Mission Creek Overstory-Understory Analysis

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7/29/2020

Introductory Note

This Rmarkdown document contains the analysis and graphs for the manuscript by Rossman et al., titled 'Long-term effects of fuels treatments, overstory structure, and wildfire on tree regeneration in dry forests of central Washington'.

Background

The initial FFS study design was a factorial test of thinning and burning. Analysis of this design has been complicated by i) the fact that prescribed fires occurred in 2004 (four units) and 2006 (two units), and differed in burn severity between years, and ii) a wildfire burned four units in 2012.

Prior analyses set 2005 as 'post1' for 10 units and 2007 as 'post1' for the two units that were burned later. However, this complicates comparisons because it is impossible to distinguish the effects of those later burns from the fact that they were monitored in a year with different growing conditions.

New Approach

Our approach is to:

- Set 2004 (overstory) or 2005 (understory) as 'Early' or 'post1' for all plots in all units.
- Set 2015 as 'Late' or 'post2' for all plots.
- Distinguish burns that occurred before or after the post1 measurement.

- Verify thin and burn treatment codes on the basis of the thinning and/or fire intensity experienced.

Advantages:

- Cleaner analysis, because post1 more directly reflects treatment rather than interannual variation.
- Allows analysis of all plots in all units (vs. separate analyses of wildfire effects and of treatment effects in non-wildfire units).

Disadvantages:

- Analyses are not directly comparable with those done previously.

Details

Structure for analysis of variables:

Pre-treatment sampling: > Response ~ SDI.plot

Early sampling: > Response ~ (SDI.plot + Thin + Fire.post1)^2

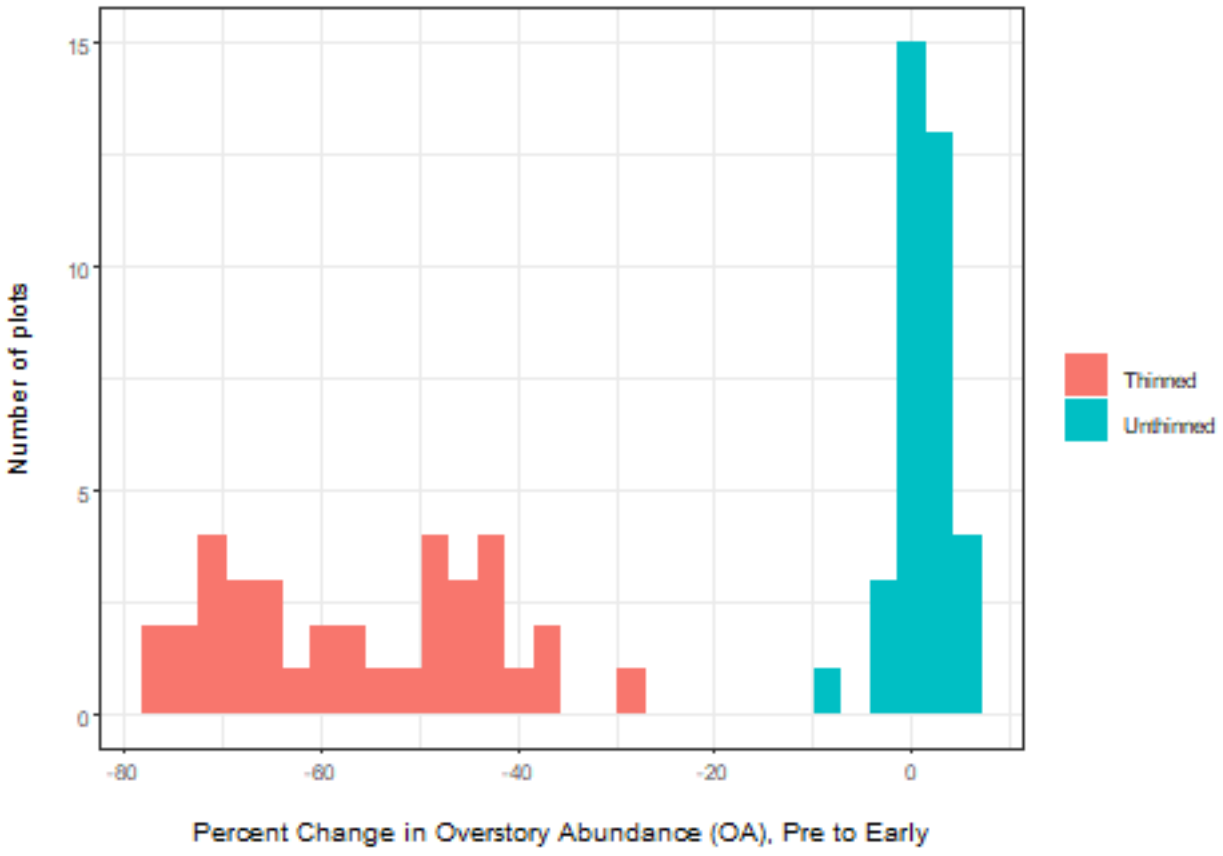
Late sampling: > Response ~ (SDI.plot + Thin + Fire.post1 + Fire.post2)^2

Rationale:

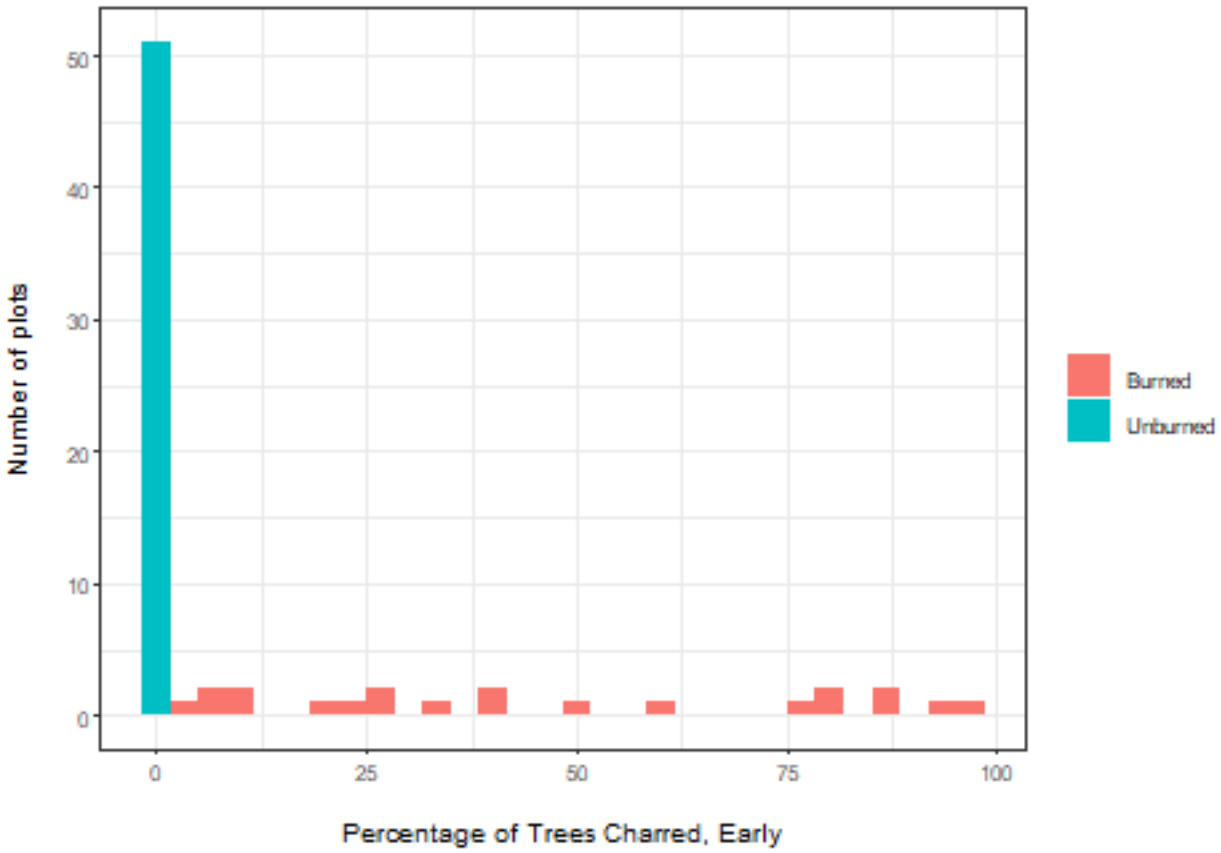
- SDI.plot is our measure of the overstory in the plot. Name changed to 'OA' (Overstory Abundance) in manuscript.
- Thin term (Yes/No) includes effects other than the change in the overstory (e.g., accumulation of fine fuels)
- Fire.post1 (Yes/No) reflects whether plots burned before the Early (post1) remeasurement.
- Fire.post2 (Yes/No) reflects whether pltos burned between the Early (post1) and Late (post2) remeasurements.
- Thin and Fire terms in chronological order.
- All two-way interactions possible.
- Not testing more complex interactions as they would be too complicated to explain and we do not have enough plots to do so robustly.

