Quantification of Cottonwood Seed Dispersal Periods

Proposal Identification TRRP-2018-019

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Synthesis Background

- Cottonwood recruitment on upper bars and floodplains is a stated goal of the IAP (TRRP and ESSA Technologies Ltd 2009), and the TRRP has made considerable effort since 2006 to create a hydrograph that promotes cottonwood recruitment.
- Flow benches, or periods of steady flow, have been added to the receding limb of the hydrograph and are intended to coincide with the cottonwood seed dispersal period.
- Field observations and peer-reviewed publications (e.g., Stella et al. 2006) since 2004 have suggested that cottonwood seed dispersal may vary annually depending on weather conditions.
- Water year type, air temperature, groundwater availability, and individual tree variability of seed dispersal timing were hypothesized explanations for observed results.

Purpose of Synthesis

Goal

- Utilize existing data to quantify the seed dispersal period for black cottonwood within the Project Reach that can consistently be applied during annual flow scheduling so that the timing of key flow benches (e.g., 4,500 cfs) can coincide with cottonwood seed release.

Objectives

- Examine if seed dispersal timing differs among trees, years, and/or sites.
- Examine the timing of seed dispersal from year to year.
- Examine the relationship of Julian date and accumulated degree-hours with seed dispersal timing.

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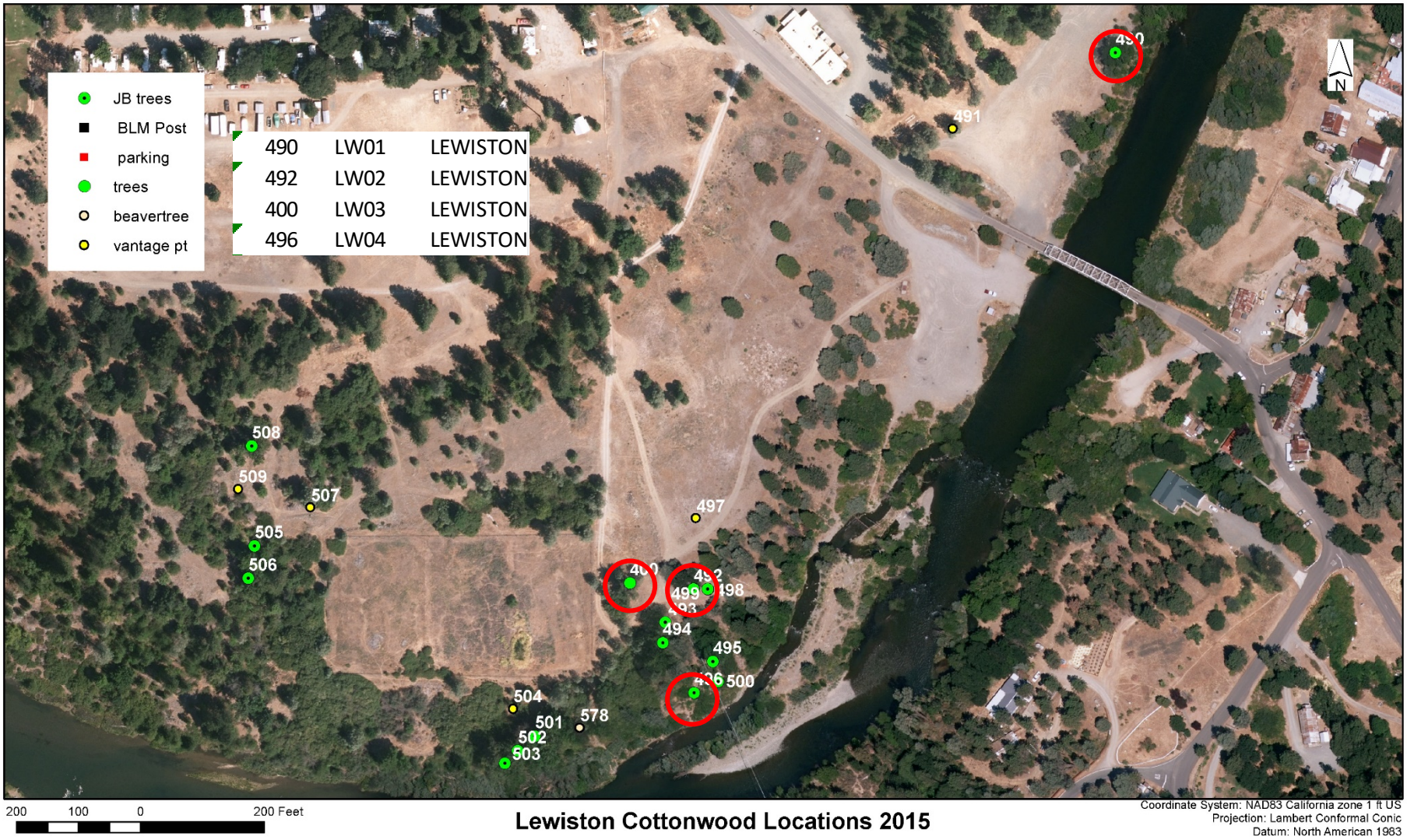
2015-2018 Lewiston (n=4)



