three 0.04 hectare plots within each 9 hectare plot. In river red gum forest the elevated stratum consists almost exclusively of *Eucalyptus camaldulensis* saplings and small trees.

Data summary

The elevated stratum was directly impacted by thinning operations in thinned plots in 2017 (Figure 59, Figure 60).

In 2019, the most commonly recorded values of live elevated vegetation cover continued to be lower in thinned plots than control plots in Site Quality 1; however, the distributions became more similar among control and thinned plots in Site Quality 2.

Mean and median live elevated vegetation cover was generally higher in 2019 than the previous two surveys.

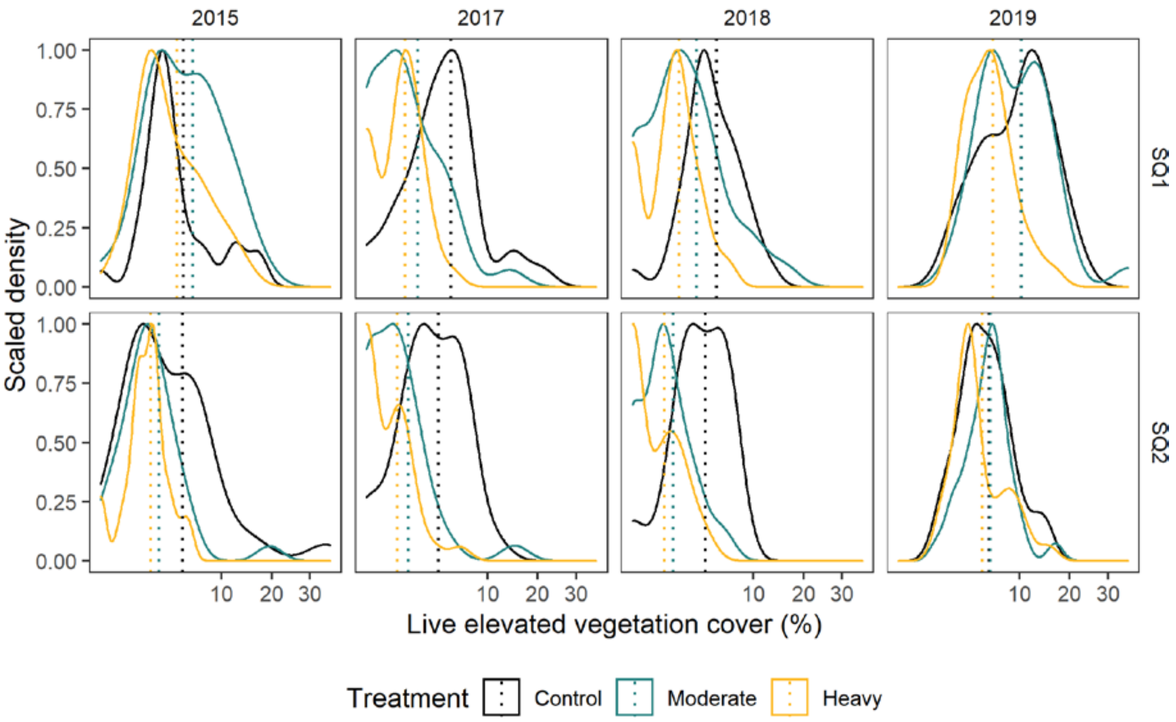

Figure 59 Density plots and averages (dotted lines) of live elevated vegetation cover (%, averaged per 9 hectare plot), by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

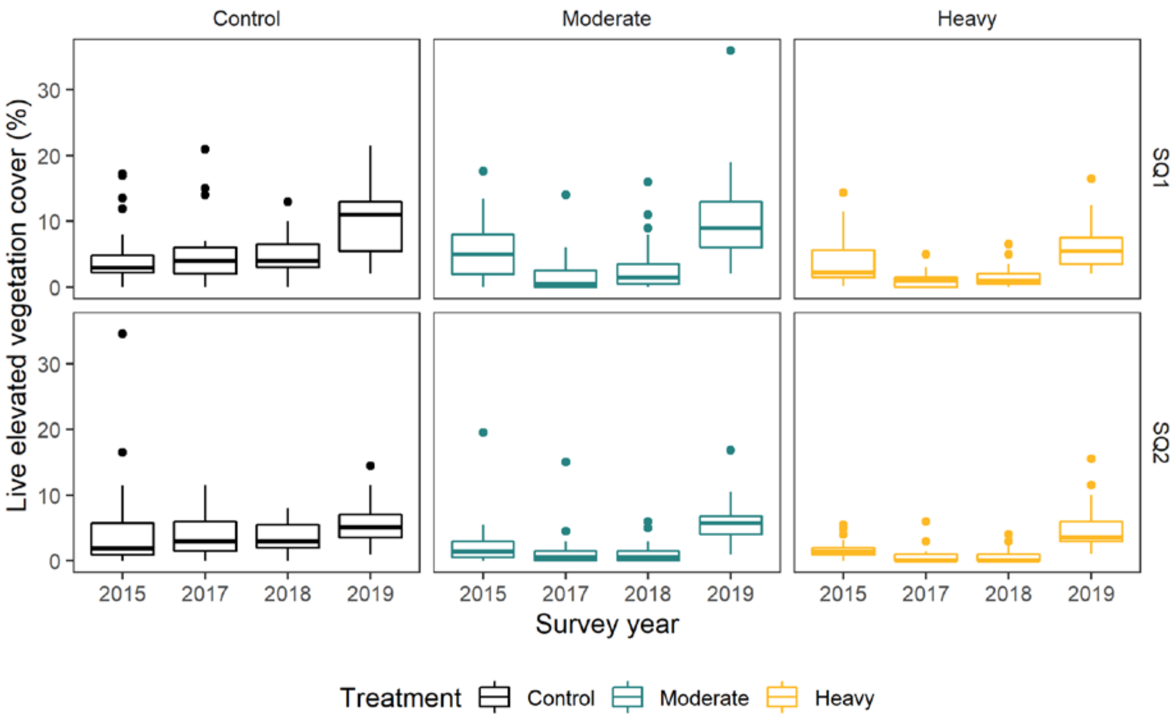

Figure 60 Boxplots of live elevated vegetation cover (%, averaged per 9 hectare plot), by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

Model results

A beta model was run to determine whether there were differences among thinning treatments over time in percent live vegetation cover, and whether any differences depended on site quality (Table 30, Figure 61).

Fitted values were significantly lower in both moderate and heavily thinned treatments in 2017 and 2018, but not 2019. This was the case for both site qualities.

Across all treatment types, elevated cover was higher in 2019 than previous years: fitted averages were 2–5% in 2015 and 4.5–9% in 2019.

Site Quality 2 plots had significantly lower averages than Site Quality 2 plots across all years, with a difference of approximately 3% in 2019.

Table 30 Model summary for live elevated vegetation cover

Response	Family	Link	Effect of year	Effect of thinning treatment	Effect of site quality	Confidence
Live elevated vegetation cover (%)	Beta	Logit	Higher in 2019 (3–4%) than 2015		Lower in Site Quality 2 (<1%)	Moderate to High Did not violate any assumptions
			Lower in thinning treatments in 2017 and 2018 (<1%)			

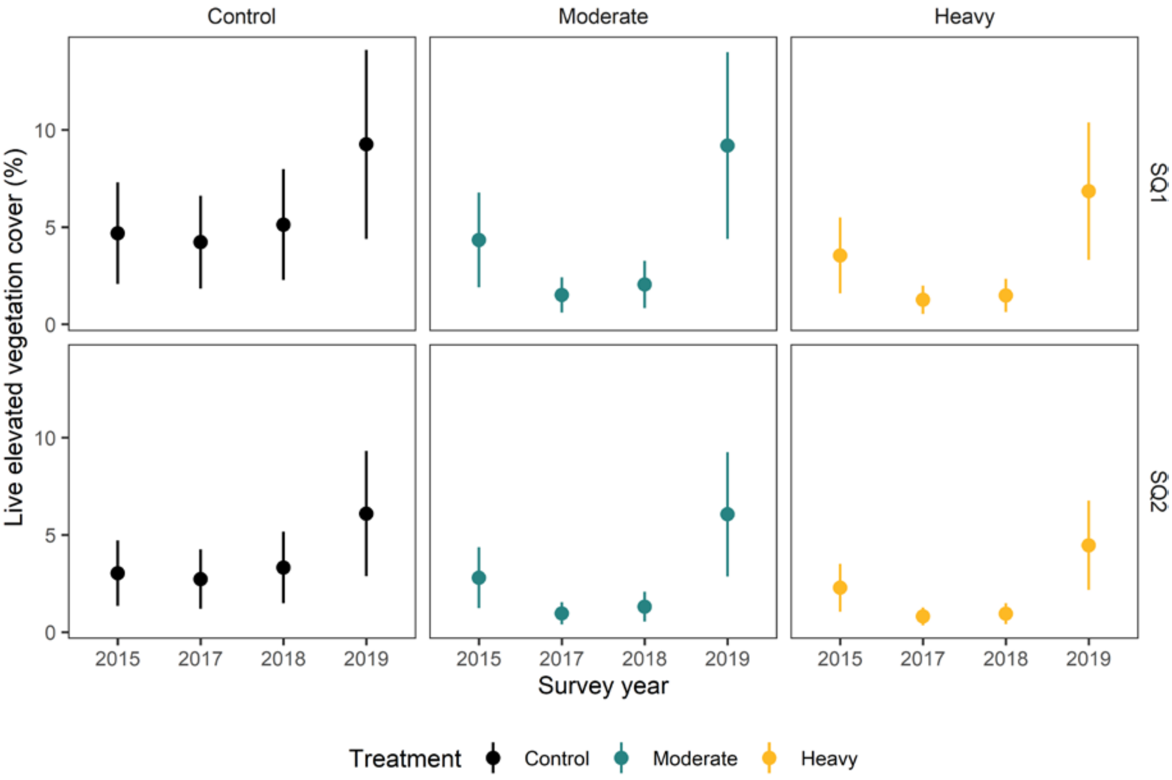

Figure 61 Modelled live elevated vegetation cover (%, averaged per 9 hectare plot) with standard errors, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

6.10 Elevated fuel component: dead elevated vegetation cover

Key result	Lower dead elevated vegetation cover in moderately and heavily thinned plots in 2017 and 2018 but not 2019

Data collection

Dead elevated vegetation cover is assessed by visual estimation in three 0.04 hectare plots within each 9 hectare plot. The elevated stratum consists almost exclusively of *Eucalyptus camaldulensis* saplings and small trees.

Data summary

In all years and on all ecological thinning treatments, the proportion of elevated vegetation cover that was dead was most commonly 1.5% or less (Figure 62, Figure 63).

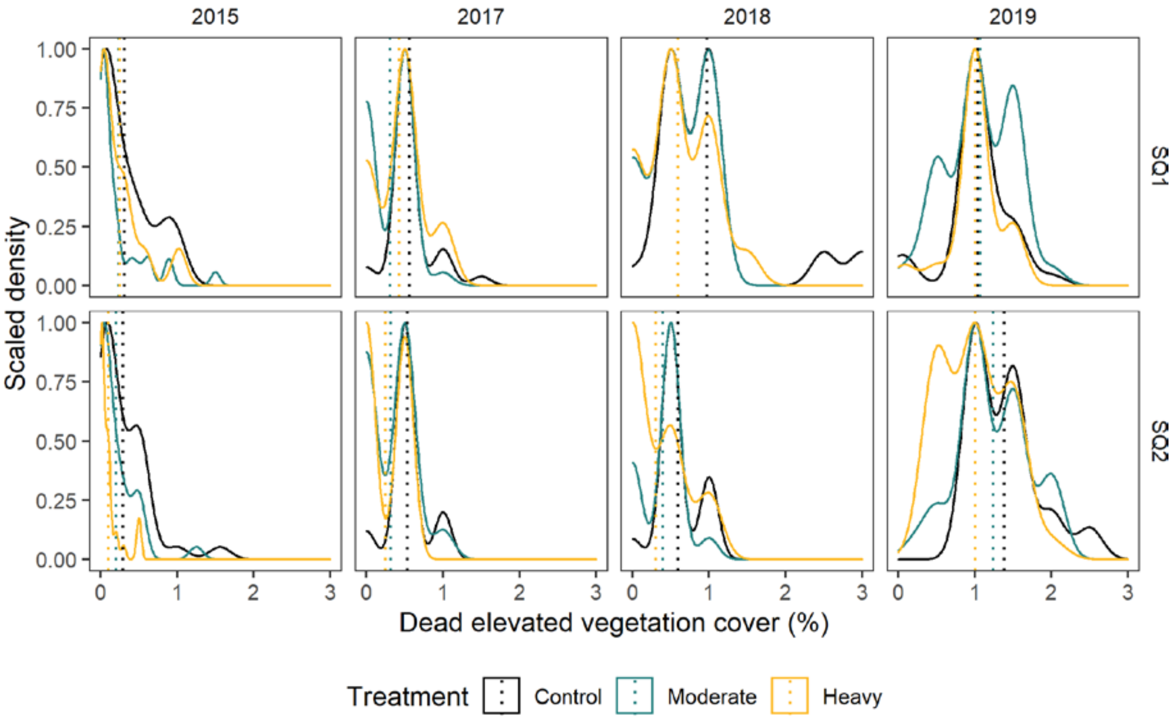

Figure 62 Density plots and averages (dotted lines) of dead elevated vegetation cover (%, averaged for 9 hectare plots), by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

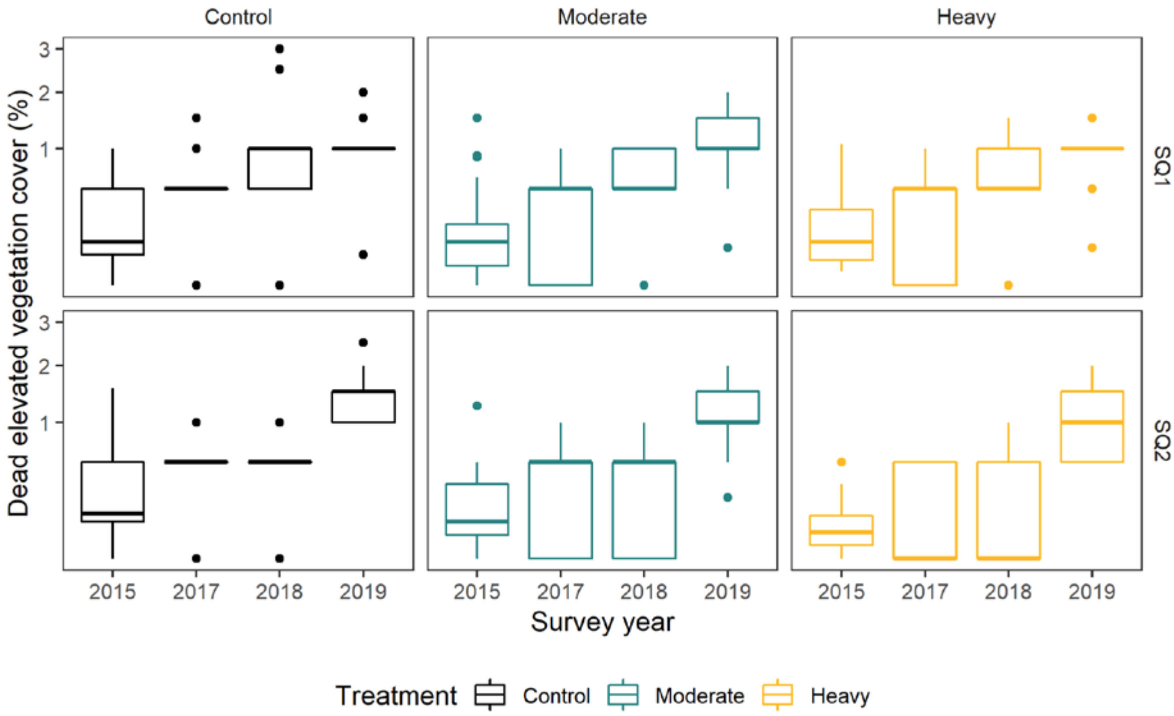

Figure 63 Boxplots of dead elevated vegetation cover (%, averaged for 9 hectare plots), by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

Model results

Dead elevated vegetation cover was lower in moderately and heavily thinned plots in 2017 and 2018 when fewer elevated trees were present. In 2019 there were no significant differences among thinning treatments (Table 31, Figure 64).