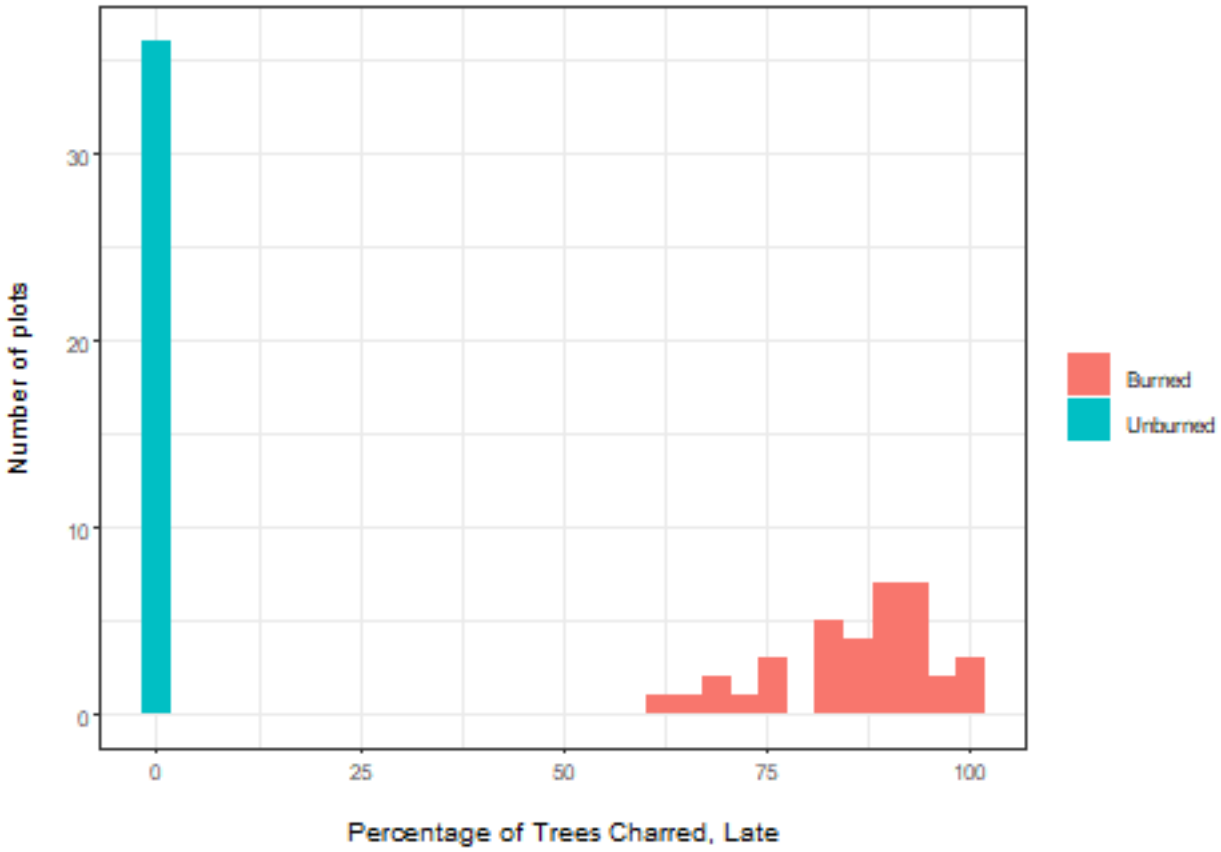
Use GLM or LM depending on distribution of data. Not using mixed models because plots are assigned to treatments based on the actual intensity of Thin or Fire, and because of singularities during model fit.

Thinning intensity

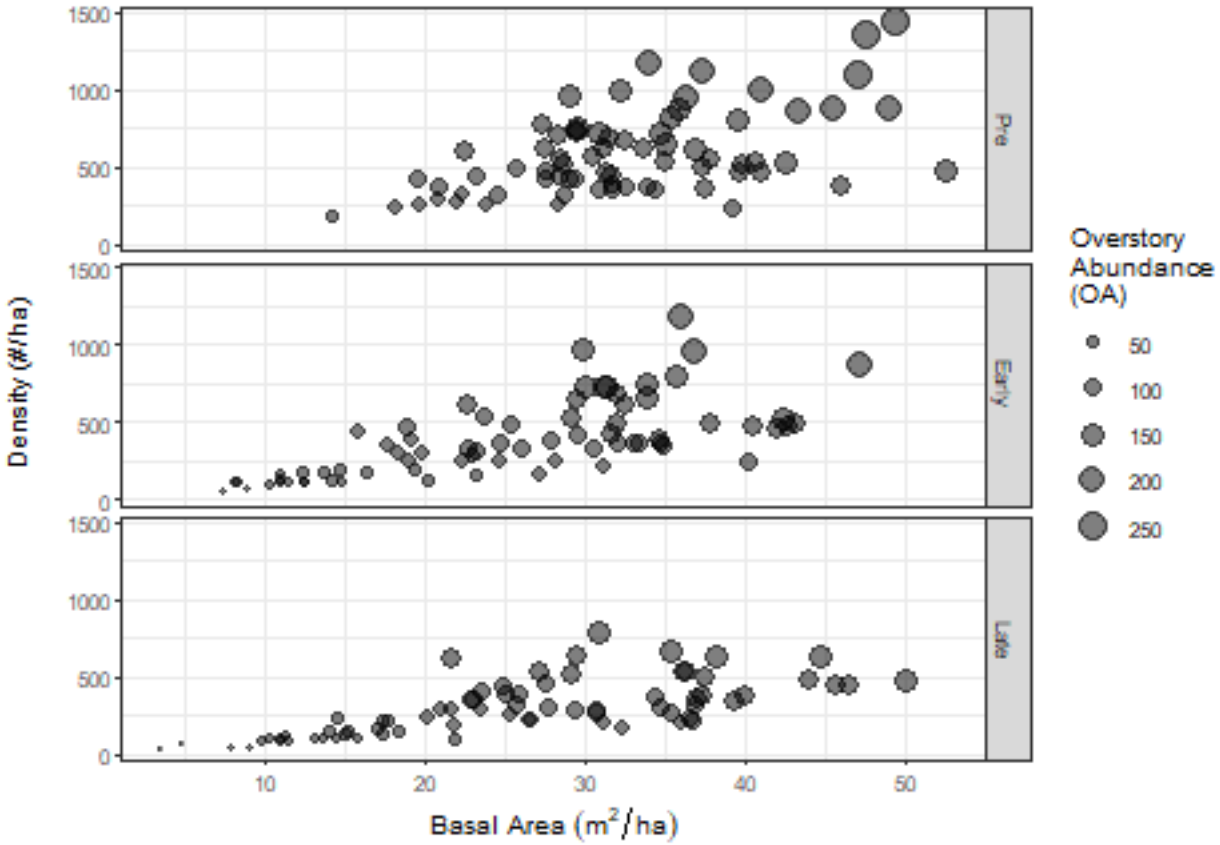


Burn severity




Number of plots
30
20
10
0
0
25
50
75
100
Percentage of Trees Charred, Late
Burned
Unburned

Relate overstory structure metrics (overstory abundance, basal area, density)



Overstory Dynamics

Using SDI.plot as our index of the overstory.