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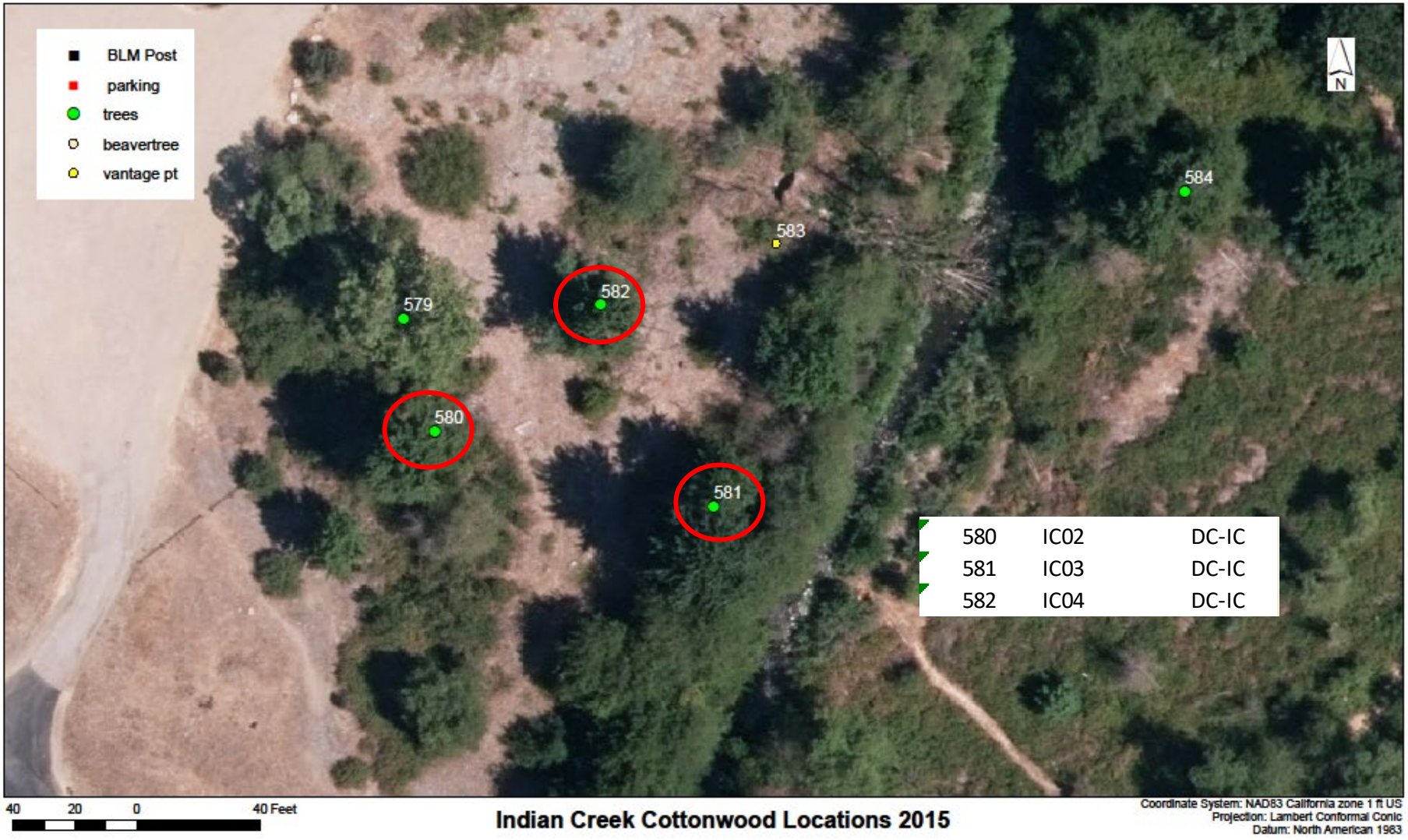