Dead elevated vegetation cover was lower in 2015 than all post-thinning years (Figure 64).

Table 31 Model summary for dead elevated vegetation cover

Response	Family	Link	Effect of year	Effect of thinning treatment	Effect of site quality	Confidence
Dead elevated vegetation cover (%)	Beta	Logit	Lower (<1%) in 2015	Lower in thinned plots in 2017 and 2018 (<1%)	No effect of site quality	Low to moderate Failed test of uniformity

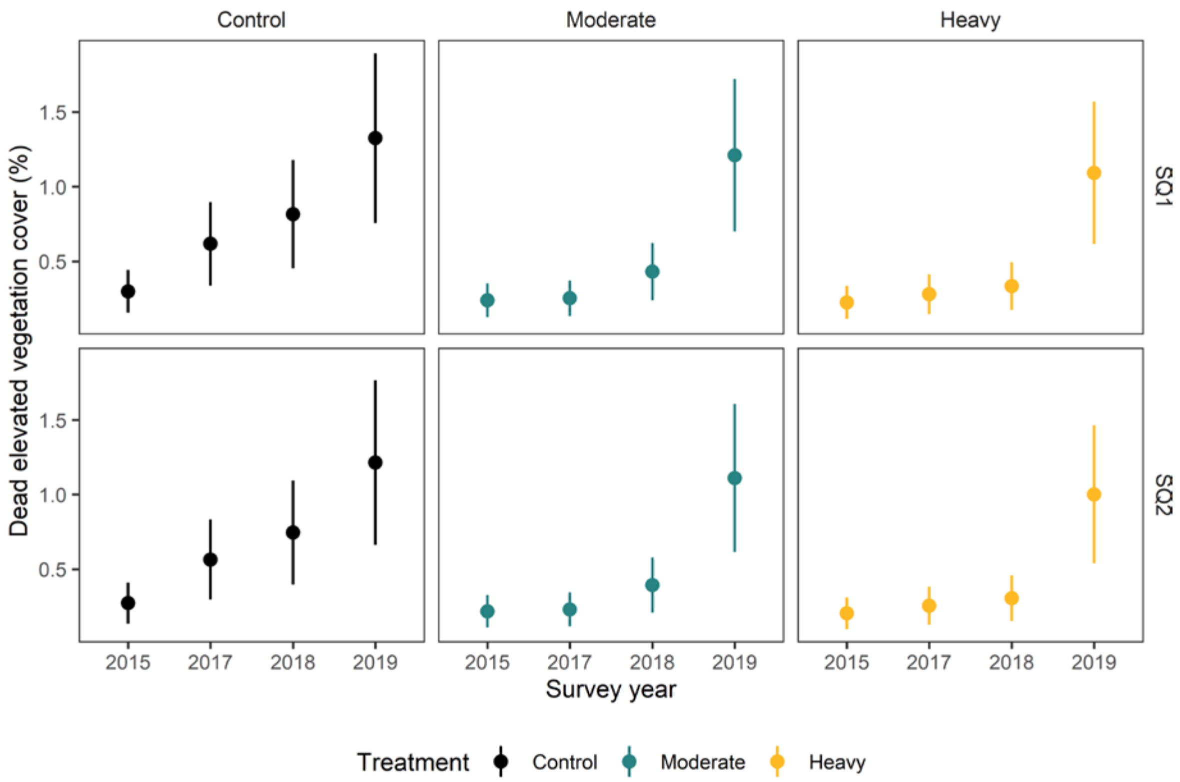

Figure 64 Modelled dead elevated vegetation cover (%, averaged for 9 hectare plots) with standard errors, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

6.11 Elevated fuel hazard assessment

Key result	The probability of being in the low category was slightly (about 5%) higher in moderately thinned plots in 2019 than control or heavily thinned plots

Data collection

Elevated fuel assessment is based on total elevated vegetation cover (i.e. live + dead cover described in the previous two sections), and the proportion of total elevated cover that is dead (i.e. dead cover divided by total cover).

Table 32 Elevated fuel hazard assessment categories (adapted from Hines et al. 2010)

Grey cells are defined by Hines et al. (2010), white cells are additionally defined to enable classification of all data.

Proportion dead cover	Total elevated plant cover (%)		
	<5	<20	20–30
<20	L	L	M
20–30	M	M	M
30–50	M	M	H
>50	M	H	VH

Data summary

In 2019 in Site Quality 1, for all control and thinned treatments there were a higher proportion of plots in the low category (and lower proportion in the moderate category) than in the previous year (Figure 42, above).

In 2019 in Site Quality 2, the proportions of plots in either the low or moderate category were similar to previous years, with the exception that a small number of control plots were in the high category.

Model results

A Bayesian ordinal categorical model was run to determine whether the probability of being in each elevated fuel hazard category differed among thinning treatments over time and whether any differences depended on site quality (Table 33, Figure 65).

The vast majority of plots were in the low or moderate categories on all treatment types over all years.

The probability of moderately thinned plots being in the higher (moderate) category had increased in 2017 and 2018 but decreased again in 2019. Note that elevated vegetation cover had increased in moderately thinned plots in 2019, which highlights the weight placed in the fuel hazard assessment method on dead material even when cover is very low.

Table 33 Model summary for probability of being in each of the elevated fuel hazard assessment categories

Response	Family	Link	Effect of year	Effect of thinning treatment	Effect of site quality	Confidence
Probability of being in each elevated fuel hazard category	Ordinal categorical (continuous ratio)	Logit	Lower probability of being in the moderate category in 2015	Higher probability of being in a higher category in moderate, but lower in moderate in 2019	No effect of site quality	Moderate

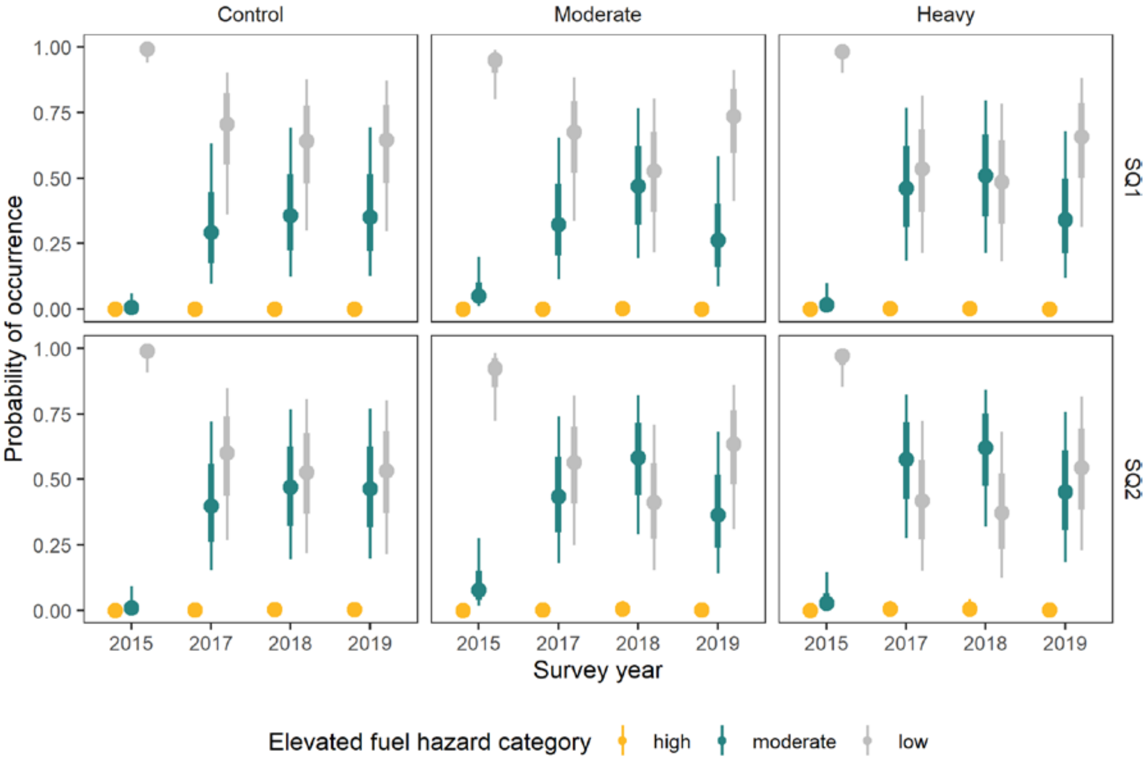

Figure 65 Modelled probability of being in each of the elevated fuel hazard assessment categories with 50% and 95% credible intervals, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

7. Results: Floristics

7.1 Native plant species richness

Key result	No effects of ecological thinning treatment on native plant species richness in 2019. Weak evidence of an additional two native species per 0.04 hectare subplot in heavily thinned plots in 2017 and 2018

Data collection

Floristic composition was surveyed in three 0.04 hectare subplots on each 9 hectare plot, with a total of 198 subplots. Floristic subplots were placed in the 9 hectare plots to sample the range of variation in understorey vegetation. Surveys involved recording all native and exotic plant species present and estimating the cover abundance of each species (Table 34).

Table 34 Cover abundance score estimated in the field

Category	Raw score as recorded in field
A	<5% cover and up to 3 individuals
B	<5% cover and 3–50 individuals
C	<5% cover and 50–100 individuals
D	<5% cover and >100 individuals
PE	Point estimates given for >5% cover

Data summary

The total number of species recorded in each year (that were able to be identified) was between approximately 170 and 200 species (Table 35), of which approximately 60% were native species. Slightly fewer native species were recorded in 2019 than previous years.

Table 35 Total native and exotic plant species richness by year

Period	Exotic	Native	Total
2015–16	68	125	193
2017–18	75	126	201
2018–19	62	112	174
2019–20	65	107	172

Most commonly, native plant species richness on each 0.04 hectare subplot was around 15 species (Figure 66, Figure 67) on both site qualities and all thinning treatments. When the unique species in the three 0.04 hectare subplots were summed, the most commonly recorded species richness was between 20 and 30 species on each 9 hectare plot, with a maximum of approximately 40 species (Figure 68).

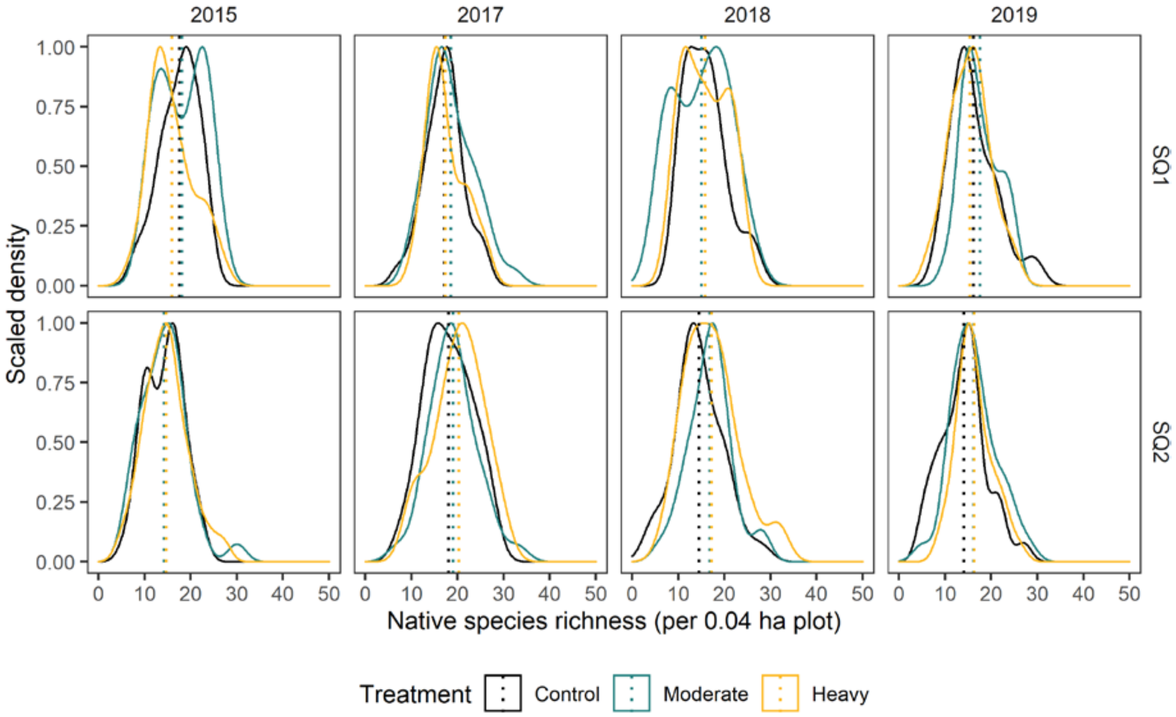

Figure 66 Density plots and averages (dotted lines) of native species richness per 0.04 hectare subplot, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

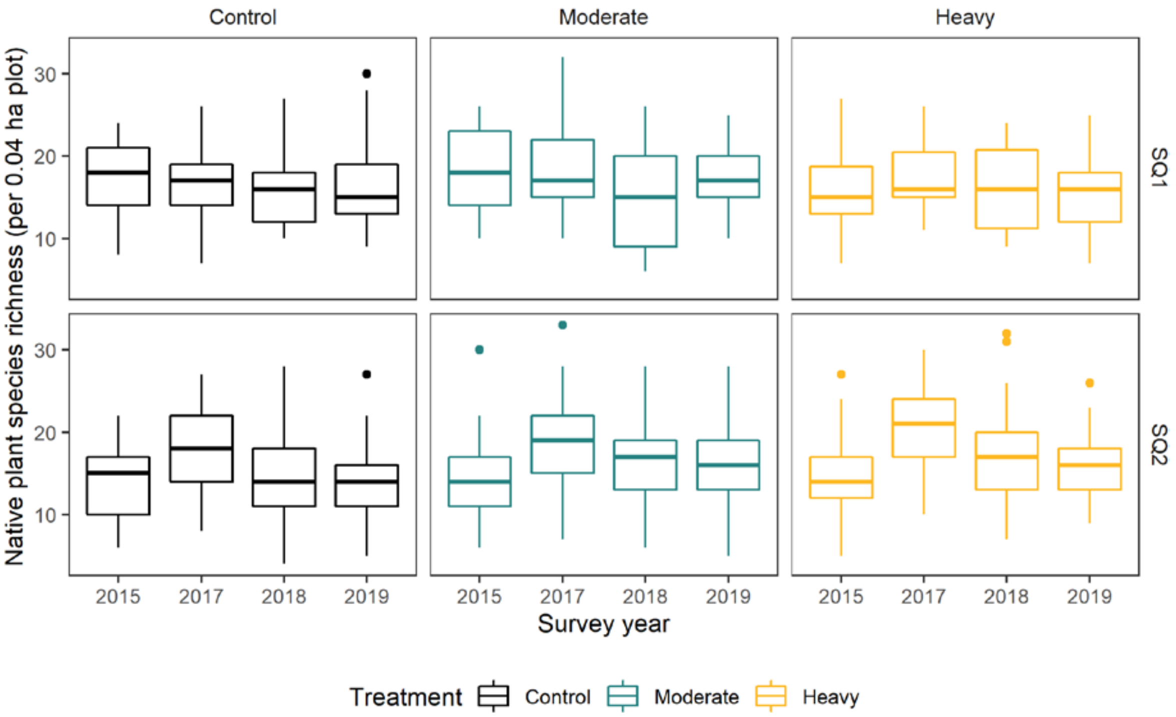

Figure 67 Boxplots of native species richness per 0.04 hectare subplot, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