Ingrowth Compared poisson and negative binomial models; negative binomial fit much better.

```
## Warning in anova.negbin(Ingrowth.res.nb <- glm.nb(Ingrowth ~ (SDI.plot_post1 + :
## tests made without re-estimating 'theta'
```

```
## Analysis of Deviance Table
##
## Model: Negative Binomial(0.5118), link: log
##
## Response: Ingrowth
##
## Terms added sequentially (first to last)
##
##
##                                    Df Deviance Resid. Df Resid. Dev Pr(>Chi)
```

```
## NULL                                                    71     73.847
## SDI.plot_post1                       1   0.1256        70     73.721  0.72299
## Thin.actual                          1   5.5595        69     68.161  0.01838 *
## Fire.actual.post1                    1   2.0595        68     66.102  0.15126
## Fire.actual.post2                    1   3.3597        67     62.742  0.06681 .
## SDI.plot_post1:Thin.actual           1   1.8927        66     60.849  0.16890
## SDI.plot_post1:Fire.actual.post1     1   1.1678        65     59.682  0.27986
## SDI.plot_post1:Fire.actual.post2     1   0.1447        64     59.537  0.70364
## Thin.actual:Fire.actual.post1        1   4.0842        63     55.453  0.04329 *
## Thin.actual:Fire.actual.post2        1   1.1258        62     54.327  0.28868
## Fire.actual.post1:Fire.actual.post2  1   0.4248        61     53.902  0.51455
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
## [1] 0.7285256
```

Thin, Thin:EarlyFire; LateFire marginal

Overstory Mortality Mortality calculated as density change minus ingrowth. Expressed as positive value so can be analyzed using GLM. Compared poisson and negative binomial models; negative binomial fit much better.

```
## Warning in anova.negbin(Mortality.res.nb <- glm.nb(Mortality ~ (SDI.plot_post1
## + : tests made without re-estimating 'theta'
```

```
## Analysis of Deviance Table
##
## Model: Negative Binomial(2.1195), link: log
##
## Response: Mortality
##
## Terms added sequentially (first to last)
##
##
##                                     Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
## NULL                                                    71    209.694
## SDI.plot_post1                       1   76.334        70    133.360 < 2.2e-16
## Thin.actual                          1    0.549        69    132.811  0.458732
## Fire.actual.post1                    1    2.470        68    130.341  0.116011
## Fire.actual.post2                    1   33.156        67     97.185 8.506e-09
## SDI.plot_post1:Thin.actual           1    1.375        66     95.810  0.241033
## SDI.plot_post1:Fire.actual.post1     1    9.990        65     85.820  0.001574
## SDI.plot_post1:Fire.actual.post2     1    3.265        64     82.555  0.070763
## Thin.actual:Fire.actual.post1        1    1.019        63     81.536  0.312777
## Thin.actual:Fire.actual.post2        1    2.947        62     78.589  0.086025
## Fire.actual.post1:Fire.actual.post2  1    2.318        61     76.270  0.127866
##
## NULL
## SDI.plot_post1                      ***
## Thin.actual
## Fire.actual.post1
## Fire.actual.post2                   ***
```

```
## SDI.plot_post1:Thin.actual
## SDI.plot_post1:Fire.actual.post1    **
## SDI.plot_post1:Fire.actual.post2    .
## Thin.actual:Fire.actual.post1
## Thin.actual:Fire.actual.post2       .
## Fire.actual.post1:Fire.actual.post2
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
## [1] 0.08999901
```

SDI.plot, LateFire, SDI.plot:LateFire

Overstory Growth (Basal Area Increment)

```
## Analysis of Variance Table
##
## Response: BAI
##                                   Df  Sum Sq Mean Sq F value   Pr(>F)
## SDI.plot_post1                     1  1.2179 1.21787  5.9724 0.017439 *
## Thin.actual                        1  0.2075 0.20752  1.0177 0.317054
## Fire.actual.post1                  1  0.8553 0.85525  4.1941 0.044875 *
## Fire.actual.post2                  1  1.8433 1.84326  9.0393 0.003833 **
## SDI.plot_post1:Thin.actual         1  0.6527 0.65266  3.2006 0.078574 .
## SDI.plot_post1:Fire.actual.post1   1  1.7472 1.74723  8.5684 0.004801 **
## SDI.plot_post1:Fire.actual.post2   1  0.0867 0.08667  0.4250 0.516885
## Thin.actual:Fire.actual.post1      1  0.3177 0.31766  1.5578 0.216757
## Thin.actual:Fire.actual.post2      1  0.0702 0.07023  0.3444 0.559456
## Fire.actual.post1:Fire.actual.post2  1  0.0787 0.07872  0.3861 0.536691
## Residuals                         61 12.4389 0.20392
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

SDI.plot, EarlyFire, LateFire; SDI.plot:EarlyFire; (SDI.plot:Thin marginal)

Regeneration Frequency (2015)

Graph regeneration frequency against regeneration density

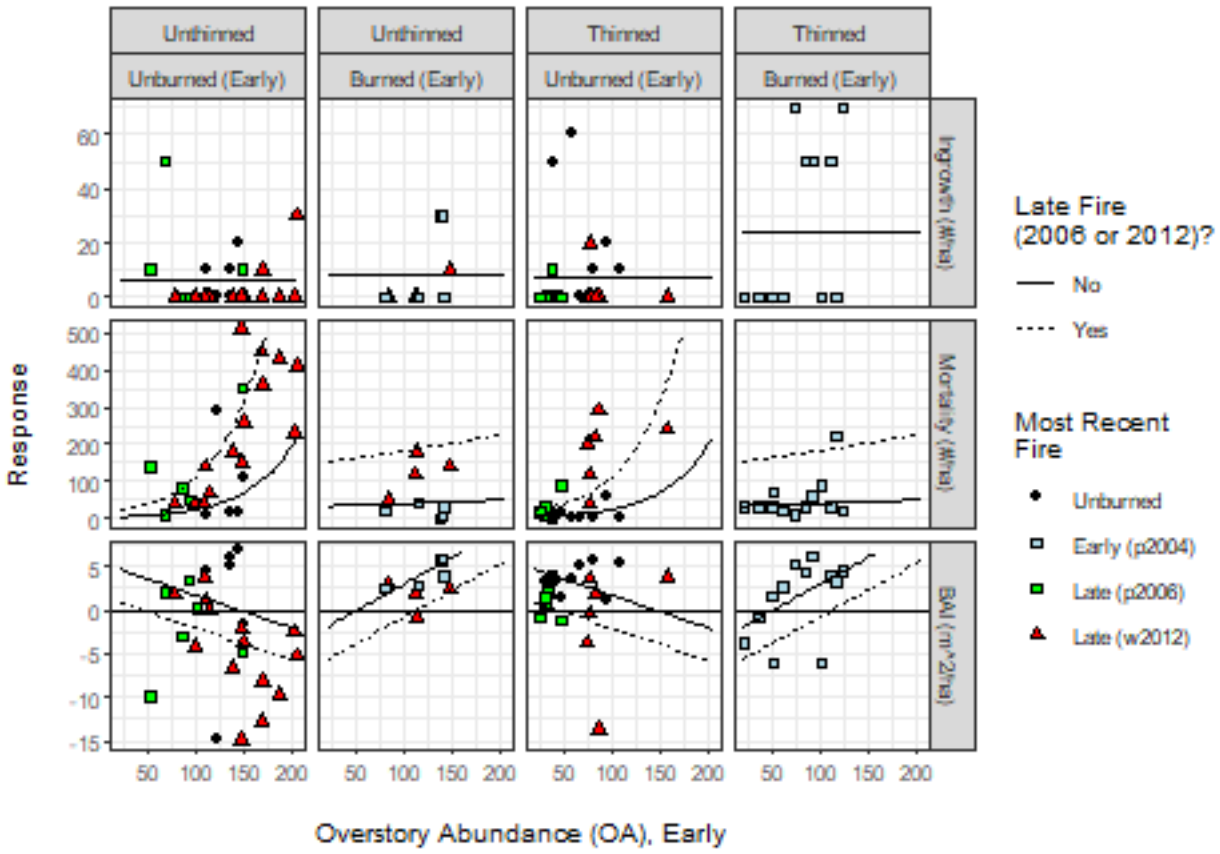
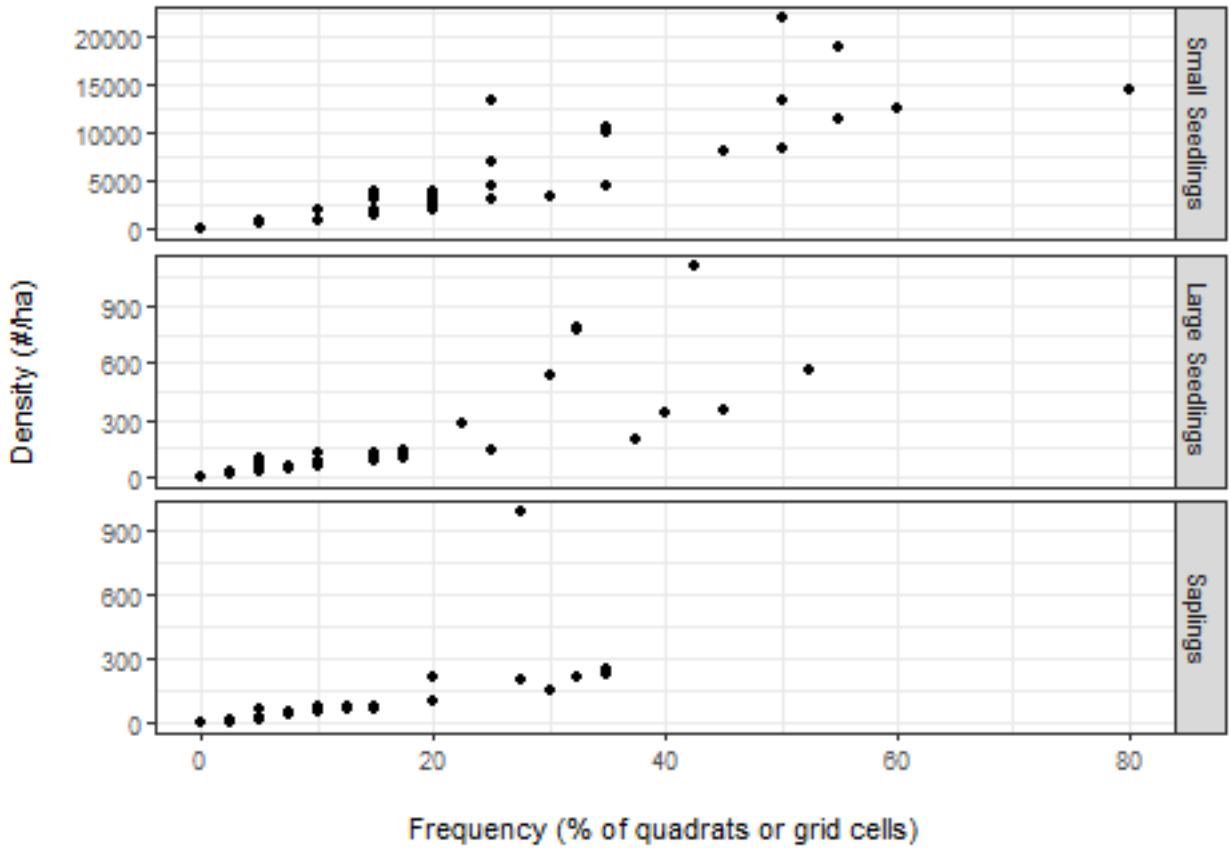


Figure 1: Overstory dynamics between Early and Late post-treatment measurements. Note difference in scale of y-axis among rows of panels.



All data from 2015.

Frequency is number of microplots that contained small seedlings, and number of grid cells that contained large seedlings or saplings - need to keep this in mind when comparing between regen classes..

Analyzed via GLM with negative binomial distribution.