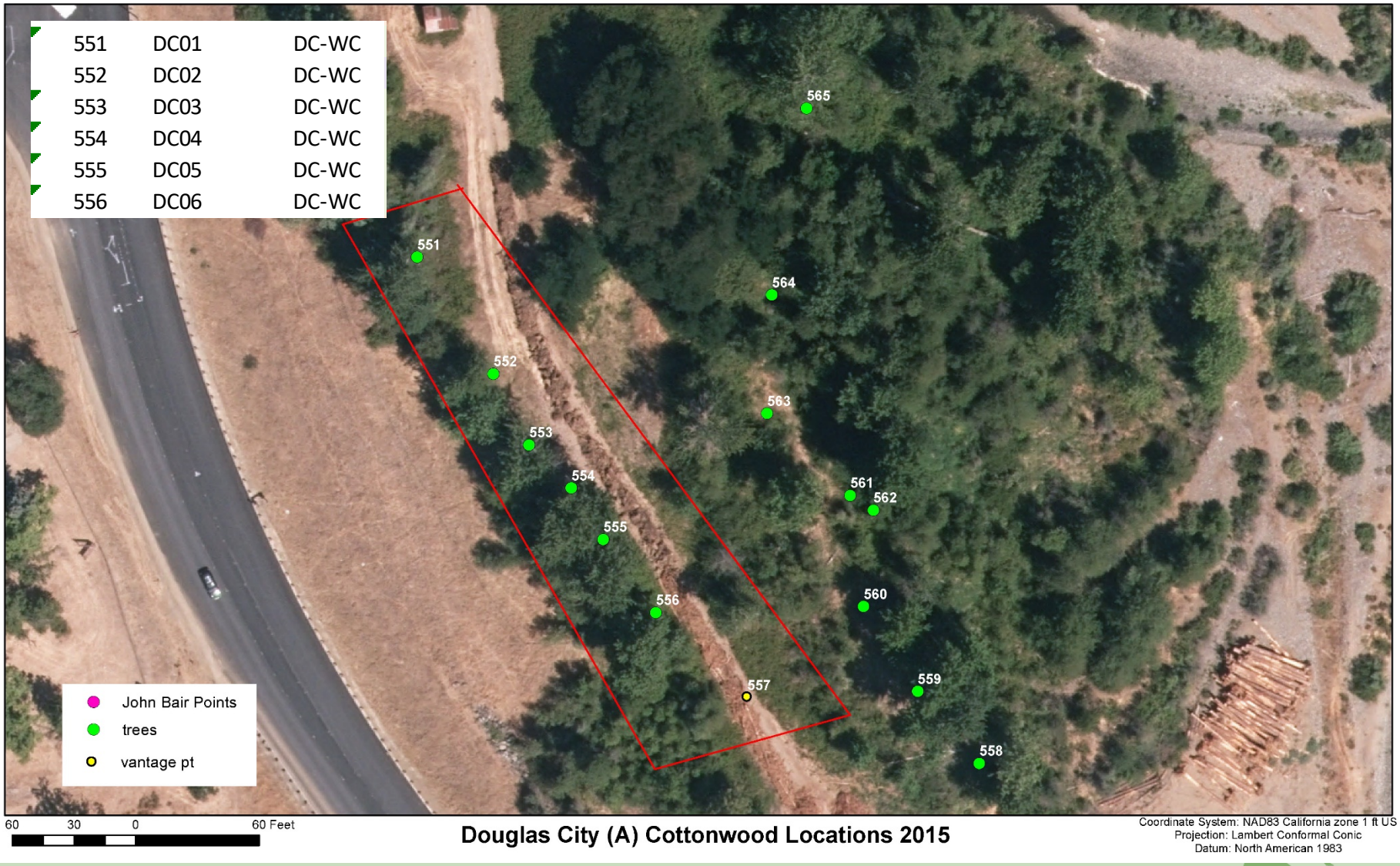
2015-2018 Lowden Ranch (n=4)