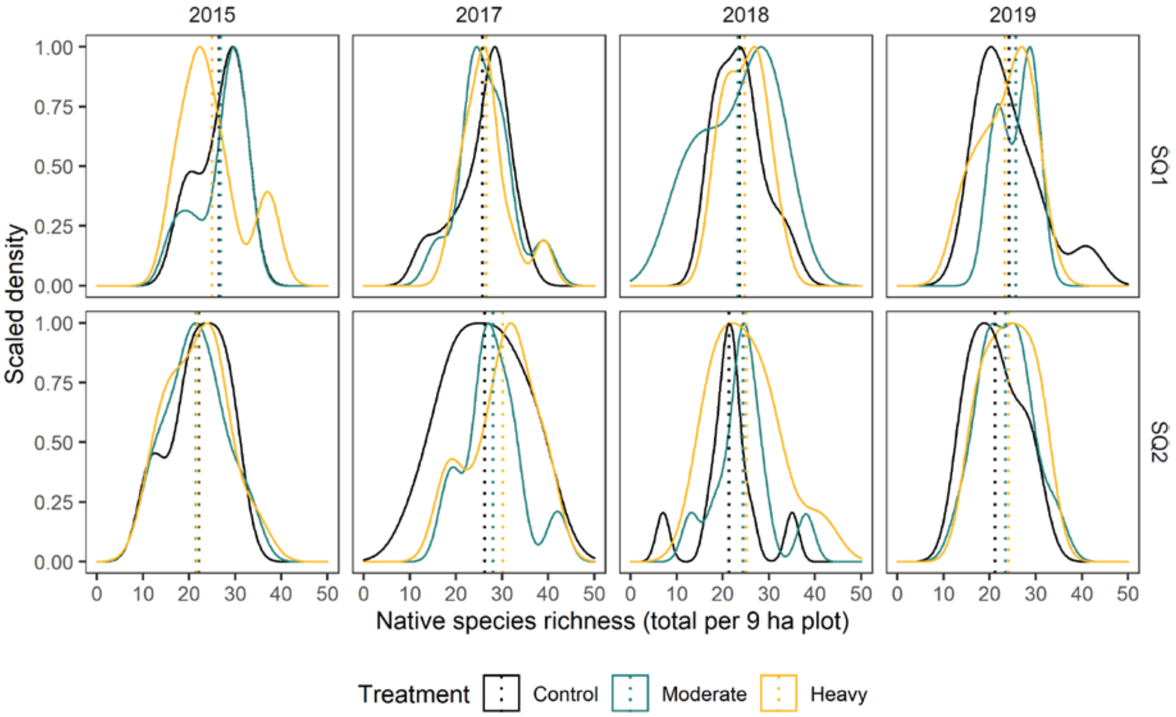

Figure 68 Density plots and averages (dotted lines) of native species richness per 9 hectare plot (total of unique species recorded in three 0.04 hectare subplots), by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

Model results

A gaussian model for number of native species per 0.04 hectare plot did not detect evidence of a difference between control and thinned plots in 2019, with fitted values between 15 and 17 for all treatments in both site qualities (Table 36, Figure 69).

Native species richness was significantly higher across control and thinned treatments (by about two species) in 2017, which was the year after extensive flooding occurred.

There was evidence that an additional two native species had been recorded in heavily thinned plots in 2017 and 2018.

Table 36 Model summary for native plant species richness per 0.04 hectare subplot

Response	Family	Link	Effect of year	Effect of thinning treatment	Effect of site quality	Confidence
Count of native species per 0.04 ha	Gaussian	None	Weak evidence for an additional two species in heavily thinned plots in 2017 and 2018 (not supported by bootstrapping)		No difference among site qualities	High R^2 = 42.0%

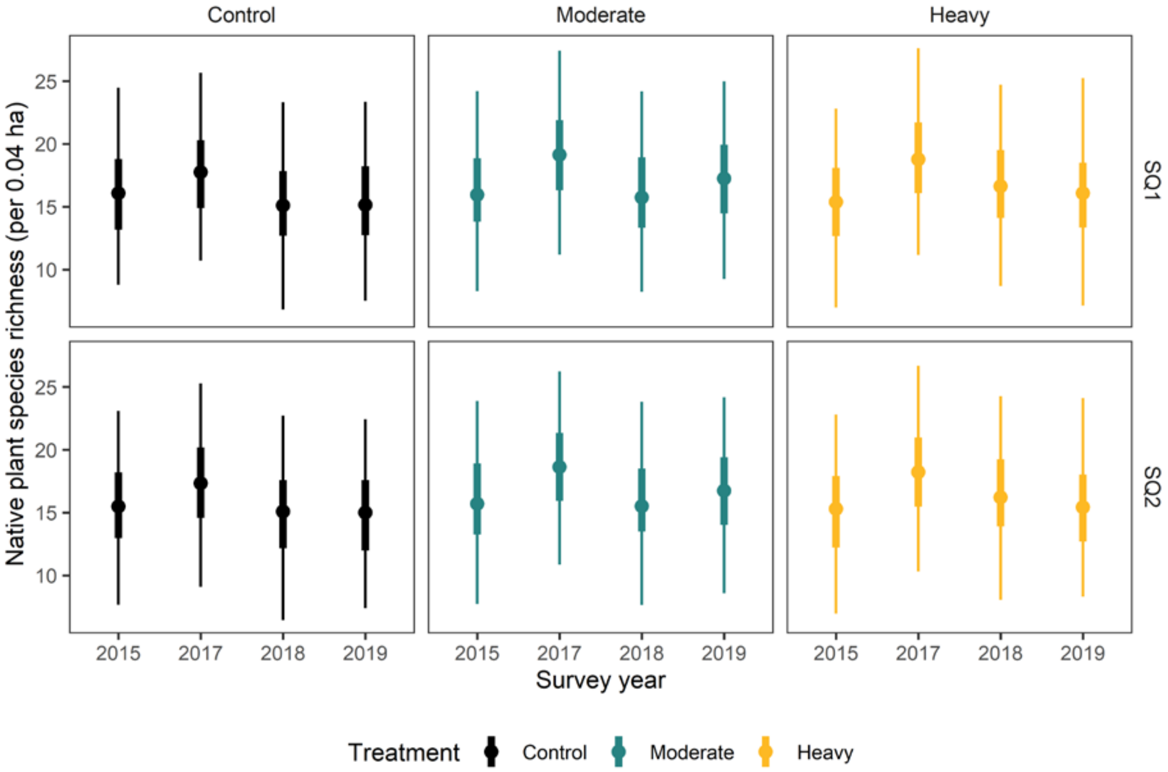

Figure 69 Modelled native species richness per 0.04 hectare subplot with bootstrapped 50% and 95% confidence intervals, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

Plate 4 Golden everlasting flower (*Xerochrysum bracteatum*)
Photo: Emma Gorrod.

7.2 Exotic plant species richness

Key result	Moderately thinned plots had higher exotic plant species richness (about two species per 0.04 hectare subplot) in 2019 Both moderately and heavily thinned plots had higher exotic plant species richness (about two species per 0.04 hectare subplot) in 2018; as did heavily thinned plots in 2017

Data collection

Floristic composition was surveyed in three 0.04 hectare subplots on each 9 hectare plot, with a total of 198 subplots. Floristic subplots were placed in the 9 hectare plots to sample the range of variation in understorey vegetation. Surveys involved recording all native and exotic plant species present and estimating the cover abundance of each species (Table 34, above).

Data summary

The average number of exotic species recorded in 0.04 hectare subplots generally varied between five and eight species (Figure 70, Figure 71). Differences among control and thinned plots were greater among Site Quality 2 site post-thinning.

When the unique exotic species recorded on each of the 0.04 hectare subplots were totalled, the average per 9 hectare plot was around 10 species (Figure 72). More exotic species were recorded in thinned plots than control plots in 2017 and 2018 in Site Quality 2.

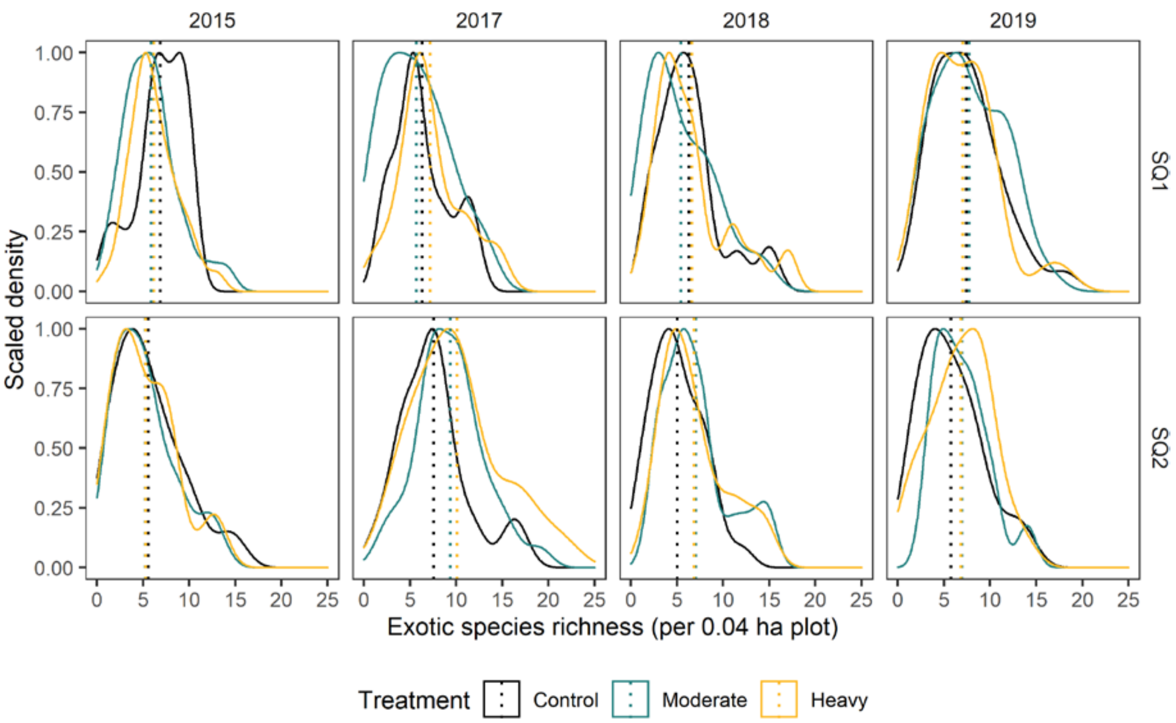

Figure 70 Density plots and averages (dotted lines) of exotic plant species richness per 0.04 hectare subplot, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

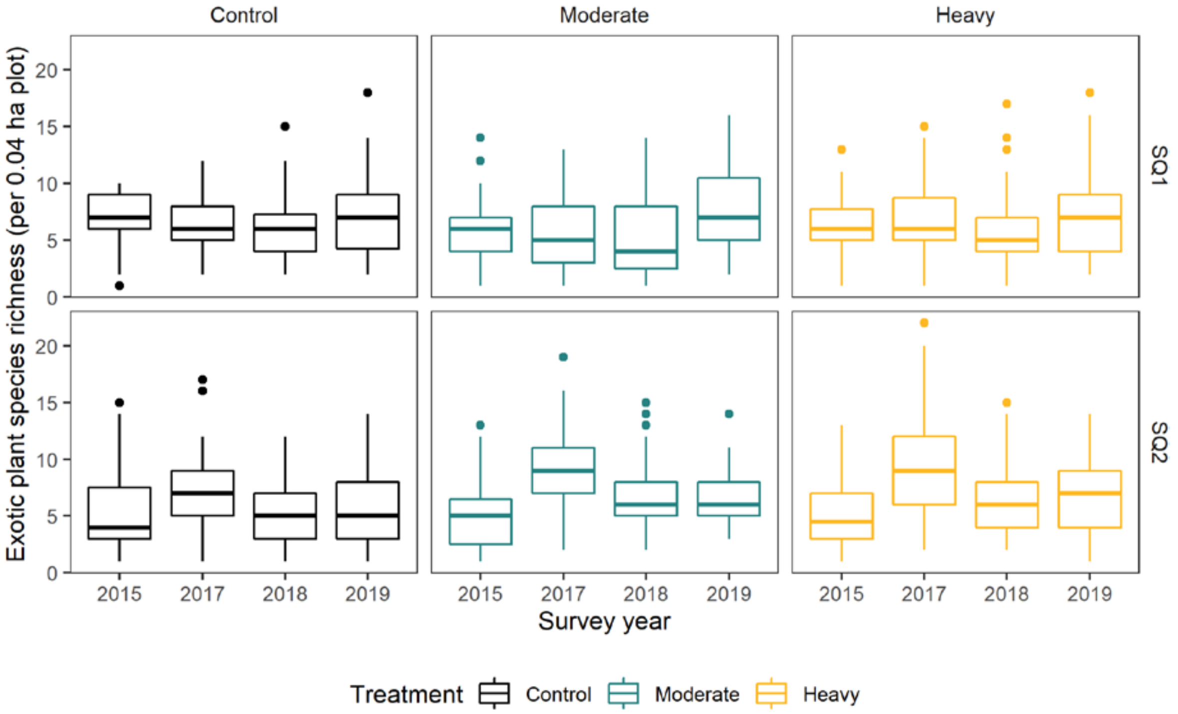

Figure 71 Boxplots of exotic plant species richness per 0.04 hectare subplot, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

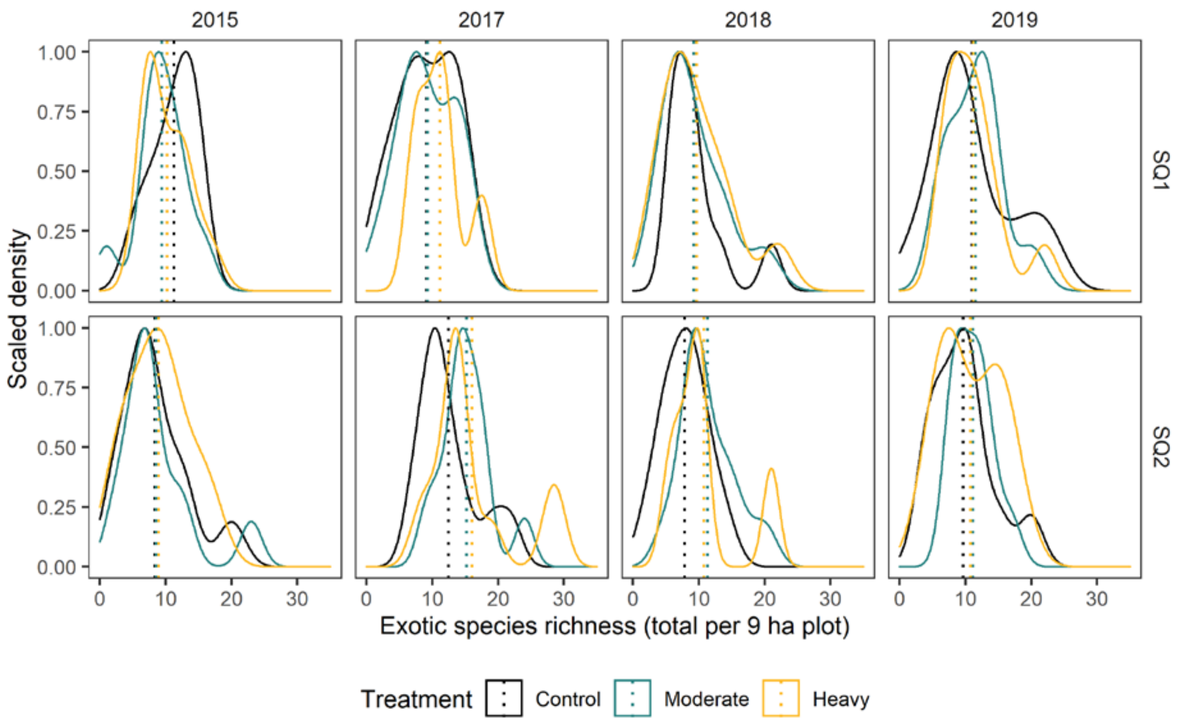

Figure 72 Density plots and averages (dotted lines) of exotic plant species richness per 9 hectare plot, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

Model results

A gaussian model was run to determine whether there were differences among thinning treatments in the number of exotic species present over time, and whether any differences depended on site quality (Table 37).