```
anova(SmallSeedling.N.res <- glm.nb(SmallSeedling.N ~ (SDI.plot_post2 + Thin.actual + Fire.actual.post1
                                    data = master, maxit = 100),
      test = "Chisq")
```

Small Seedlings

```
## Analysis of Deviance Table
##
## Model: Negative Binomial(2.5371), link: log
##
## Response: SmallSeedling.N
##
## Terms added sequentially (first to last)
##
##
##                                    Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
```

```
## NULL                                                    71    129.436
## SDI.plot_post2                        1    0.544        70    128.893  0.460930
## Thin.actual                           1    4.015        69    124.878  0.045106
## Fire.actual.post1                     1    7.693        68    117.185  0.005544
## Fire.actual.post2                     1   32.875        67     84.310 9.828e-09
## SDI.plot_post2:Thin.actual            1    1.042        66     83.269  0.307438
## SDI.plot_post2:Fire.actual.post1      1    0.085        65     83.183  0.770061
## SDI.plot_post2:Fire.actual.post2      1    2.185        64     80.998  0.139357
## Thin.actual:Fire.actual.post1         1    0.175        63     80.823  0.675683
## Thin.actual:Fire.actual.post2         1    0.063        62     80.760  0.801827
## Fire.actual.post1:Fire.actual.post2   1    3.813        61     76.947  0.050843
##
## NULL
## SDI.plot_post2
## Thin.actual                          *
## Fire.actual.post1                    **
## Fire.actual.post2                    ***
## SDI.plot_post2:Thin.actual
## SDI.plot_post2:Fire.actual.post1
## SDI.plot_post2:Fire.actual.post2
## Thin.actual:Fire.actual.post1
## Thin.actual:Fire.actual.post2
## Fire.actual.post1:Fire.actual.post2 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Thin, Fire.actual.post1, Fire.actual.post2 (Fire.actual.post1:Fire.actual.post2 marginal)

```
anova(LargeSeedling.N.res <- glm.nb(LargeSeedling.N ~ (SDI.plot_post2 + Thin.actual + Fire.actual.post1
                                    data = master, maxit = 100),
      test = "Chisq")
```

Large Seedlings

```
## Analysis of Deviance Table
##
## Model: Negative Binomial(0.7468), link: log
##
## Response: LargeSeedling.N
##
## Terms added sequentially (first to last)
##
##
##                                    Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
## NULL                                                    71    111.952
## SDI.plot_post2                      1   2.1536        70    109.798  0.142240
## Thin.actual                         1   7.6317        69    102.167  0.005735
## Fire.actual.post1                   1   1.9674        68    100.199  0.160724
## Fire.actual.post2                   1   8.0143        67     92.185  0.004641
## SDI.plot_post2:Thin.actual          1  16.6486        66     75.536 4.498e-05
## SDI.plot_post2:Fire.actual.post1    1   0.3540        65     75.182  0.551841
```

```
## SDI.plot_post2:Fire.actual.post2     1   5.5807        64     69.602  0.018160
## Thin.actual:Fire.actual.post1        1   0.0082        63     69.593  0.927953
## Thin.actual:Fire.actual.post2        1   0.3267        62     69.267  0.567620
## Fire.actual.post1:Fire.actual.post2  1   0.6816        61     68.585  0.409036
##
## NULL
## SDI.plot_post2
## Thin.actual                         **
## Fire.actual.post1
## Fire.actual.post2                   **
## SDI.plot_post2:Thin.actual          ***
## SDI.plot_post2:Fire.actual.post1
## SDI.plot_post2:Fire.actual.post2    *
## Thin.actual:Fire.actual.post1
## Thin.actual:Fire.actual.post2
## Fire.actual.post1:Fire.actual.post2
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Thin.actual, Fire.actual.post2, SDI.plot_post2:Thin.actual, SDI.plot_post2:Fire.actual.post2

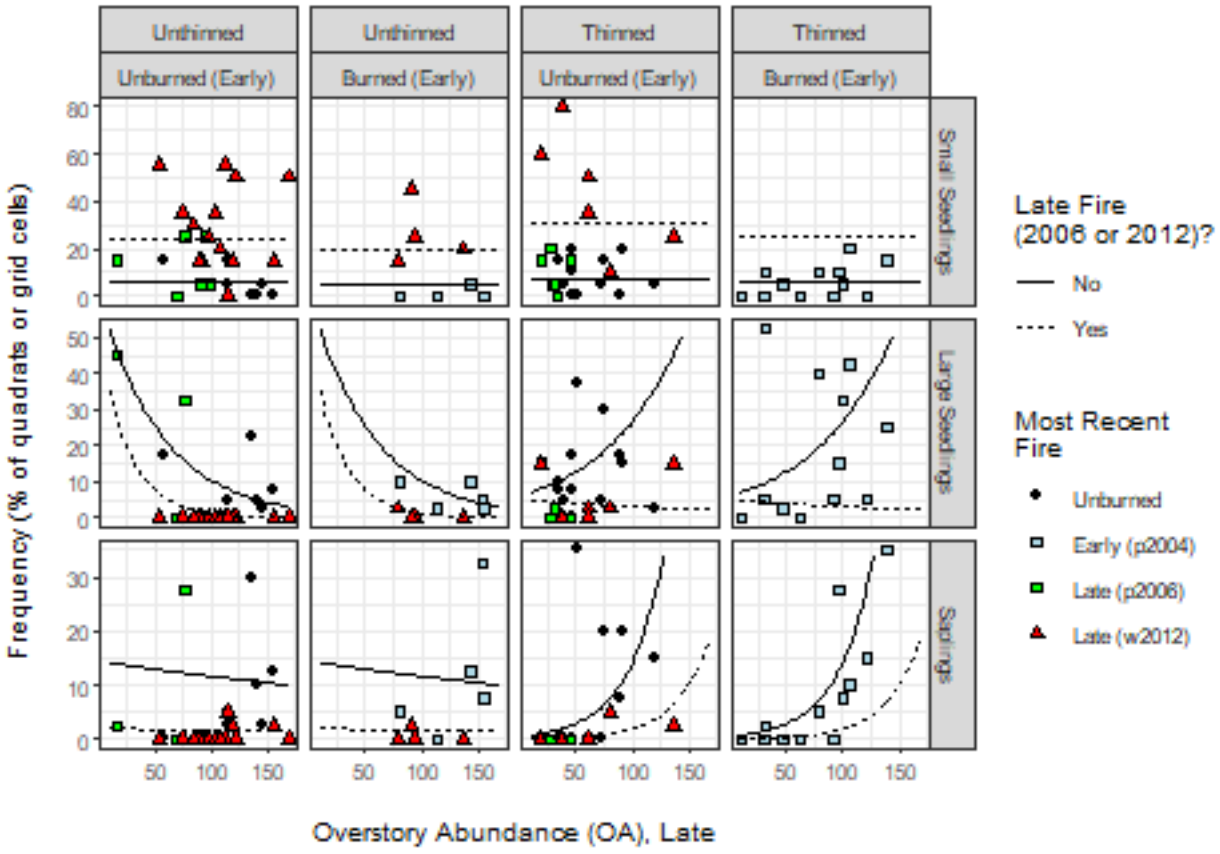
```
anova(Sapling.N.res <- glm.nb(Sapling.N ~ (SDI.plot_post2 + Thin.actual + Fire.actual.post1 + Fire.actua
                              data = master, maxit = 100),
      test = "Chisq")
```

Saplings