2015-2018 Indian Creek (n=3)



2015-2018 Douglas City (n=6)



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2004, 2015-2018 Lower Junction City (n=11)

Proposed Analyses

- Analysis of variance (ANOVA) was initially proposed to explore statistical relationships.
  - within-tree variation compared to between-tree variation;
  - within-site variation compared to between-site variation; and
  - ANOVA was to be run on data from each year separately, and then run for all years.
- Results from ANOVA were expected to show that there is wide variation in seed dispersal timing within individual trees but little variation between sites, suggesting that the seed dispersal timing period is stable across years.
- If seed dispersal period varies inter-annually at the population level, then this suggests that weather-related covariates (e.g., patterns of degree-day accumulation, solar insolation, precipitation patterns, and groundwater availability) may drive patterns of black cottonwood seed dispersal.

Data Considerations

- Data set: 2015–2018 whole tree catkin dispersal
  - Original data are percent seed dispersal of trees during survey period.
  - Seed dispersal was estimated for a whole tree; data not collected in the top, middle, and lower canopy
  - Removed potential male DC02
- Non-parametric analysis was most appropriate because data had a non-normal distribution (not a bell curve).
- Transforming the data was not possible because of all the 0 values that were real data points.
- Some analyses used binomial data.
  - Binomial data: Original data (percent dispersal) were modified to have only a 0 or 1 value:
    - 0% dispersal = 0 [no dispersal]
    - >0% dispersal = 1 [some dispersal, regardless of amount]

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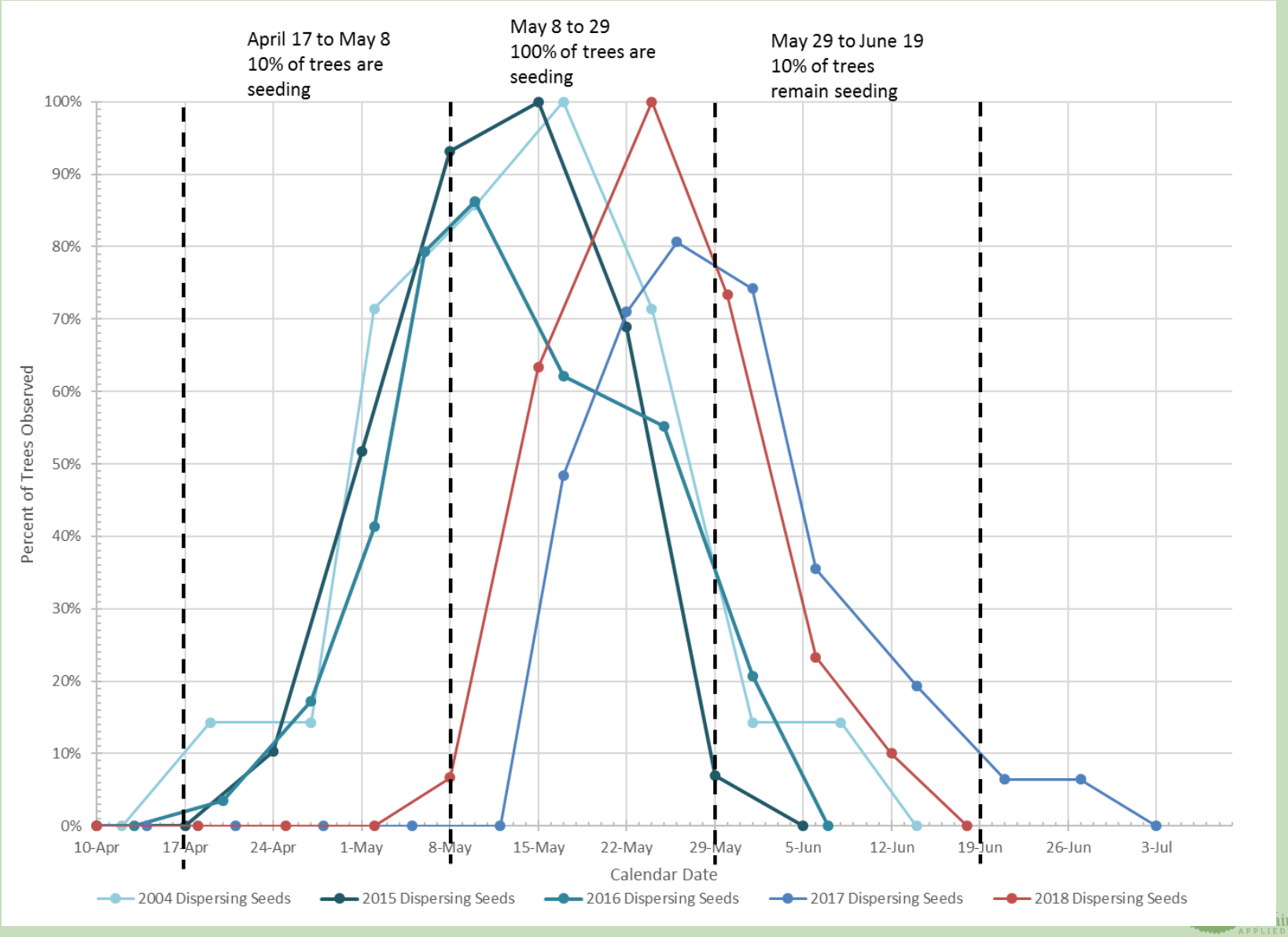
Analyses Data