The number of exotic species per 0.04 hectare plot was relatively stable over time, with fitted values of about 5–8 species (Figure 73).

Moderately thinned plots had about two more exotic plant species per 0.04 hectare plot than control and heavily thinned plots in 2019, which was statistically significant.

Both moderately and heavily thinned plots had about two additional exotic species per 0.04 hectare plot in 2018; as did heavily thinned plots in 2017.

Table 37 Model summary for count of exotic species per 0.04 hectare subplot

Response	Family	Link	Effect of year	Effect of thinning treatment	Effect of site quality	Confidence
Count of exotic species per 0.04 ha	Gaussian	None	Higher by two species in moderately thinned plots in 2019; and by two species on both thinned treatments in 2018		No effect of site quality	High R^2 = 55.4%

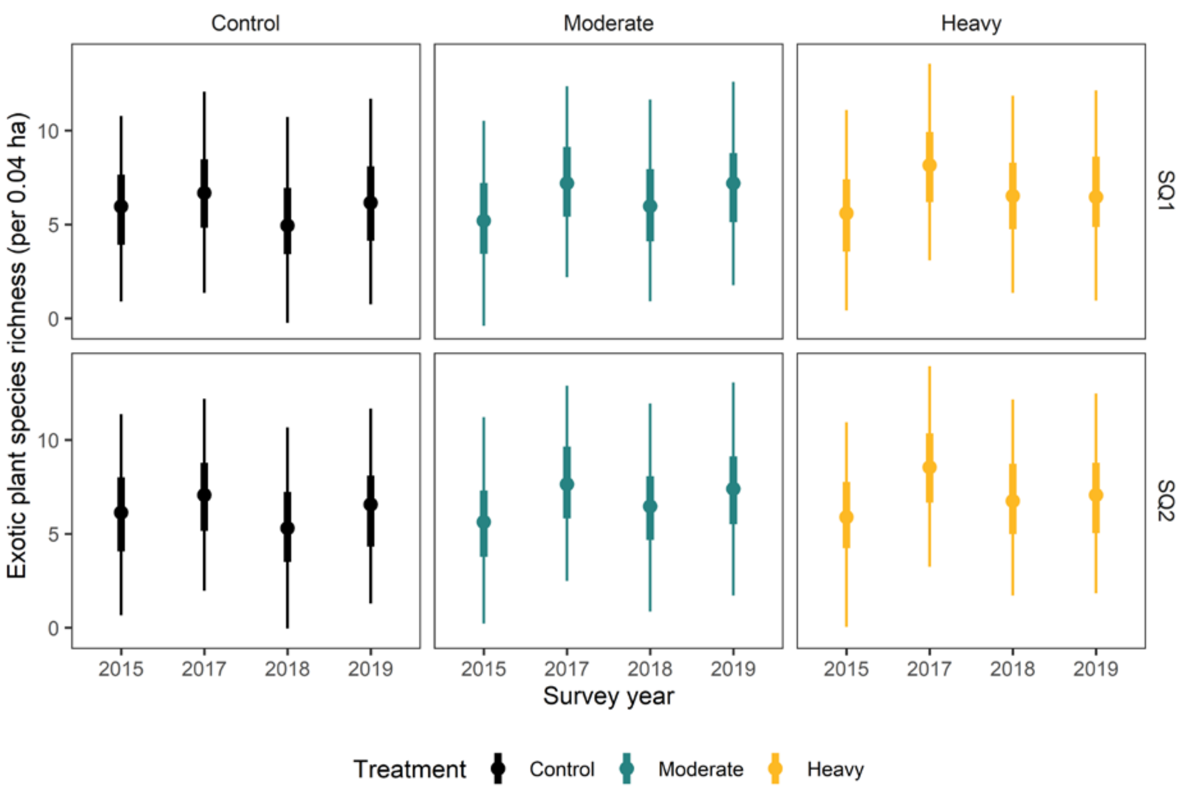

Figure 73 Modelled exotic species richness per 0.04 hectare subplot with bootstrapped 50% and 95% confidence intervals, by survey year, ecological thinning treatment and site quality (SQ1 and SQ2)

7.3 Native plant cover

Key result	Slightly lower native plant cover (0.5%) in heavily thinned plots in 2019, with low confidence

Data collection

In 2019, live native vegetation cover (not including tree cover) was visually estimated as a percentage of each 0.04 hectare plot. It had not been estimated in previous years.

Data summary

The range of commonly recorded native vegetation cover values was broader in Site Quality 1 sites (Figure 74). Average native vegetation cover values were higher in control and moderately thinned plots in Site Quality 1, and moderately thinned plots had some of the highest recorded values. In Site Quality 2, averages were similar among thinned and control plots (<2%), and very few plots of all treatment types had higher values.

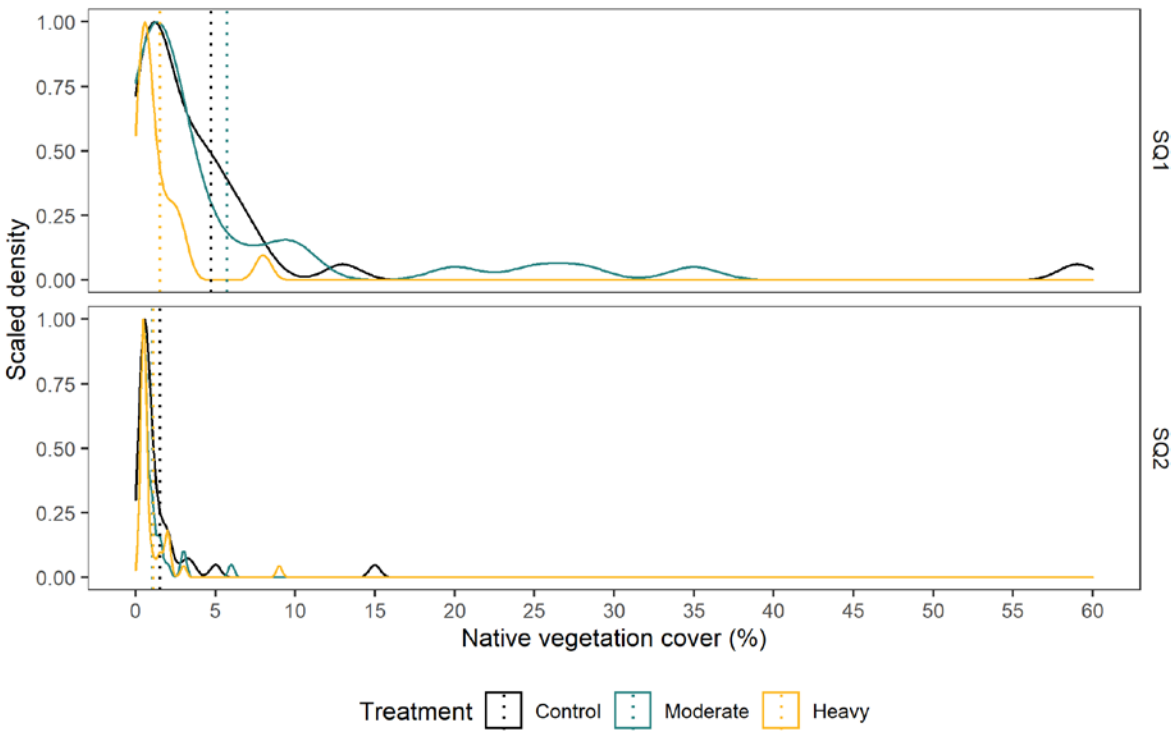

Figure 74 Density plots and averages (dotted lines) of live native vegetation cover (%) per 0.04 hectare subplot in 2019, by ecological thinning treatment and site quality (SQ1 and SQ2)

Model results

A binomial model was fit but the skewed nature of the data, with many near-zero values and few large values, was difficult to fit and therefore model confidence was low (Table 38).

Native live vegetation cover values were slightly lower (by 1%) in heavily thinned plots than control in 2019, and this result was statistically significant (Figure 75).

Native live vegetation cover was slightly but significantly higher on wetter Site Quality 1 sites (2–3%) than Site Quality 2 sites (1.5%).

Table 38 Model summary for live native vegetation cover (%)

Response	Family	Link	Effect of thinning treatment	Effect of site quality	Confidence
Native ground cover %	Binomial	Logit	Slightly lower cover in heavily thinned plots in 2019 (0.5%)	Slightly lower cover in Site Quality 2 plots (0.6%)	Low R^2 = 9.5% Fails uniformity and outlier tests

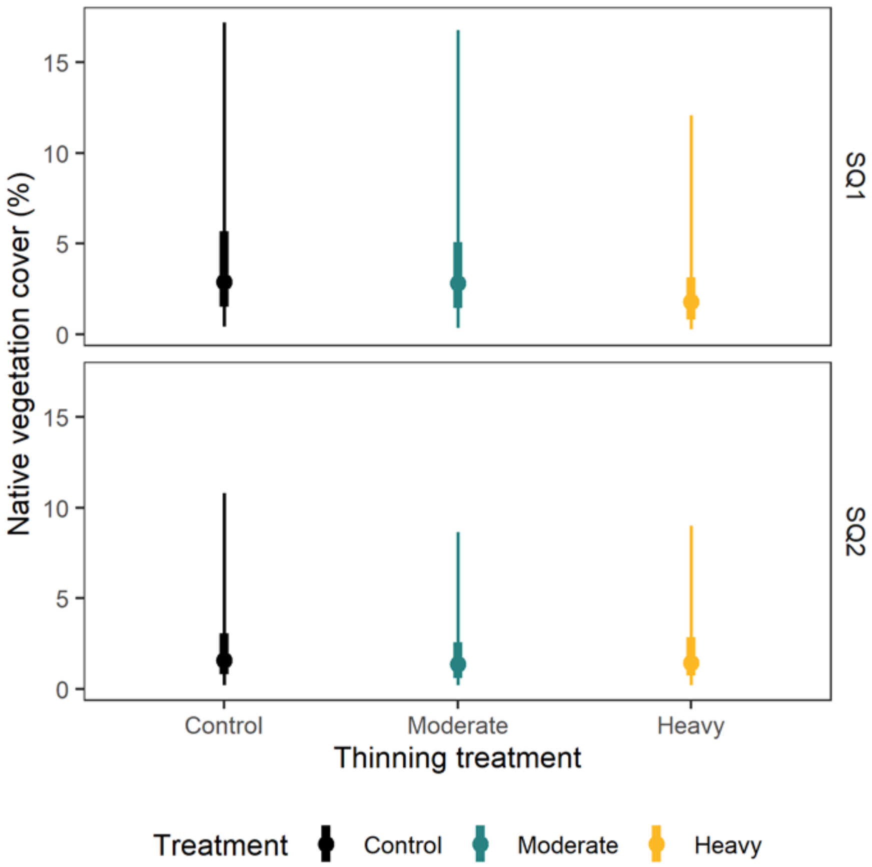

Figure 75 Modelled live native vegetation cover (%) per 0.04 hectare subplot in 2019 with bootstrapped 50% and 95% confidence intervals, by ecological thinning treatment and site quality (SQ1 and SQ2)

7.4 Exotic plant cover

Key result	Slightly higher exotic plant cover in heavily thinned plots in Site Quality 1 (0.58%) and slightly lower in heavily thinned plots in Site Quality 2 (0.43%), with low confidence

Data collection

In 2019, total live exotic vegetation cover was visually estimated as a percentage of each 0.04 hectare plot. It had not been estimated in previous years.

Data summary

Most commonly, exotic cover was estimated to be <1%, with values between about 4 and 15% recorded occasionally (Figure 76). Of the higher values recorded, the highest proportion of them were in heavily thinned plots in Site Quality 1.

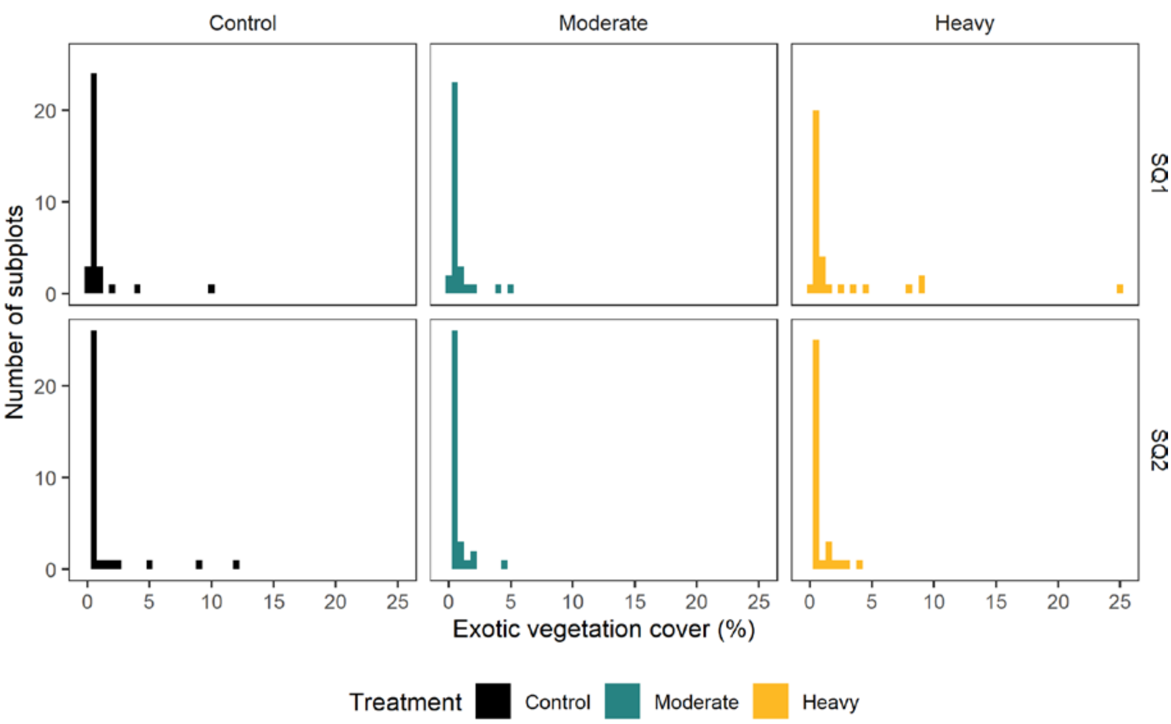

Figure 76 Histograms of live exotic vegetation cover per 0.04 hectare subplot in 2019 (each bar is 0.5%), by ecological thinning treatment and site quality (SQ1 and SQ2)

Model results

The strongly skewed data, with many values close to zero and few higher values, was difficult to model. A binomial model was run, but confidence in the results was poor (Table 39).