```
## Analysis of Deviance Table
##
## Model: Negative Binomial(0.6278), link: log
##
## Response: Sapling.N
##
## Terms added sequentially (first to last)
##
##
##                                     Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
## NULL                                                    71    105.626
## SDI.plot_post2                       1  15.7589        70     89.867 7.195e-05
## Thin.actual                          1   7.5246        69     82.343  0.006086
## Fire.actual.post1                    1   0.0571        68     82.286  0.811066
## Fire.actual.post2                    1   9.4900        67     72.796  0.002066
## SDI.plot_post2:Thin.actual           1   7.9010        66     64.895  0.004941
## SDI.plot_post2:Fire.actual.post1     1   1.7914        65     63.103  0.180760
## SDI.plot_post2:Fire.actual.post2     1   0.1118        64     62.992  0.738154
## Thin.actual:Fire.actual.post1        1   0.0033        63     62.988  0.954061
## Thin.actual:Fire.actual.post2        1   1.7065        62     61.282  0.191436
## Fire.actual.post1:Fire.actual.post2  1   0.7999        61     60.482  0.371135
##
## NULL
## SDI.plot_post2                      ***
```

```
## Thin.actual                          **
## Fire.actual.post1
## Fire.actual.post2                    **
## SDI.plot_post2:Thin.actual           **
## SDI.plot_post2:Fire.actual.post1
## SDI.plot_post2:Fire.actual.post2
## Thin.actual:Fire.actual.post1
## Thin.actual:Fire.actual.post2
## Fire.actual.post1:Fire.actual.post2
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

SDI, Thin, Fire.actual.post2, SDI:Thin



Colonization and Persistence

Colonization = number of microplots in which conifer seedlings were absent at start but present at end of interval divided by number of microplots in which conifer seedlings remained absent at end of interval.

Persistence = number of microplots in which conifer seedlings were present at start and end of interval divided by number of microplots in which conifer seedlings were present at start of interval. Opposite of extinction.

Analyzed using SDI at start of interval.

```
anova(pre.CONIF.N.res <- glm.nb(pre.Present ~ SDI.plot_pre,
                       data = master),
      test = "Chisq")
```

Pre

```
## Analysis of Deviance Table
##
## Model: Negative Binomial(0.7161), link: log
##
## Response: pre.Present
##
## Terms added sequentially (first to last)
##
##
##              Df Deviance Resid. Df Resid. Dev Pr(>Chi)
## NULL                             71     73.759
## SDI.plot_pre  1   5.0284        70     68.730  0.02493 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

SDI

```
anova(post1.CONIF.N.res <- glm.nb(post1.Present ~ (SDI.plot_post1 + Thin.actual + Fire.actual.post1)^2,
                                  data = master),
      test = "Chisq")
```

Post1

```
## Warning in anova.negbin(post1.CONIF.N.res <- glm.nb(post1.Present ~
## (SDI.plot_post1 + : tests made without re-estimating 'theta'
```

```
## Analysis of Deviance Table
##
## Model: Negative Binomial(15.2644), link: log
##
## Response: post1.Present
##
## Terms added sequentially (first to last)
##
##
##                                    Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
## NULL                                                   71    112.652
## SDI.plot_post1                      1   1.4519        70    111.200   0.22823
## Thin.actual                         1   1.5585        69    109.641   0.21189
## Fire.actual.post1                   1   4.6968        68    104.945   0.03022 *
## SDI.plot_post1:Thin.actual          1  16.6762        67     88.268 4.433e-05 ***
## SDI.plot_post1:Fire.actual.post1    1   1.2130        66     87.055   0.27074
```

```
## Thin.actual:Fire.actual.post1     1   1.0363        65     86.019   0.30869
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

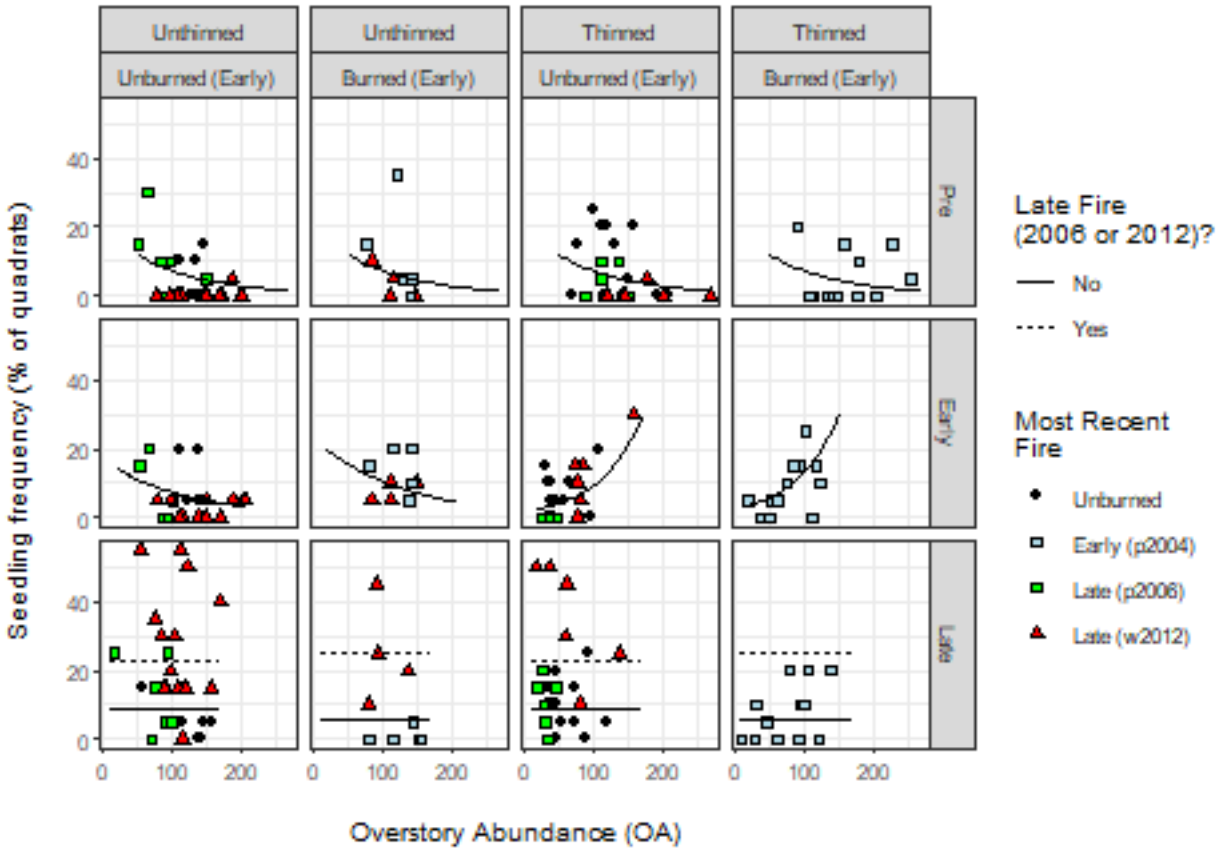
Fire, SDI:Thin

```
anova(post2.CONIF.N.res <- glm.nb(post2.Present ~ (SDI.plot_post2 + Thin.actual + Fire.actual.post1 + Fi
                                  data = master),
      test = "Chisq")
```

Post2

```
## Analysis of Deviance Table
##
## Model: Negative Binomial(3.5236), link: log
##
## Response: post2.Present
##
## Terms added sequentially (first to last)
##
##
##                                    Df Deviance Resid. Df Resid. Dev Pr(>Chi)
## NULL                                                   71    125.787
## SDI.plot_post2                      1   0.5256        70    125.262  0.46846
## Thin.actual                         1   3.5173        69    121.744  0.06073
## Fire.actual.post1                   1   6.0557        68    115.689  0.01386
## Fire.actual.post2                   1  26.1925        67     89.496 3.09e-07
## SDI.plot_post2:Thin.actual          1   2.3350        66     87.161  0.12649
## SDI.plot_post2:Fire.actual.post1    1   0.1746        65     86.987  0.67610
## SDI.plot_post2:Fire.actual.post2    1   2.6357        64     84.351  0.10449
## Thin.actual:Fire.actual.post1       1   0.4805        63     83.870  0.48821
## Thin.actual:Fire.actual.post2       1   0.4206        62     83.450  0.51666
## Fire.actual.post1:Fire.actual.post2 1   4.9652        61     78.485  0.02586
##
## NULL
## SDI.plot_post2
## Thin.actual                         .
## Fire.actual.post1                   *
## Fire.actual.post2                   ***
## SDI.plot_post2:Thin.actual
## SDI.plot_post2:Fire.actual.post1
## SDI.plot_post2:Fire.actual.post2
## Thin.actual:Fire.actual.post1
## Thin.actual:Fire.actual.post2
## Fire.actual.post1:Fire.actual.post2 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Fire.actual.post1, Fire.actual.post2, Fire.actual.post1:Fire.actual.post2 (Thin marginal)



Seedling Transitions

Pre to Early Colonization

```
## Warning in sqrt(1/i): NaNs produced

## Warning in sqrt(1/i): NaNs produced

## Warning in anova.negbin(pre.CONIF.col.res <- glm.nb(Colonization ~ (SDI.plot + :
## tests made without re-estimating 'theta'

## Analysis of Deviance Table
##
## Model: Negative Binomial(6.670614e+12), link: log
##
## Response: Colonization
##
## Terms added sequentially (first to last)
##
##
##                              Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
## NULL                                             71    115.407
## SDI.plot                      1  10.4429         70    104.965 0.0012312 **
## Thin.actual                   1   0.6419         69    104.323 0.4230064
```

```
## Fire.actual.post1              1   7.2093        68     97.113 0.0072526 **
## SDI.plot:Thin.actual           1  12.2542        67     84.859 0.0004642 ***
## SDI.plot:Fire.actual.post1     1   2.2304        66     82.629 0.1353160
## Thin.actual:Fire.actual.post1  1   1.4564        65     81.172 0.2275040
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

SDI, Fire.actual.post1, SDI:Thin

Persistence

```
## Warning in theta.ml(Y, mu, sum(w), w, limit = control$maxit, trace =
## control$trace > : iteration limit reached
```

```
## Warning in sqrt(1/i): NaNs produced
```

```
## Warning in theta.ml(Y, mu, sum(w), w, limit = control$maxit, trace =
## control$trace > : iteration limit reached
```

```
## Warning in sqrt(1/i): NaNs produced
```

```
## Warning in anova.negbin(pre.CONIF.per.res <- glm.nb(Persistence ~ (SDI.plot + :
## tests made without re-estimating 'theta'
```

```
## Analysis of Deviance Table
##
## Model: Negative Binomial(3795030167), link: log
##
## Response: Persistence
##
## Terms added sequentially (first to last)
##
##
##                               Df Deviance Resid. Df Resid. Dev Pr(>Chi)
## NULL                                              31     30.766
## SDI.plot                       1  0.34393        30     30.422   0.5576
## Thin.actual                    1  0.03733        29     30.384   0.8468
## Fire.actual.post1              1  1.51501        28     28.869   0.2184
## SDI.plot:Thin.actual           1  2.52569        27     26.344   0.1120
## SDI.plot:Fire.actual.post1     1  0.57997        26     25.764   0.4463
## Thin.actual:Fire.actual.post1  1  0.04443        25     25.719   0.8331
```

iteration limit reached

Early to Late Colonization

```
## Warning in anova.negbin(post1.CONIF.col.res <- glm.nb(Colonization ~ (SDI.plot
## + : tests made without re-estimating 'theta'
```

```
## Analysis of Deviance Table
##
## Model: Negative Binomial(4.5007), link: log
##
## Response: Colonization
##
## Terms added sequentially (first to last)
##
##
##                                    Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
## NULL                                                   71    132.803
## SDI.plot                            1   6.2209        70    126.582 0.0126248
## Thin.actual                         1   0.0002        69    126.582 0.9895094
## Fire.actual.post1                   1  11.6211        68    114.960 0.0006521
## Fire.actual.post2                   1  29.7930        67     85.167 4.807e-08
## SDI.plot:Thin.actual                1   2.6046        66     82.563 0.1065530
## SDI.plot:Fire.actual.post1          1   0.7468        65     81.816 0.3874991
## SDI.plot:Fire.actual.post2          1   3.5781        64     78.238 0.0585461
## Thin.actual:Fire.actual.post1       1   0.4269        63     77.811 0.5134959
## Thin.actual:Fire.actual.post2       1   1.1893        62     76.622 0.2754630
## Fire.actual.post1:Fire.actual.post2 1   6.8083        61     69.813 0.0090736
##
## NULL
## SDI.plot                           *
## Thin.actual
## Fire.actual.post1                  ***
## Fire.actual.post2                  ***
## SDI.plot:Thin.actual
## SDI.plot:Fire.actual.post1
## SDI.plot:Fire.actual.post2         .
## Thin.actual:Fire.actual.post1
## Thin.actual:Fire.actual.post2
## Fire.actual.post1:Fire.actual.post2 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

SDI, Fire.actual.post1, Fire.actual.post2, Fire.actual.post1:Fire.actual.post2; (SDI:Fire.actual.post2 marginal)

Persistence

```
## Warning in theta.ml(Y, mu, sum(w), w, limit = control$maxit, trace =
## control$trace > : iteration limit reached

## Warning in sqrt(1/i): NaNs produced

## Warning in theta.ml(Y, mu, sum(w), w, limit = control$maxit, trace =
## control$trace > : iteration limit reached

## Warning in sqrt(1/i): NaNs produced

## Warning in anova.negbin(post1.CONIF.per.res <- glm.nb(Persistence ~ (SDI.plot
## + : tests made without re-estimating 'theta'
```

```
## Analysis of Deviance Table
##
## Model: Negative Binomial(7.652227e+15), link: log
##
## Response: Persistence
##
## Terms added sequentially (first to last)
##
##
##                                    Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
## NULL                                                   46    24.8135
## SDI.plot                            1  16.1582        45     8.6553 5.827e-05
## Thin.actual                         1   0.0000        44    11.4311  1.000000
## Fire.actual.post1                   1   0.0000        43    14.8149  1.000000
## Fire.actual.post2                   1   6.2414        42     8.5735  0.012480
## SDI.plot:Thin.actual                1   3.5514        41     5.0221  0.059494
## SDI.plot:Fire.actual.post1          1   0.0000        40    13.0416  1.000000
## SDI.plot:Fire.actual.post2          1   0.2383        39    12.8033  0.625455
## Thin.actual:Fire.actual.post1       1   7.8385        38     4.9648  0.005115
## Thin.actual:Fire.actual.post2       1   0.0000        37     6.5216  1.000000
## Fire.actual.post1:Fire.actual.post2 1   0.0000        36     7.6649  1.000000
##
## NULL
## SDI.plot                           ***
## Thin.actual
## Fire.actual.post1
## Fire.actual.post2                  *
## SDI.plot:Thin.actual               .
## SDI.plot:Fire.actual.post1
## SDI.plot:Fire.actual.post2
## Thin.actual:Fire.actual.post1      **
## Thin.actual:Fire.actual.post2
## Fire.actual.post1:Fire.actual.post2
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