The model results, however, did reflect the underlying data with a significantly higher exotic cover detected in heavily thinned plots in Site Quality 1 (Figure 77). Conversely, significantly lower exotic cover was detected in heavily thinned plots in Site Quality 2. The magnitude of both of these effects was small, with fitted values for the heavily thinned plots of 0.5% higher and lower than control plots in the site qualities, respectively.

Table 39 Model summary for exotic plant cover

Response	Family	Link	Effect of thinning treatment	Effect of site quality	Confidence
Exotic plant cover %	Binomial	Logit	Slightly higher in heavily thinned plots in Site Quality 1 (0.58% higher than controls) Slightly lower in heavily thinned plots in Site Quality 2 (0.43% lower than controls)		Low R^2 = 7.2% Failed uniformity and dispersion tests

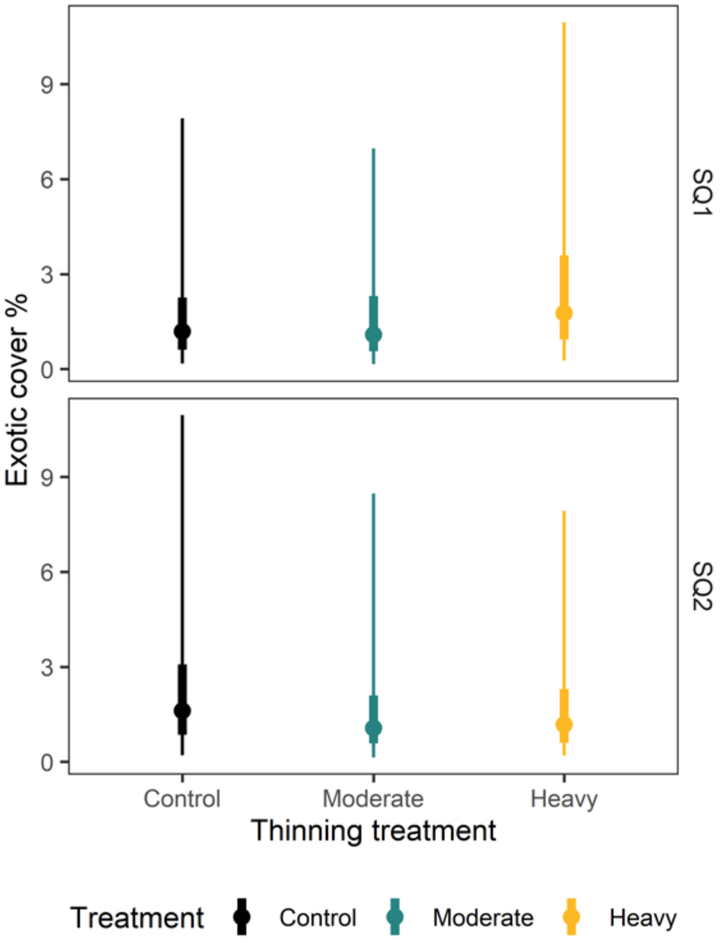

Figure 77 Modelled live exotic vegetation cover (%) per 0.04 hectare subplot in 2019 with bootstrapped 50% and 95% confidence intervals, by ecological thinning treatment and site quality (SQ1 and SQ2)

7.5 Current floristic community composition 2019

Key result	No marked differences in the native or exotic floristic community composition of control and treatment plots in 2019. Native and exotic floristic composition differed between site quality classes.

Data collection

As described above, all native and exotic plant species were recorded in each of three 0.04 hectare subplots in each 9 hectare treatment plot.

Model results

Using the unique native plant species recorded as present in at least four 9 hectare plots, hierarchical clustering was used to arrange the data in order of similarity of species composition and similarity of location. If there were strong patterns of community composition among thinning treatments (or site qualities), then blocks of colour would be apparent in the plots. The same procedure was run separately for exotic plant species.

Native species

There was no evidence that the native floristic composition of control plots was distinct from the composition of thinned plots in a cross-classification of floristic community composition (Figure 78). Approximately 15 native species were common to almost all plots; and another 8–10 are commonly found together in wetter plots (e.g. sites 3, 4, 5, 20 and 22). There were strong patterns in native species occurrence by site quality (Figure 79).

Exotic species

There was also no evidence that the exotic floristic composition of control plots was distinct from the composition of thinned plots in a cross-classification of floristic community composition (Figure 80). Approximately 6–8 exotic species were common to almost all plots. There were strong patterns in exotic species occurrence by site quality (Figure 81).

Figure 78 Cross-classification of native plant species and 9 hectare plots in 2019, coloured by ecological thinning treatment

Sites that are close together on the x axis have a similar plant species composition; and species that are close together on the y axis tend to occur in similar plots.

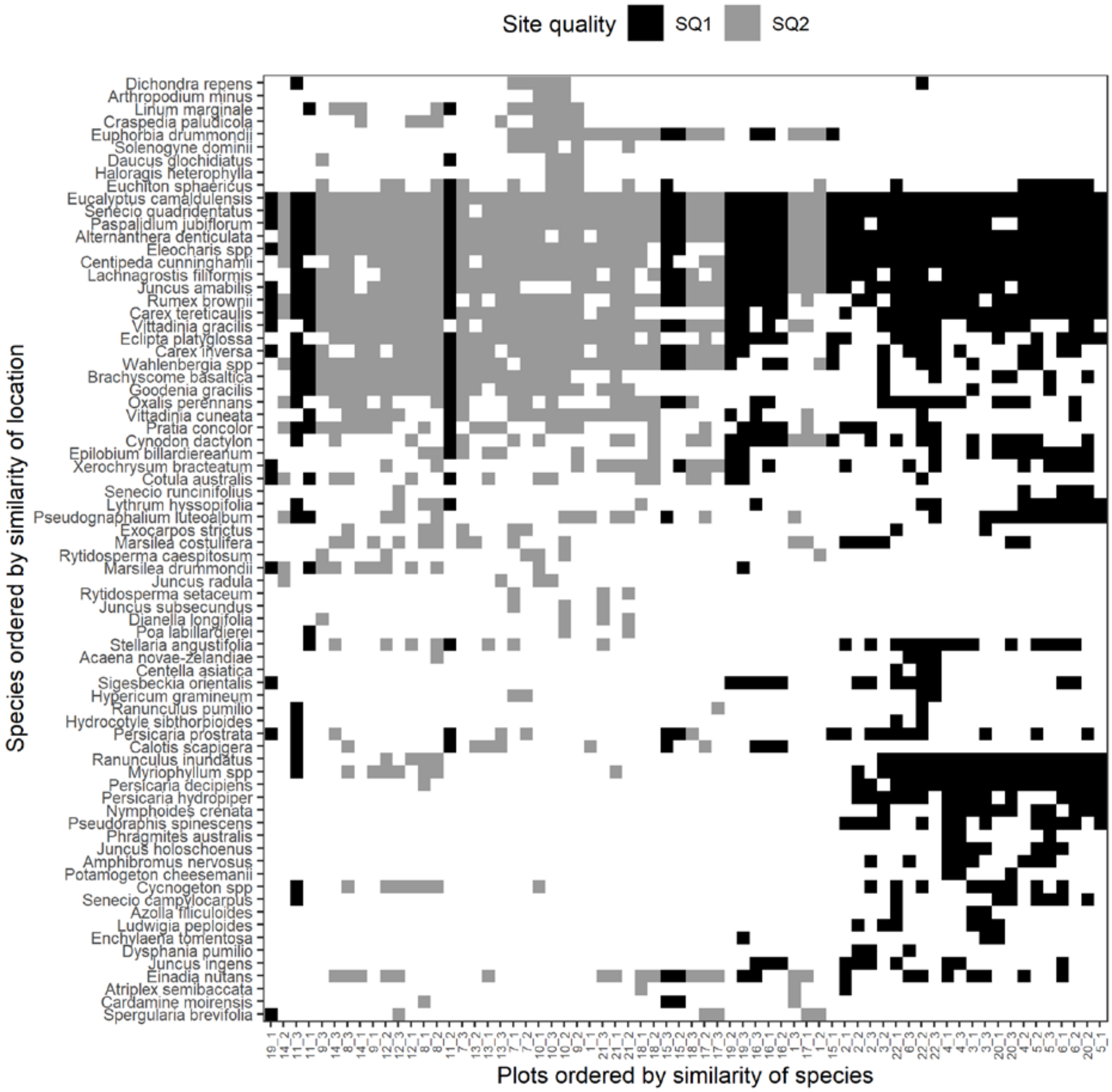

Figure 79 Cross-classification of native plant species and 9 hectare plots in 2019, coloured by site quality (SQ1 and SQ2)

Sites that are close together on the x axis have a similar plant species composition; and species that are close together on the y axis tend to occur in similar plots.

Figure 80 Cross-classification of exotic plant species and 9 hectare plots in 2019, coloured by ecological thinning treatment

Sites that are close together on the x axis have a similar plant species composition; and species that are close together on the y axis tend to occur in similar plots.

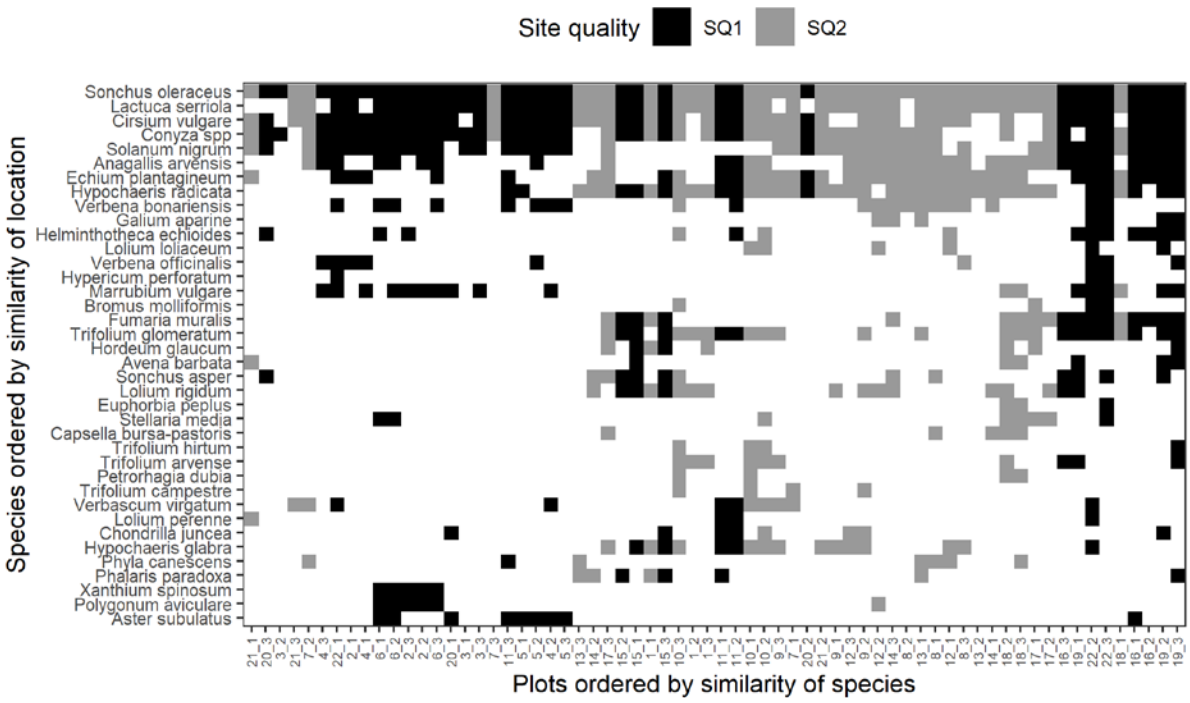

Figure 81 Cross-classification of exotic plant species and 9 hectare plots in 2019, coloured by site quality (SQ1 and SQ2)

Sites that are close together on the x axis have a similar plant species composition; and species that are close together on the y axis tend to occur in similar plots.

7.6 Threatened plant species

Key result	Floating swamp wallaby grass was not recorded in 2019

The threatened plant species floating swamp wallaby grass (*Amphibromus fluitans*) was not recorded in 2019–20. This species is listed as vulnerable in the NSW *Biodiversity Conservation Act 2016* and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

The habitat for *Amphibromus fluitans* is almost exclusively aquatic. Its occurrence tends to be temporary, associated with standing floodwaters. The ongoing dry conditions are likely to have limited appropriate habitat conditions again during 2019–20.

8. Results: Birds

8.1 Bird species richness

Key result	Bird species richness was higher (approximately two species) in moderately thinned plots than control plots in 2019

Data collection

Birds were surveyed in a 2 hectare subplot within each 9 hectare treatment plot, with visual and auditory observations recorded for 20 minutes on four occasions (two pre-9am and two post-9am where possible).

Four observers conducted all the surveys, two of whom had conducted surveys in previous years. Each observer tended to survey all sites over a period of three or four weeks, without necessarily overlapping in dates with other observers.

Data summary

The average number of birds recorded on all plots in all years was between 16 and 21, with a maximum of 34 and minimum of six. There were no substantial differences between site qualities, and differences among thinning treatments changed over time (Figure 82).

Between 2018 and 2019, median bird species richness declined in control plots in Site Quality 2 and also in heavily thinned plots in Site Quality 1 (Figure 83). Median richness slightly increased in moderately thinned plots between 2018 and 2019.