iteration limit reached

Pre to Late Colonization

```
## Warning in anova.negbin(post2.CONIF.col.res <- glm.nb(Colonization ~ (SDI.plot
## + : tests made without re-estimating 'theta'

## Analysis of Deviance Table
##
## Model: Negative Binomial(5.0473), link: log
##
## Response: Colonization
##
## Terms added sequentially (first to last)
##
##
##                                    Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
```

```
## NULL                                                    71    139.208
## SDI.plot                             1   2.9664        70    136.242 0.0850106
## Thin.actual                          1   4.8659        69    131.376 0.0273931
## Fire.actual.post1                    1  12.0266        68    119.349 0.0005245
## Fire.actual.post2                    1  30.7277        67     88.622 2.969e-08
## SDI.plot:Thin.actual                 1   2.5426        66     86.079 0.1108128
## SDI.plot:Fire.actual.post1           1   1.4854        65     84.594 0.2229266
## SDI.plot:Fire.actual.post2           1   0.0048        64     84.589 0.9447450
## Thin.actual:Fire.actual.post1        1   0.7808        63     83.808 0.3768823
## Thin.actual:Fire.actual.post2        1   3.9740        62     79.834 0.0462090
## Fire.actual.post1:Fire.actual.post2  1   8.3489        61     71.485 0.0038591
##
## NULL
## SDI.plot                            .
## Thin.actual                         *
## Fire.actual.post1                   ***
## Fire.actual.post2                   ***
## SDI.plot:Thin.actual
## SDI.plot:Fire.actual.post1
## SDI.plot:Fire.actual.post2
## Thin.actual:Fire.actual.post1
## Thin.actual:Fire.actual.post2       *
## Fire.actual.post1:Fire.actual.post2 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Thin, Fire.actual.post1, Fire.actual.post2, Thin:Fire.actual.post2, Fire.actual.post1:Fire.actual.post2; (SDI marginal)

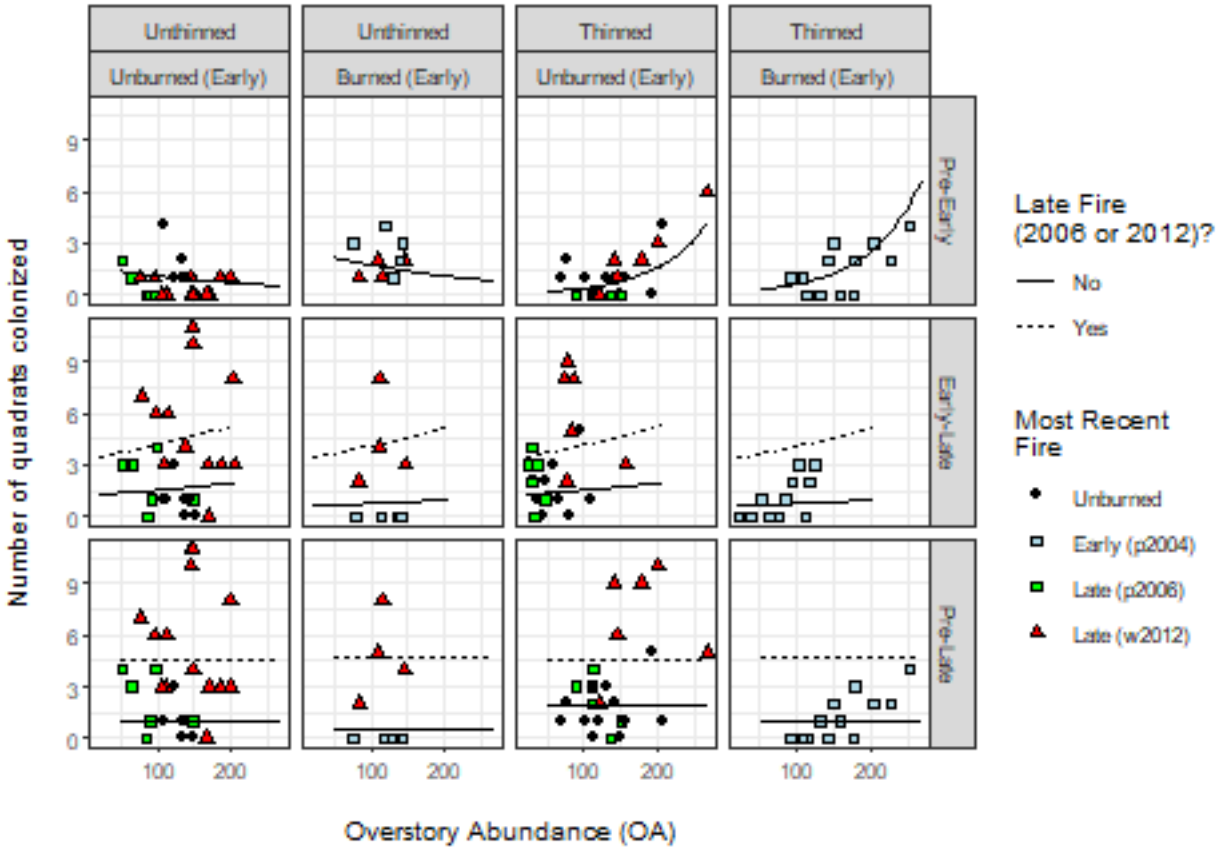
Persistence

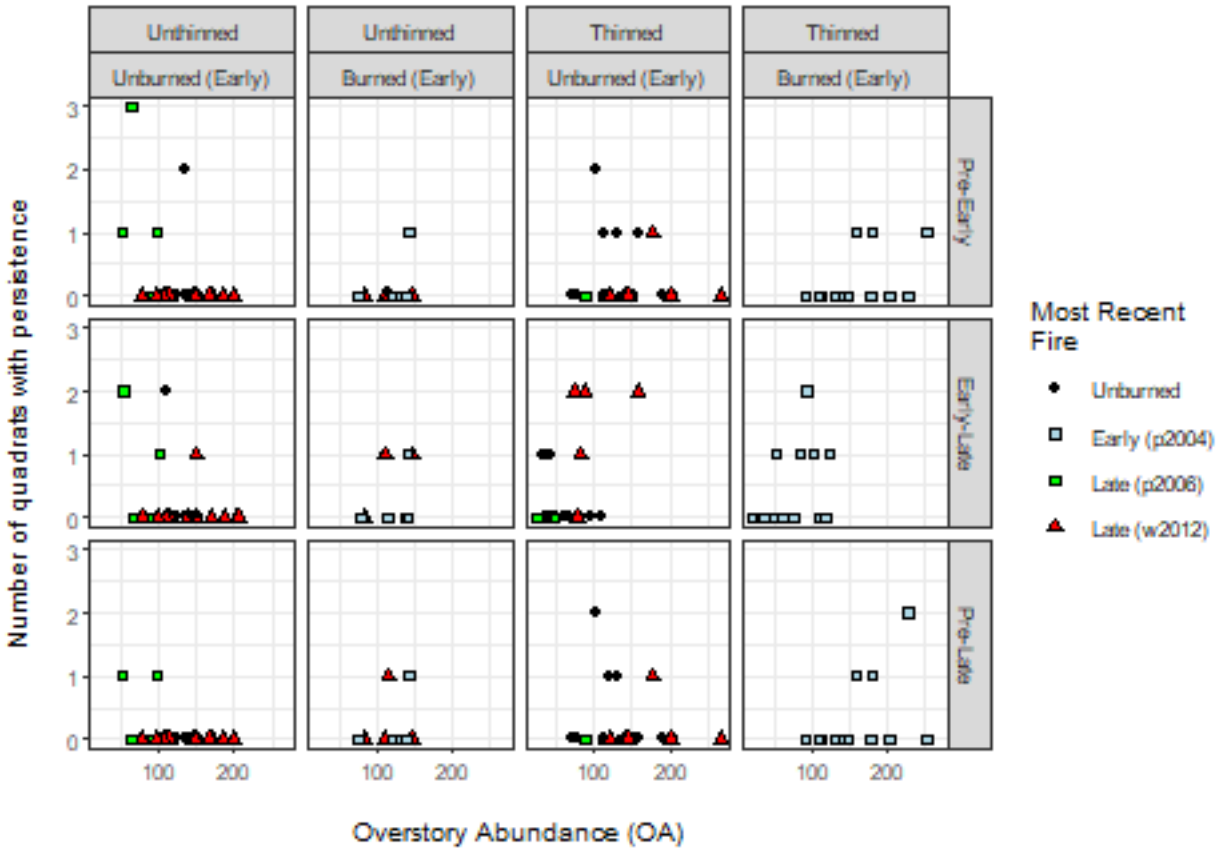
```
## Warning in sqrt(1/i): NaNs produced

## Warning in sqrt(1/i): NaNs produced

## Warning in anova.negbin(post2.CONIF.per.res <- glm.nb(Persistence ~ (SDI.plot
## + : tests made without re-estimating 'theta'

## Analysis of Deviance Table
##
## Model: Negative Binomial(2.311805e+15), link: log
##
## Response: Persistence
##
## Terms added sequentially (first to last)
##
##
##                                    Df Deviance Resid. Df Resid. Dev Pr(>Chi)
## NULL                                                   31     30.462
## SDI.plot                            1   3.1486        30     27.314  0.07599 .
## Thin.actual                         1   4.4919        29     22.822  0.03406 *
## Fire.actual.post1                   1   0.1962        28     22.625  0.65780
## Fire.actual.post2                   1   2.1806        27     20.445  0.13976
## SDI.plot:Thin.actual                1   0.0000        26     21.364  1.00000
```