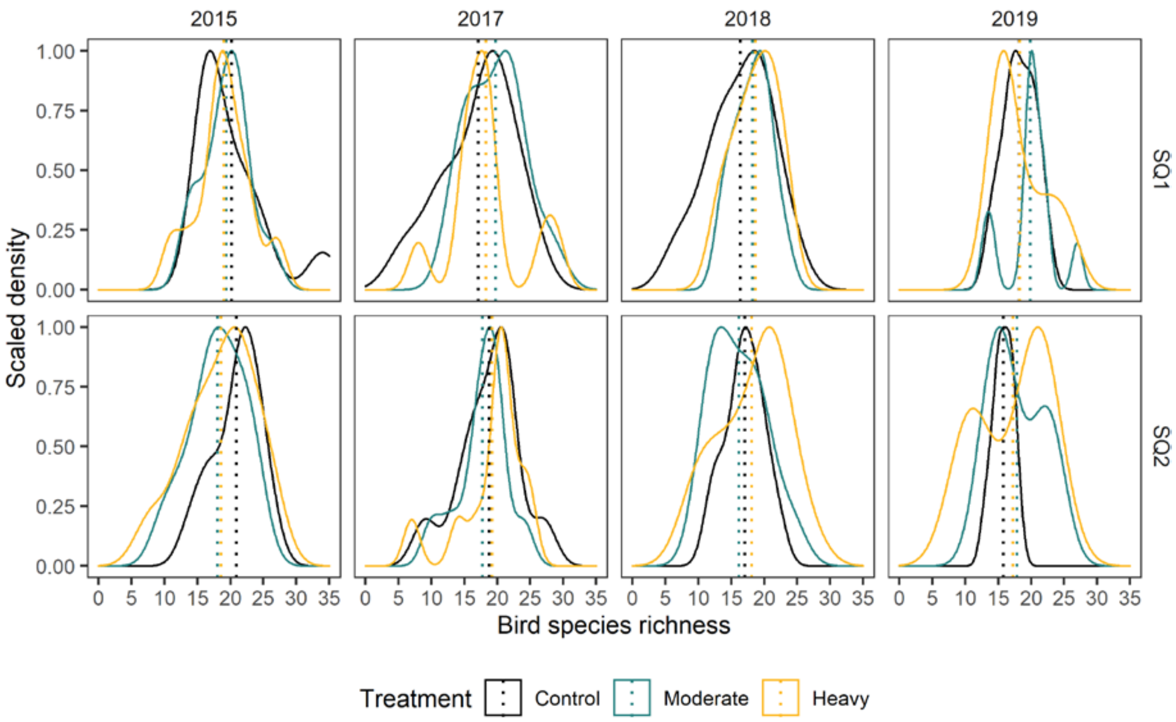

Figure 82 Density plots and averages (dotted lines) of bird species richness per 2 hectare subplot, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

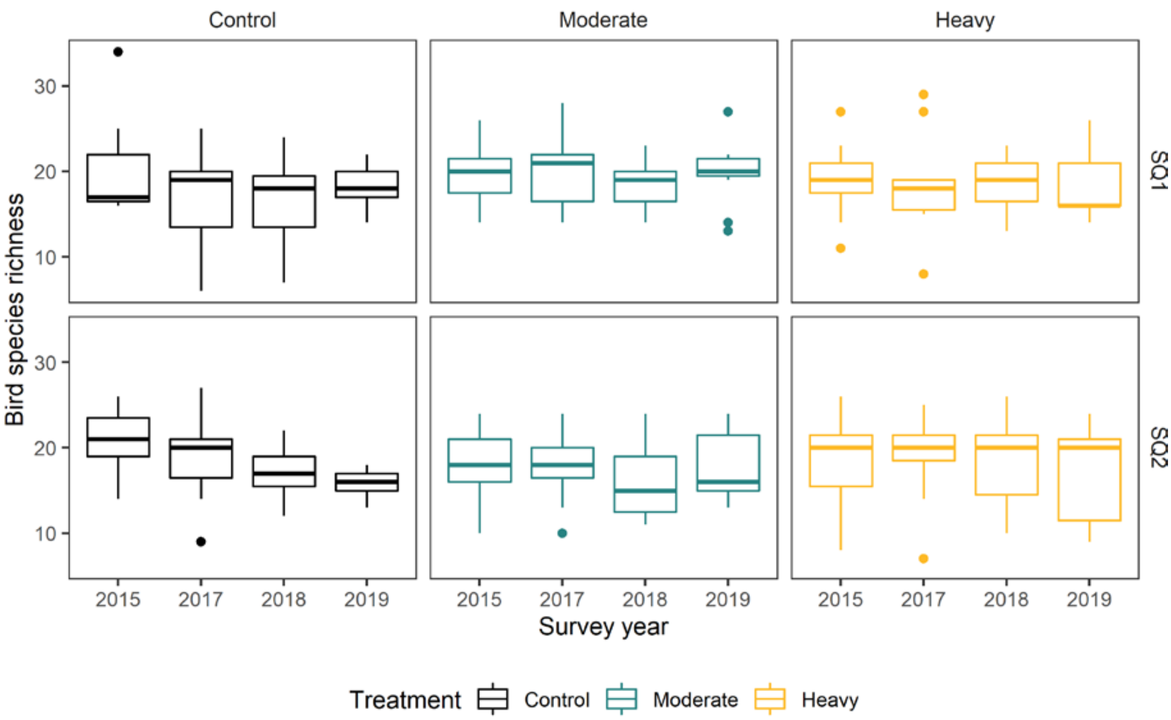

Figure 83 **Boxplots of bird species richness per 2 hectare subplot, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)**

Model results

A gaussian model was run for bird species richness (Table 40, Figure 84).

Bird species richness was higher in moderately thinned plots (18–19 species) than control plots (16–17 species) in 2019, which was a statistically significant difference.

Bird species richness was also higher in heavily thinned plots (17–18 species) than control plots in 2019, but the tip of the bootstrapped confidence interval included zero so there was uncertainty in the result.

In previous post-thinning years, bird species richness has also been slightly higher in thinned plots than control plots (most often by one species).

Overall, however, species richness was significantly higher in 2015 than any post-thinning year.

No effect of site quality on bird species richness.

Table 40 **Model summary for bird species richness per 2 hectare subplot**

Response	Family	Link	Effect of year	Effect of thinning treatment	Effect of site quality	Confidence
Count of bird species per 2 hectare subplot	Gaussian	None	Higher in 2015	Higher by 1–2 species in thinned plots in all post-thinning years (not statistically significant for heavily thinned plots in 2019)	No effect of site quality	High R^2 = 54.5%

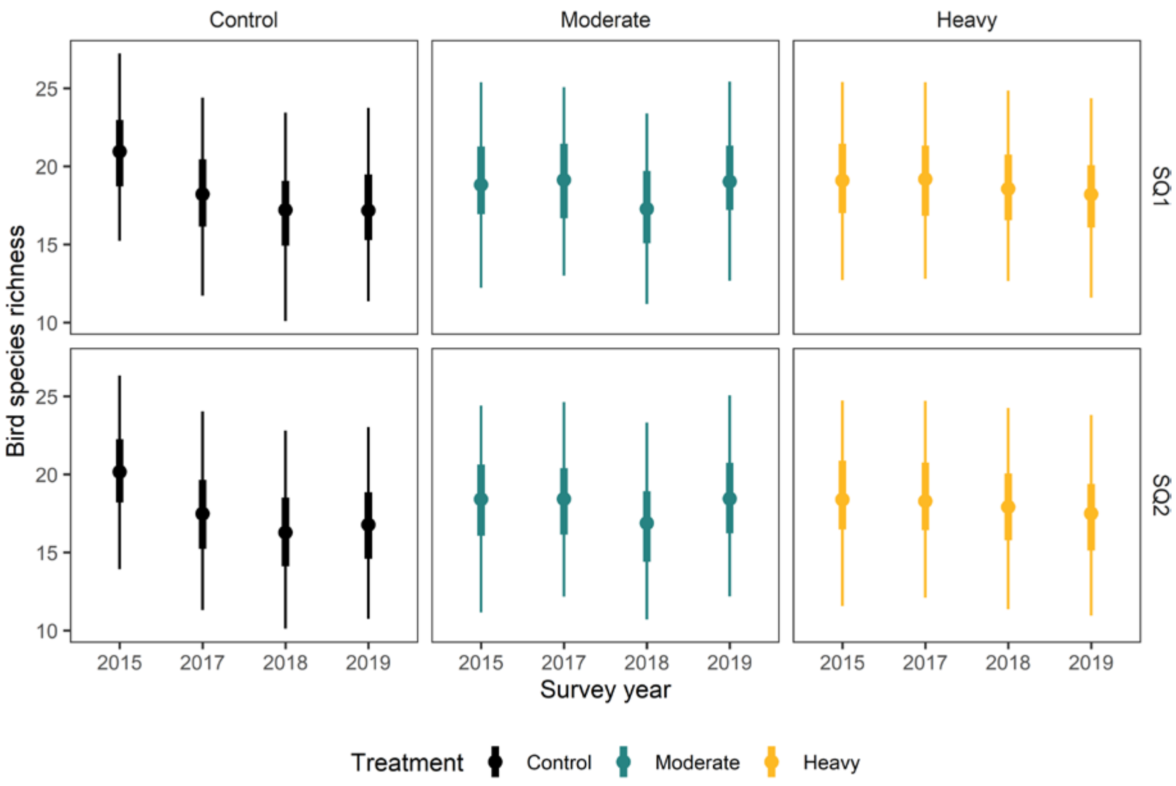

Figure 84 Modelled bird species richness per 2 hectare subplot with bootstrapped 50% and 95% confidence intervals, by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

8.2 Current bird community composition 2019

Key result	No strong evidence of differentiation in bird community composition by ecological thinning treatment

Data collection

Data collection was as described for bird species richness above. This analysis excluded bird species that were recorded on three or fewer plots.

Model results

Hierarchical clustering was used to arrange the data in order of similarity of bird species composition and similarity of location. If there were strong patterns of bird community composition among thinning treatments (or site qualities), then blocks of colour would be apparent in the plots.

Native species

There was some banding among moderately thinned plots (e.g. plots 6-1, 3-1, 5-2 and 4-1) and heavily thinned plots but overall there was little suggestion that bird species composition was strongly distinct among ecological thinning treatments (Figure 85). There were some patterns in bird species occurrence by site quality (Figure 86), but the effect was not as strong as observed for plant species above (Figure 79).

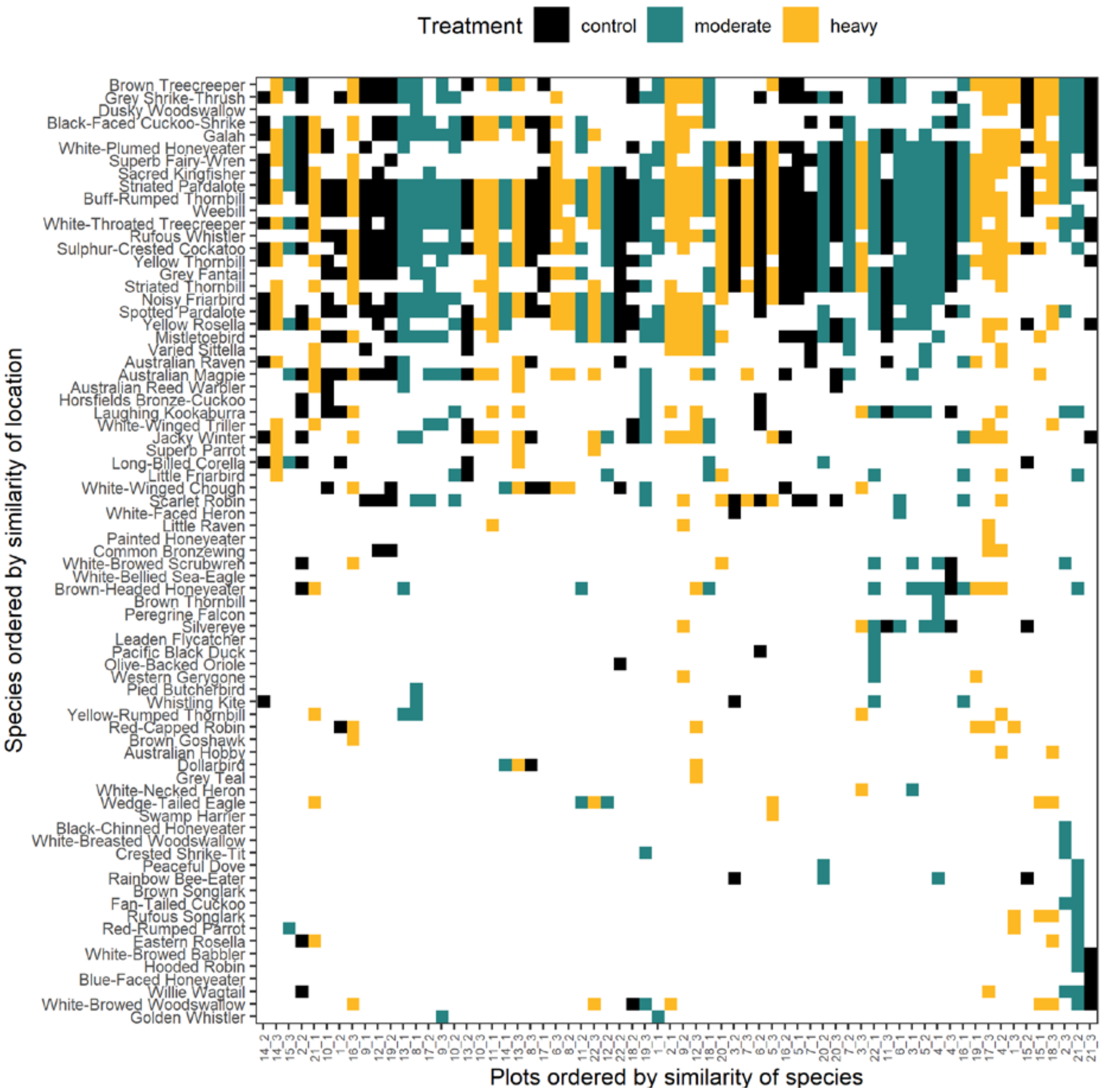

Figure 85 Hierarchical cross-classification of bird species, coloured by ecological thinning treatment

Sites that are close together on the x axis have a similar bird species composition; and species that are close together on the y axis tend to occur in similar plots.

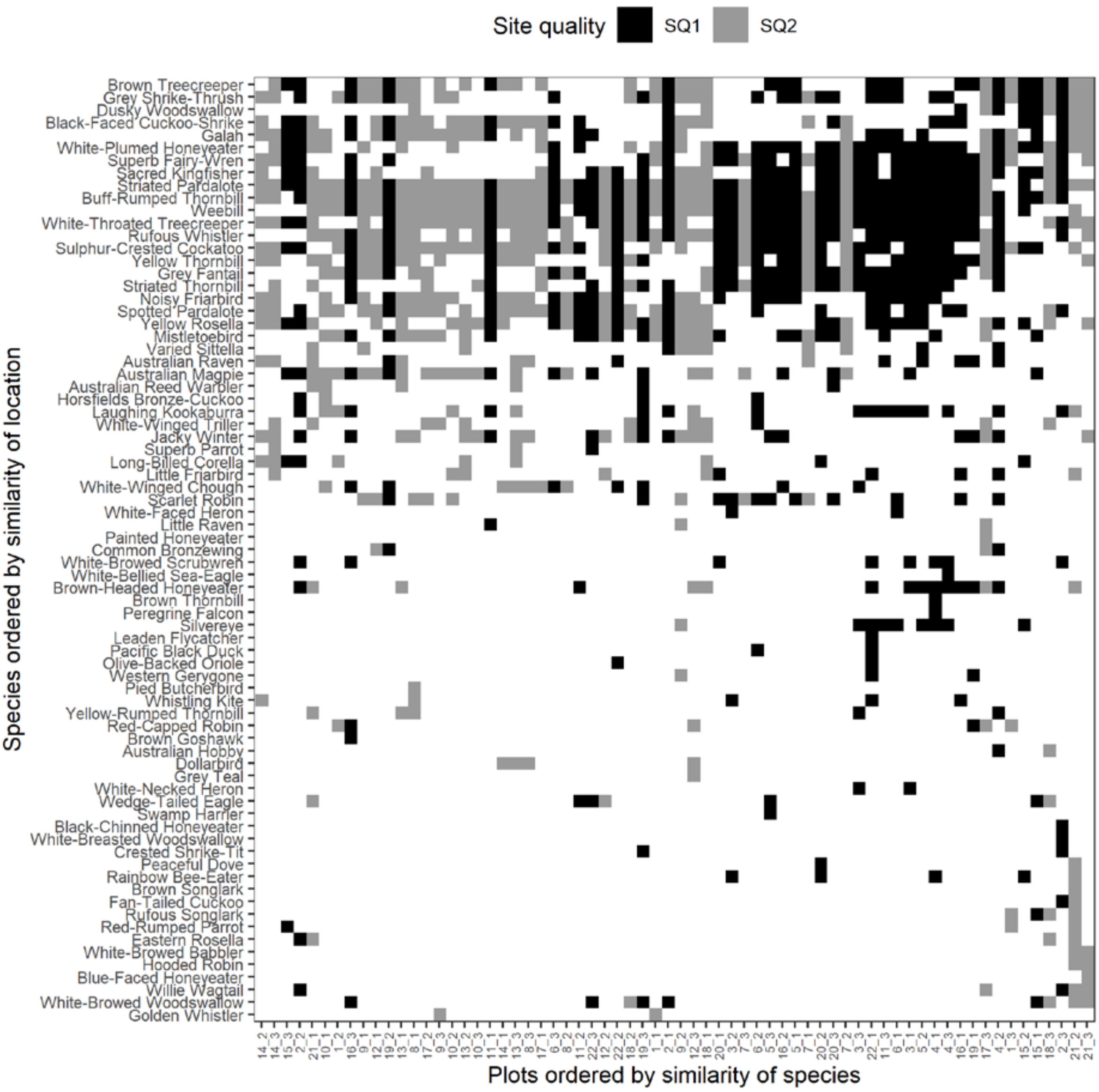

Figure 86 Hierarchical cross-classification of bird species, coloured by site quality (SQ1 and SQ2)

Sites that are close together on the x axis have a similar bird species composition; and species that are close together on the y axis tend to occur in similar plots.

8.3 Threatened bird species

Key result	No significant effects of ecological thinning on threatened bird species detected Nine threatened bird species were recorded in 2019. Between 7 and 9 have been recorded in previous years

Data collection

Data collection was as described above for bird species richness.

Data summary

Ten bird species that are listed as vulnerable under the NSW Biodiversity Conservation Act have been recorded in two or more survey years (Table 41). Nine were recorded in 2019.

Table 41 Threatened bird species recorded

Name	Habitat	Number of 9 hectare plots			
		2015	2017	2018	2019
Black-chinned honeyeater	Found in drier open forests and woodlands. Large feeding territories; species locally nomadic. Forages in upper branches, trunks and canopy; feeds on insects and nectar. Nests high in the crown of a tree.	1	–	–	1
Brown treecreeper	Found in river red gum forest bordering wetlands. Fallen timber is important for foraging. Nests in standing dead or live trees and tree stumps.	32	42	37	38
Dusky woodswallow	Forest with open or sparse understorey and groundcover of grasses, sedges or fallen woody debris. Forages primarily over leaf litter and dead timber.	9	7	9	12
Hooded robin	Prefers lightly wooded vegetation. Requires structurally diverse habitats. Perches on low stumps and branches to forage. Nests in tree fork or crevice.	1	2	–	2
Little eagle	Found in eucalypt forest and riparian woodlands. Nests in tall living trees. Soars above trees or swoops from trees to take prey from the ground, trees or bushes.	1	1	–	–
Painted honeyeater	Occurs in box-gum woodlands and other inland slopes vegetation. Nomadic. Specialist feeder on the fruits of mistletoes. Nests in the outer canopy of drooping tree foliage.	–	–	1	1
Scarlet robin	Abundant logs and fallen timber. Forages from low perches or the ground; sometimes the shrub or canopy layer. Nests are often found in a dead branch in a live tree, or a dead tree or shrub.	29	21	29	19
Superb parrot	Feeds on the ground and in understorey shrubs and trees. Nests in the hollows of large trees (dead or alive).	3	1	2	3
Varied sittella	Eucalypt forests with mature smooth-barked gums with dead branches. Forages in crevices in bark, dead branches and dead trees. Nests in an upright tree fork high in the canopy.	5	4	11	11
White-bellied sea eagle	Large areas of open water. Breeds in mature tall open forest close to foraging habitat. Nests in large emergent eucalypts often with emergent dead branches or large dead trees nearby.	2	–	2	1

Occurrence data indicates that the occurrence of all species fluctuates over time and does not suggest there are any strong effects of ecological thinning on threatened bird species (Figure 87). Increased occurrence of brown treecreepers and dusky woodswallows in thinned plots in Site Quality 2 appear to have been temporary. No models were run for threatened bird species occurrence.

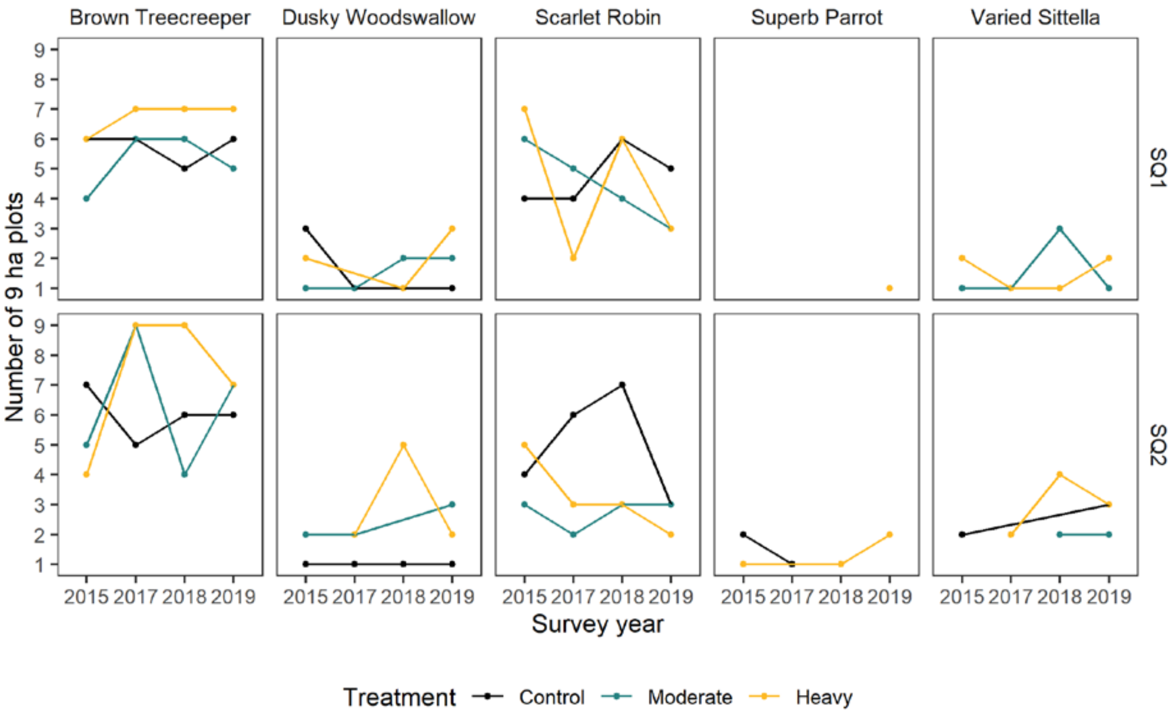

Figure 87 Number of 9 hectare plots with threatened bird species recorded (species with more than five records over four surveys), by ecological thinning treatment, survey year and site quality (SQ1 and SQ2)

9. Results: Bats

Data collection

Ultrasonic recording of bats occurred across five successive summers:

- December 2015 immediately before the commencement of the thinning phase
- February 2017 during the thinning phase but excluding plots where thinning was in progress
- February 2018, 2019 and 2020 after the thinning phase.

Each survey period occurred around the time of the new moon. At the centre of each plot an Anabat detector was mounted on a tree facing towards a flyway and all ultrasonic sounds were recorded for three nights. The recordings were processed through Anascheme to separate recordings that only contained noise from those containing bat calls, with tentative identifications being provided for the calls. Sonograms of the calls are visually inspected to validate species identification.

These data were used to assess overall bat activity, activity of two guilds (clutter specialists and avoiders) and activity of two individual species (that were reliably identified by Anascheme processing).

9.1 Overall bat activity

Key result	Overall bat activity was lowest in control plots and highest in heavily thinned plots in 2020 All treatment types have fluctuated over time Overall bat activity was increased in Site Quality 1, sites with higher FPC and surveys with higher temperature

Data summary

There were 64,640 sound recordings collected during 2020 of which 44,752 contained bat calls.

Model results

Patterns of activity were analysed using generalised linear mixed models with thinning state at the time of each survey as the primary fixed effect of interest but also using predictor variables of year, site quality and temperature (maximum of the preceding day and minimum during the night of recording), with plot being designated as the random effect due to repeated sampling.

Overall bat activity decreased during the thinning phase but increased on plots that had been heavily thinned, increased by 2018 but declined by 2019 before increasing again by 2020 (Table 42, Figure 88).

Analysis revealed that increasing site quality, foliage projective cover (FPC) and temperature had positive influences on bat activity.

Table 42 Model summary for overall bat activity

Response	Family	Link	Effect of time	Effect of thinning treatment	Effect of site quality	Confidence
Overall bat activity	Poisson	Log	Significant decline during active thinning; significant increase post-thinning	Significantly higher activity on treatment plots	Significantly higher activity on higher quality sites	R^2 = 47.2% (24.5% from fixed factors)

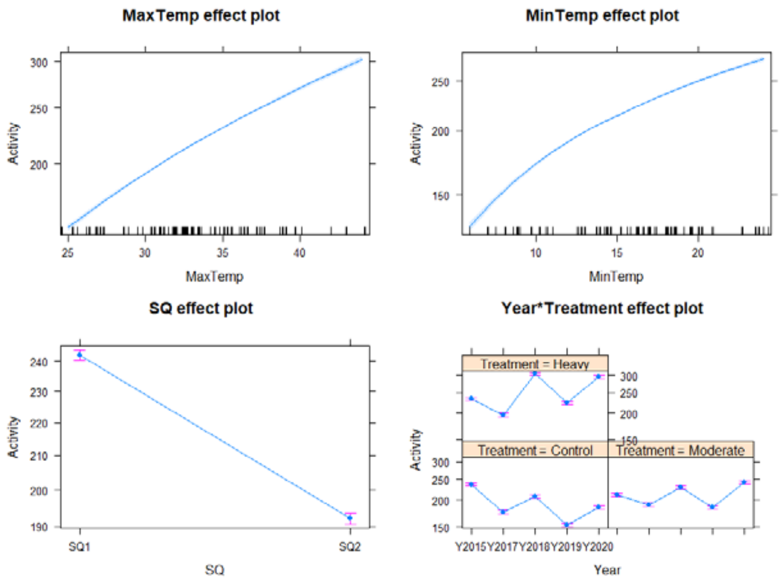

Figure 88 Model results for all bat activity, showing the modelled relationship between activity (passes per night per plot, on the y axis) and the explanatory variables

9.2 Bat guild activity: clutter specialists

Key result	Clutter specialist activity was lowest on plots that had been heavily thinned

Data summary

Species in the genus *Nyctophilus* have indistinguishable calls but all use the same feeding strategy of searching around vegetation for prey, and are grouped as the clutter specialists guild.

Model results

Overall activity initially declined across time, but returned to 2015 levels by 2019, before declining again by 2020, and was lowest on plots that had been heavily thinned (Table 43, Figure 89).

Analysis revealed that increasing site quality, FPC and temperature had positive influences on bat activity.

Table 43 Linear mixed model summary for clutter specialist guild activity

Response	Family	Link	Effect of time	Effect of thinning treatment	Effect of site quality	Confidence
Clutter specialists bat activity	Poisson	Log	Significant changes across the period	The effect varied markedly between years	Significantly higher activity on higher quality sites	R^2 = 56.4% (51.7% from fixed factors)

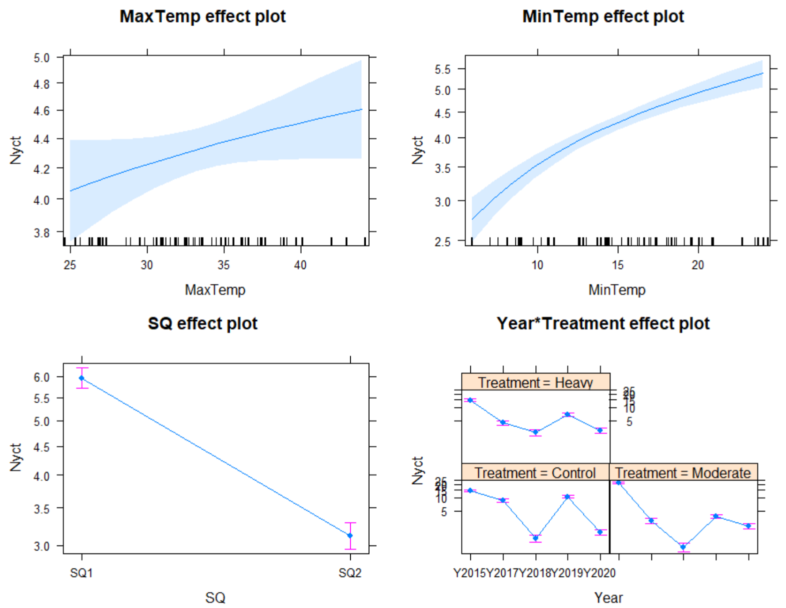

Figure 89 Model results for clutter specialist guild activity, showing the modelled relationship between activity (passes per night per plot, on the y axis) and the explanatory variables

9.3 Bat guild activity: clutter avoiders

Key result	Clutter avoider activity was highest on plots that had been heavily thinned, with marked fluctuations over previous years

Data summary

Bat species detected in the forest, excluding the genus *Nyctophilus,* have feeding strategies that avoid clutter.

Model results

Overall activity initially declined followed by marked fluctuations and was highest on plots that had been heavily thinned (Table 44, Figure 90).

Analysis revealed that increasing site quality, FPC and temperature had positive influences on bat activity.

Table 44 Linear mixed model summary for clutter avoider activity

Response	Family	Link	Effect of time	Effect of thinning treatment	Effect of site quality	Confidence
Clutter avoiders bat activity	Poisson	Log	Significant fluctuations across time	Significantly higher activity on treatment plots especially heavily treated	Significantly higher activity on higher quality sites	R^2 = 47.1% (24.6% from fixed factors)

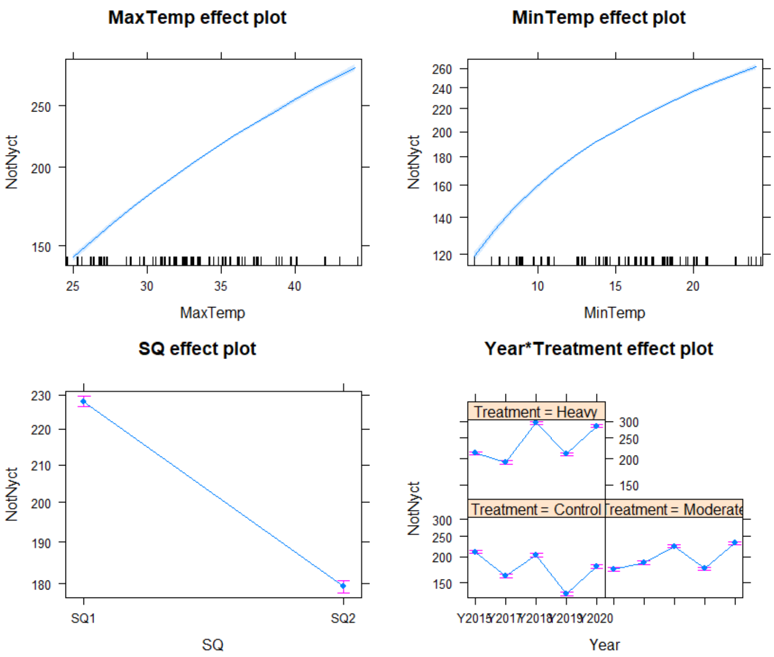

Figure 90 Model results for clutter avoider bat activity, showing the modelled relationship between activity (passes per night per plot, on the y axis) and the explanatory variables

9.4 Individual bat species: White-striped mastiff bat

Key result	White-striped mastiff bat activity was slightly higher in thinned plots than control plots in 2020

Data summary

White-striped mastiff bats are fast high-fliers with powerful calls that often feed above the canopy.