```
## SDI.plot:Fire.actual.post1           1   0.0000        25     21.684  1.00000
## SDI.plot:Fire.actual.post2           1   1.6435        24     20.040  0.19984
## Thin.actual:Fire.actual.post1        1   0.0000        23     22.623  1.00000
## Thin.actual:Fire.actual.post2        1   2.3224        22     20.301  0.12752
## Fire.actual.post1:Fire.actual.post2  1   0.0000        21     21.055  1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

NaNs produced

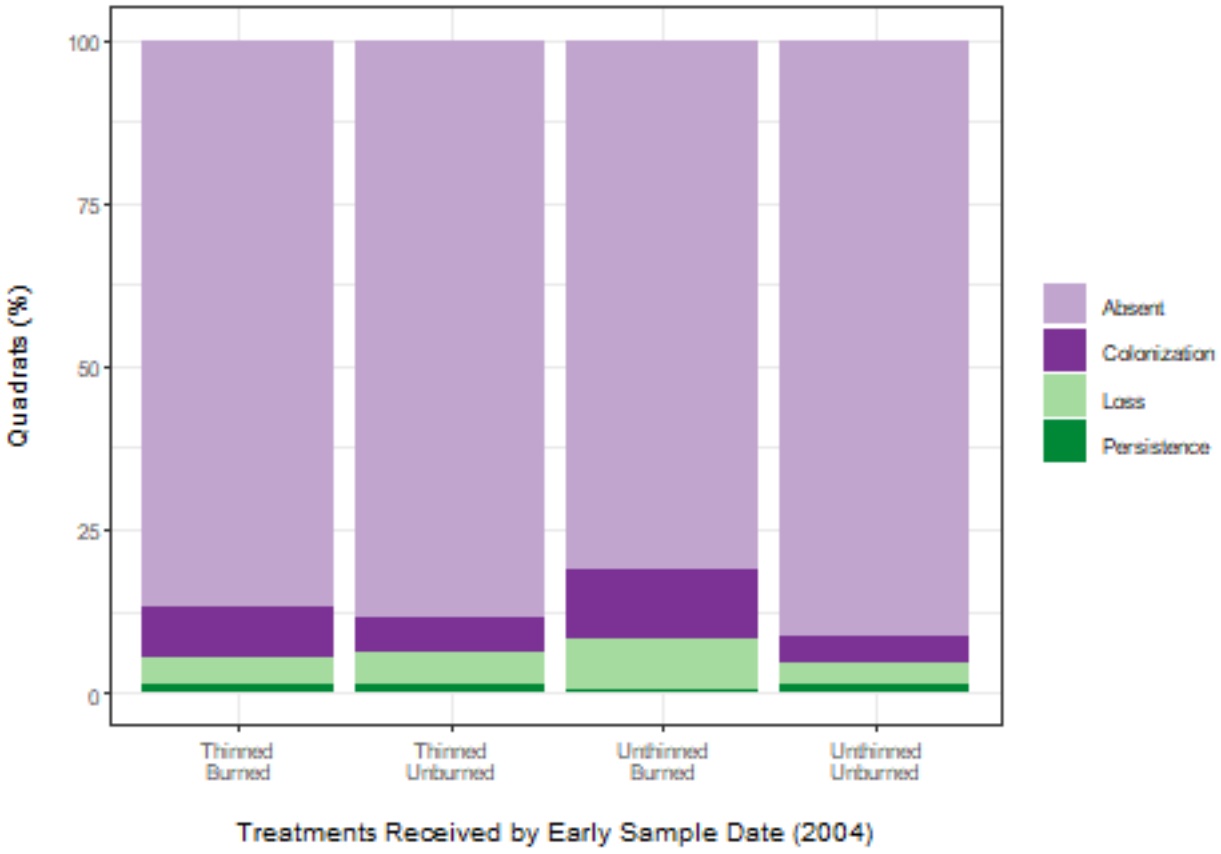
graphs of colonization/persistence





Seedling Dynamics (graphics)

Pre to Early

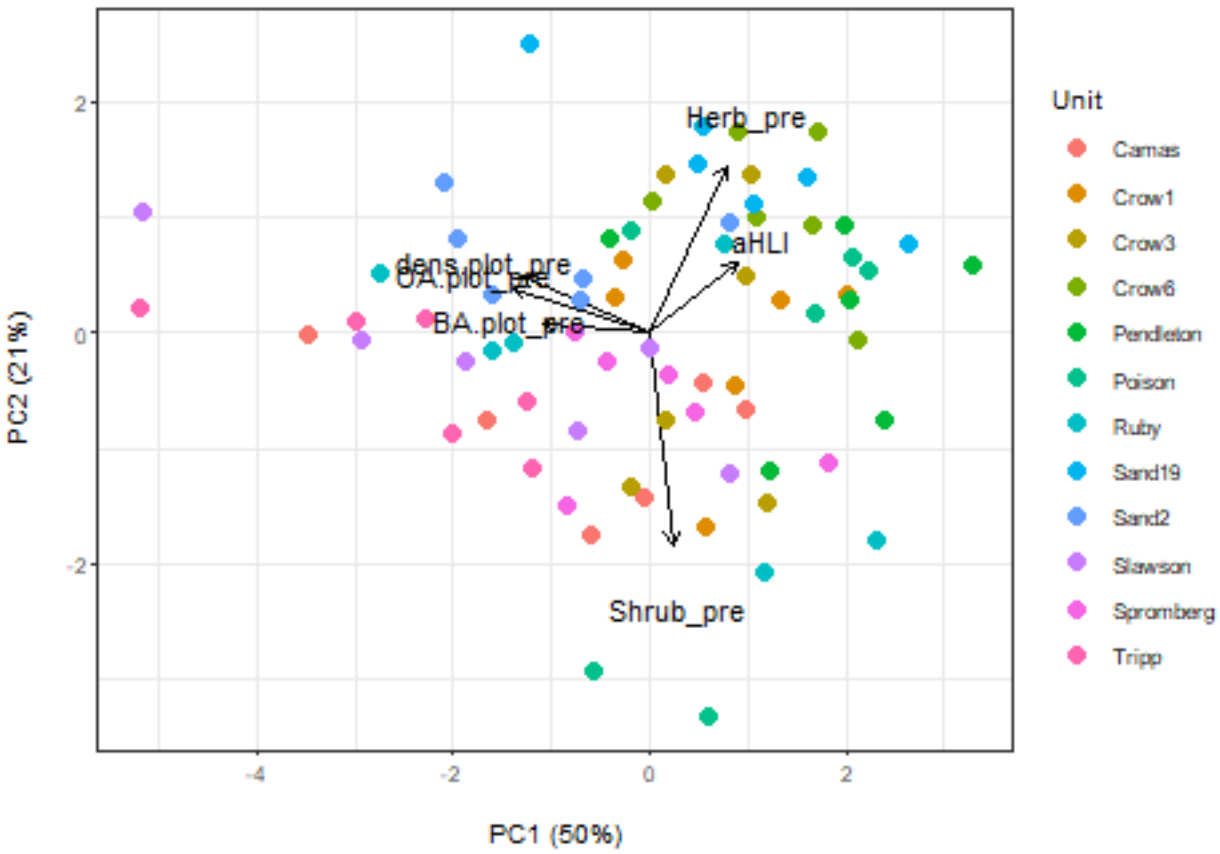


Early to Late and Pre to Late

PCA of Environment and Pretreatment Variables

```
## Importance of components:
##                           Comp.1    Comp.2    Comp.3     Comp.4    Comp.5
## Standard deviation     1.7297825 1.1196291 0.9412592 0.68865336 0.6259934
## Proportion of Variance 0.4986913 0.2089282 0.1476615 0.07904057 0.0653113
## Cumulative Proportion  0.4986913 0.7076195 0.8552810 0.93432153 0.9996328
##                            Comp.6
## Standard deviation     0.0469367070
## Proportion of Variance 0.0003671757
## Cumulative Proportion  1.0000000000

##                    Comp.1      Comp.2       Comp.3      Comp.4       Comp.5
## Herb_pre        0.3117990  0.57876907  0.222583544  0.71608794  0.07350663
## Shrub_pre       0.0923071 -0.73685884  0.455199197  0.43694388 -0.22447061
## aHLI            0.3542812  0.24571311  0.648375824 -0.51787874 -0.35401192
## BA.plot_pre    -0.4377695  0.03274241  0.531134195 -0.06566794  0.66458971
## dens.plot_pre -0.5208934  0.19245472 -0.005713224  0.13974096 -0.57968229
## OA.plot_pre    -0.5529679  0.15355651  0.201799095  0.06526797 -0.20291437
```

One PC explains half of variation in environmental and initial conditions; two explain 71%.



First PC associated with overstory abundance and aHLI.