Model results

Overall activity was lowest during the thinning phase but increased on plots that had been heavily thinned (Table 45, Figure 91). There had been a decline from 2018 to 2019.

Analysis revealed that site quality had no detectable effect but increasing temperature had positive influences on bat activity while increasing FPC had a negative impact.

Table 45 Model summary for white-striped mastiff bat activity

Response	Family	Link	Effect of time	Effect of thinning treatment	Effect of site quality	Confidence
White-striped mastiff bat activity	Poisson	Log	Significant annual differences which were less pronounced on treatment plots	Significantly higher activity on treatment plots	No significant effect	R^2 = 38.9% (24.9% from fixed factors)

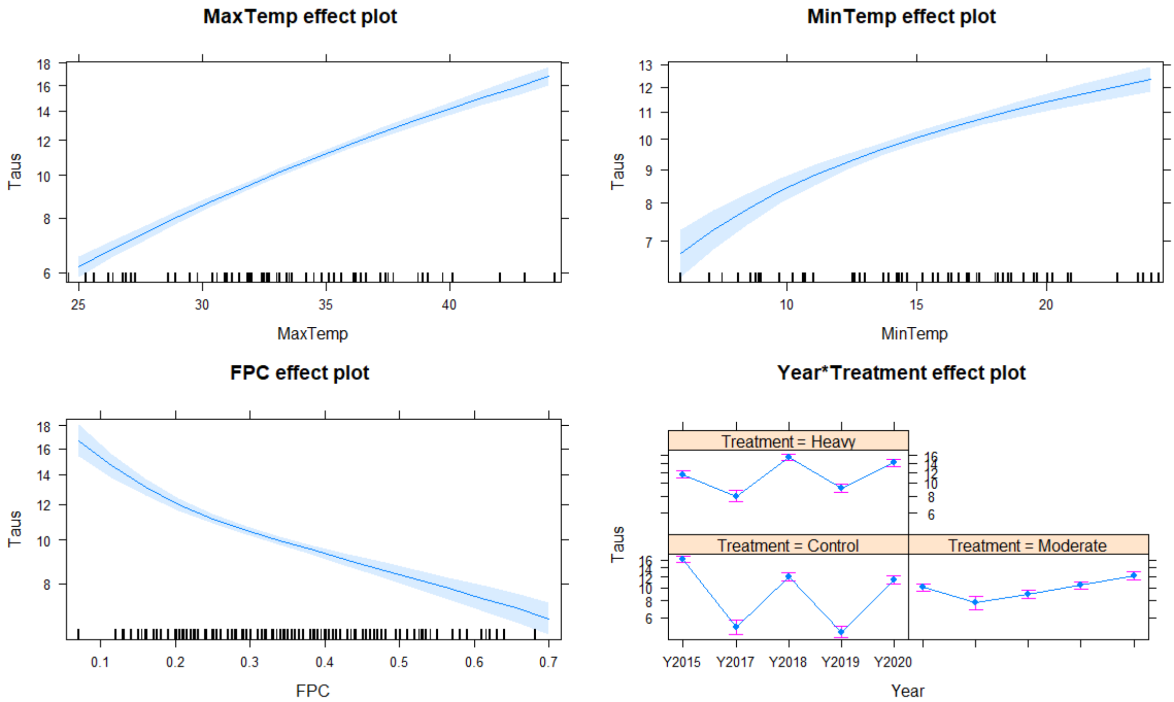

Figure 91 Model results for white-striped mastiff bat activity, showing the modelled relationship between activity (passes per night per plot, on the y axis) and the explanatory variables

9.5 Individual bat species: large forest bat

Key result	Large forest bat activity was lowest in control plots and highest in heavily thinned plots in 2020

Data summary

Large forest bats are the largest and least manoeuvrable of the *Vespedalus* species. They often hunt in the spaces between the canopies.

Model results

Overall activity was not significantly impacted during the thinning phase but decreased by 2018 (Table 46, Figure 92). However, activity increased on plots that had been heavily thinned.

Analysis revealed that site quality had no detectable effect but increasing temperature and FPC, indicative of larger trees, had positive influences on bat activity.

A strong impact of the fixed factor of plot in the model indicated a patchy distribution within the forest being driven by factors other than those studied.

Table 46 Model summary for large forest bat activity

Response	Family	Link	Effect of time	Effect of thinning treatment	Effect of site quality	Confidence
Large forest bat activity	Poisson	Log	Some fluctuations across time	Significantly more activity in thinned plots	No significant effect	R^2 = 44.6% (16.7% from fixed factors)

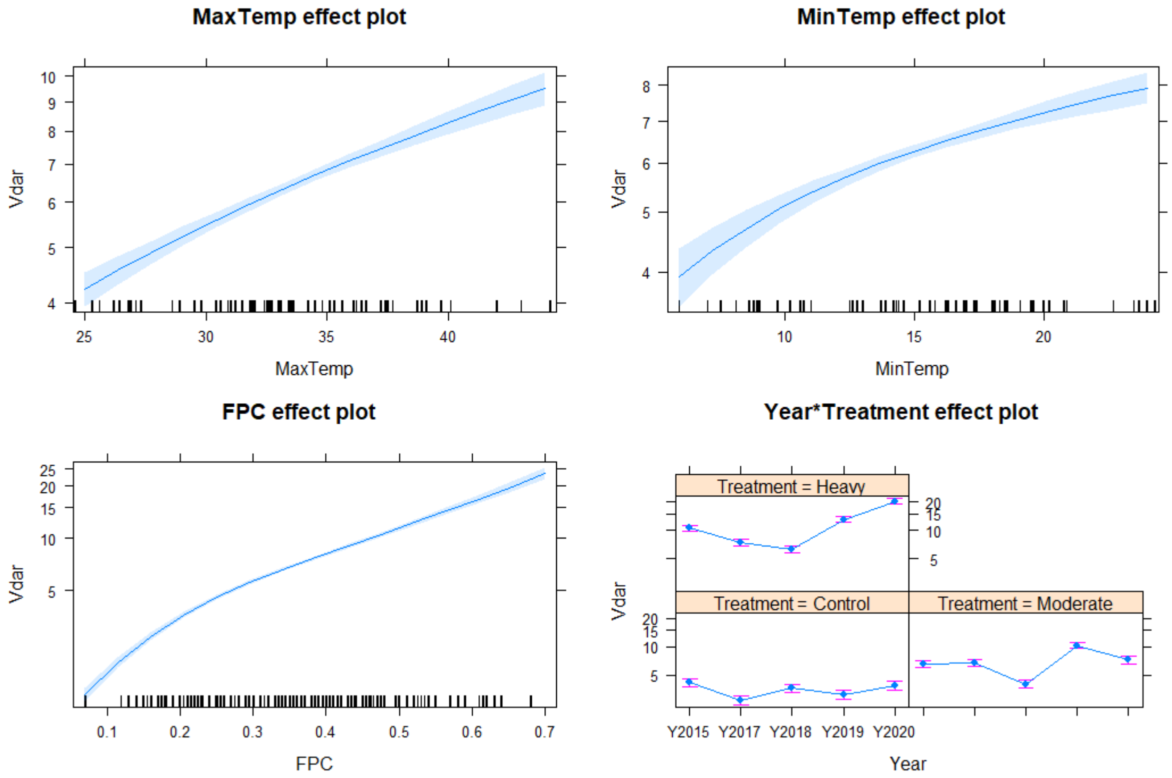

Figure 92 Model results for large forest bat activity, showing the modelled relationship between activity (passes per night per plot, on the y axis) and the explanatory variables

10. Results: Fox scats

Fox scat surveys have been conducted in each survey year, by searching each 0.04 hectare floristic plot and sending any uncertain specimens to a scat analysis expert.

In total, fewer than 10 scats have been recorded in all four surveys to date. These data were insufficient to analyse or report on.

11. Results: Coppice

Data collection

New shoots (coppice regrowth) may emerge from cut stumps of *Eucalyptus camaldulensis*. Coppice regrowth from previous commercial logging operations is evident in many large trees in the study. Roundup Biactive® was sprayed onto each cut stump in the ecological thinning operations to prevent coppice growth.

Eucalyptus camaldulensis saplings that were too small for removal by thinning equipment were pushed over during the ecological thinning operations where unavoidable. New shoots may emerge from pushed over or snapped off saplings.

Data on coppice regrowth from cut stumps and pushed over saplings were recorded in three 0.04 hectare subplots in each 9 hectare plot in 2019. The number of seedling- and sapling-sized stems emerging from all stumps (old and new) and pushed over saplings was recorded.

Data summary

For coppice growth emerging from stumps, the strongest coppice response was recorded in Site Quality 2 plots that were thinned after flooding (average of 12–18 emergent stems per 0.04 hectare subplot) and the smallest coppice response was recorded in Site Quality 1 plots that were moderately thinned prior to flooding (average of three emergent stems per 0.04 hectare subplot) (Figure 3, Figure 93). Generally, heavily thinned plots had a higher coppice response from stumps than moderately thinned plots.

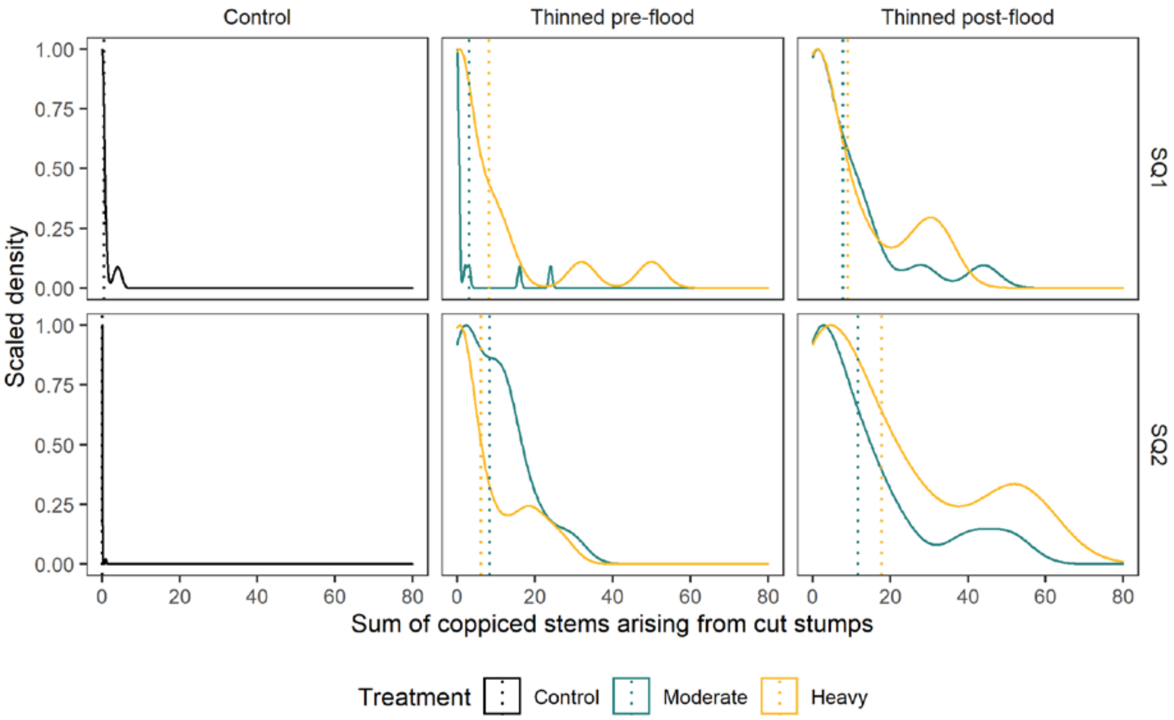

Figure 93 Density plots and averages (dotted lines) of coppiced stems arising from cut stumps per 0.04 hectare subplot, by ecological thinning treatment, order of thinning and flooding, and site quality (SQ1 and SQ2)

For coppice arising from pushed over saplings, the strongest coppice response was recorded on plots in Site Quality 1 that were moderately thinned prior to flooding and the smallest responses were in heavily thinned plots in Site Quality 2 (Figure 94). Generally, moderately thinned plots had a higher coppice response from pushed over saplings than heavily thinned plots.

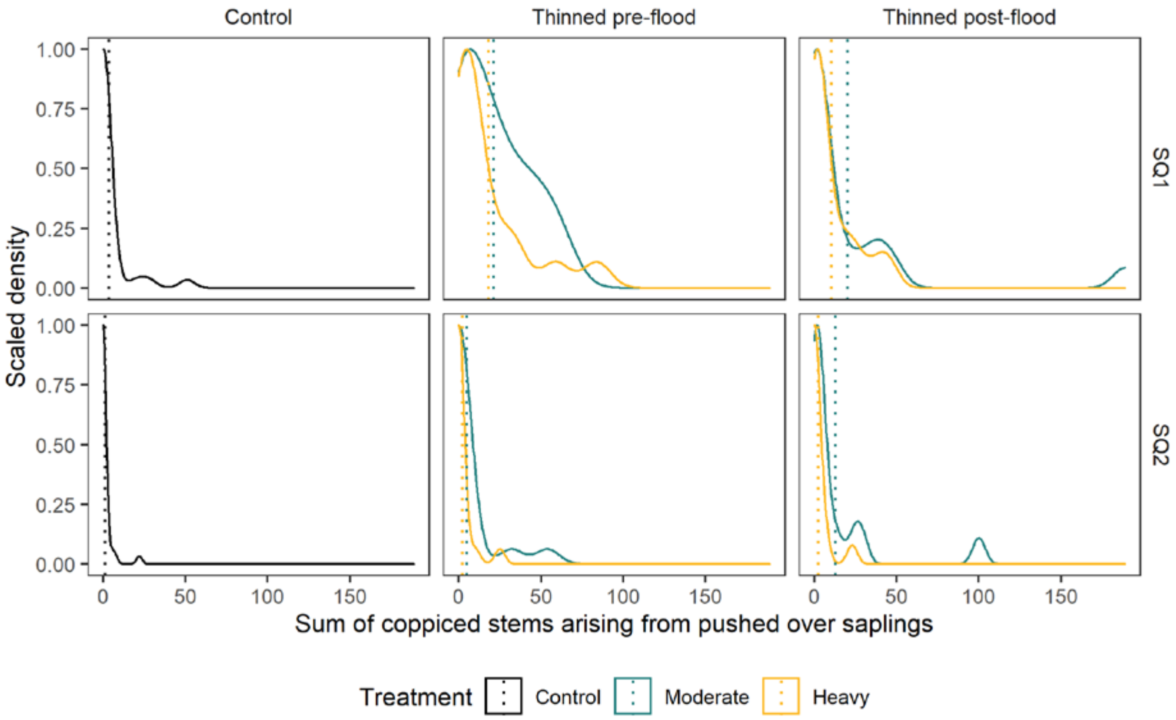

Figure 94 Density plots and averages (dotted lines) of coppiced stems arising from pushed over samplings per 0.04 hectare subplot, by ecological thinning treatment, order of thinning and flooding, and site quality (SQ1 and SQ2)

Coppicing activity from both stumps and pushed over stems was more common on plots thinned in 2016 prior to flooding (44% of sites had coppicing pushed over stems and 49% had coppicing stumps) than 2017 post-flooding (49% of sites had sprouting pushed over stems and 62% had coppicing stumps).

Models were not run for coppicing activity in 2019.

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