Data Type Term	Definition	Data Format	Statistical Test or Approach	Hypotheses Tested
Original seed dispersal data	Raw data, the percent of each tree canopy that was dispersing seeds in each survey week.	Multiple data points per week per year	Scatter Plots	H_0: There is no relationship between percent seed dispersal and accumulated degree-hour.
Median seed dispersal	The median percent dispersal value of all trees in each survey week	1 data point per week per year	Line Charts	H_0: There is no relationship between median percent seed dispersal and accumulated degree-hour.
Peak seed dispersal	The Julian date when a tree has greater than or equal to 75% dispersal in each year.	1 data point per tree per year	Scatter Plots Box Plots	H_0: Timing of the beginning of peak seed dispersal (≥ 75% canopy dispersing) does not differ between years, sites, and/or trees.
Binary seed dispersal	Indicator of seed dispersal data represented by 1 if seed dispersal was occurring and a 0 if not occurring.	Multiple data points per week per year	Kruskal-Wallis Rank Sum Test	H_0: Seed dispersal timing (i.e., start, duration, and end) does not differ between years, sites, and/or trees.
		Multiple data points per week per year	Generalized linear model (GLM)	H_0: Timing of seed dispersal (i.e., start, duration, and end) cannot be predicted by years, sites, trees, Julian data, and/or accumulated degree-hours.

2004 & 2015–2018 Seed Dispersal



Initial Analyses

- Kruskal-Wallis Rank Sum test: non-parametric equivalent to ANOVA. Determines if groups of data are different.
  - Performed on binomial data (0 = no seed dispersal, 1= 1% - 100% seed dispersal)
  - Tested if seed dispersal was different among years, among sites, and among trees.
- Box plots: plots min, 1st quartile, median, 3rd quartile, and max.
  - Julian date of peak dispersal was extracted from original data (percent dispersal)
  - Julian date of peak dispersal: The Julian date when beginning % peak dispersal (≥75%) occurred for each tree for each year:

Tree	Year	Beginning Peak Dispersal Julian Date
IC02	2016	131
IC03	2016	131
IC03	2017	142

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Kruskal-Wallis Rank Sum test
Seed Dispersal vs. Trees, Years, Sites

- Kruskal-Wallis test (binomial data):
  - H_0= there are no differences in seed dispersal timing among trees, years, or sites
  - If a test was significant ($p \leq 0.05$), a post hoc analysis was conducted to test which relationship within a variable (i.e., tree 1 vs tree 2 of all trees, or 2015 vs 2018 of all years) had the most significant effect on the probability of seed dispersal

Variables	Chi-squared	Degrees of freedom	P-value
Binomial Seed Dispersal vs. Trees	25.90	38	0.93
Binomial Seed Dispersal vs. Years	18.72	3	0.00
Binomial Seed Dispersal vs. Sites	7.74	4	0.10

  - Tree and Site are not significantly related to seed dispersal
  - Year is significantly related to seed dispersal

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Kruskal-Wallis Post Hoc Analysis

- Kruskal-Wallis test (binomial data):
  - Which years are different (post hoc analysis)?
    - 2015 and 2016 are not different (p=0.23)
    - 2015 is different from 2017 (p=0.0005) and 2018 (p=0.0003)
    - 2016 is different from 2017 (p=0.0042) and 2018 (p=0.0026)

```
data: x and group
Kruskal-Wallis chi-squared = 18.7147, df = 3, p-value = 0


                          Comparison of x by group
                                (No adjustment)
Col Mean-|
Row Mean |       2015       2016       2017
---------+---------------------------------
    2016 |   0.735193
         |     0.2311
         |
    2017 |   3.289463   2.636124
         |    0.0005*    0.0042*
         |
    2018 |   3.417349   2.793541   0.304649
         |    0.0003*    0.0026*     0.3803

alpha = 0.05
Reject Ho if p <= alpha/2
```

WY2015 DRY
WY2016 WET
WY2017 EXT WET
WY2018 CRIT DRY

?

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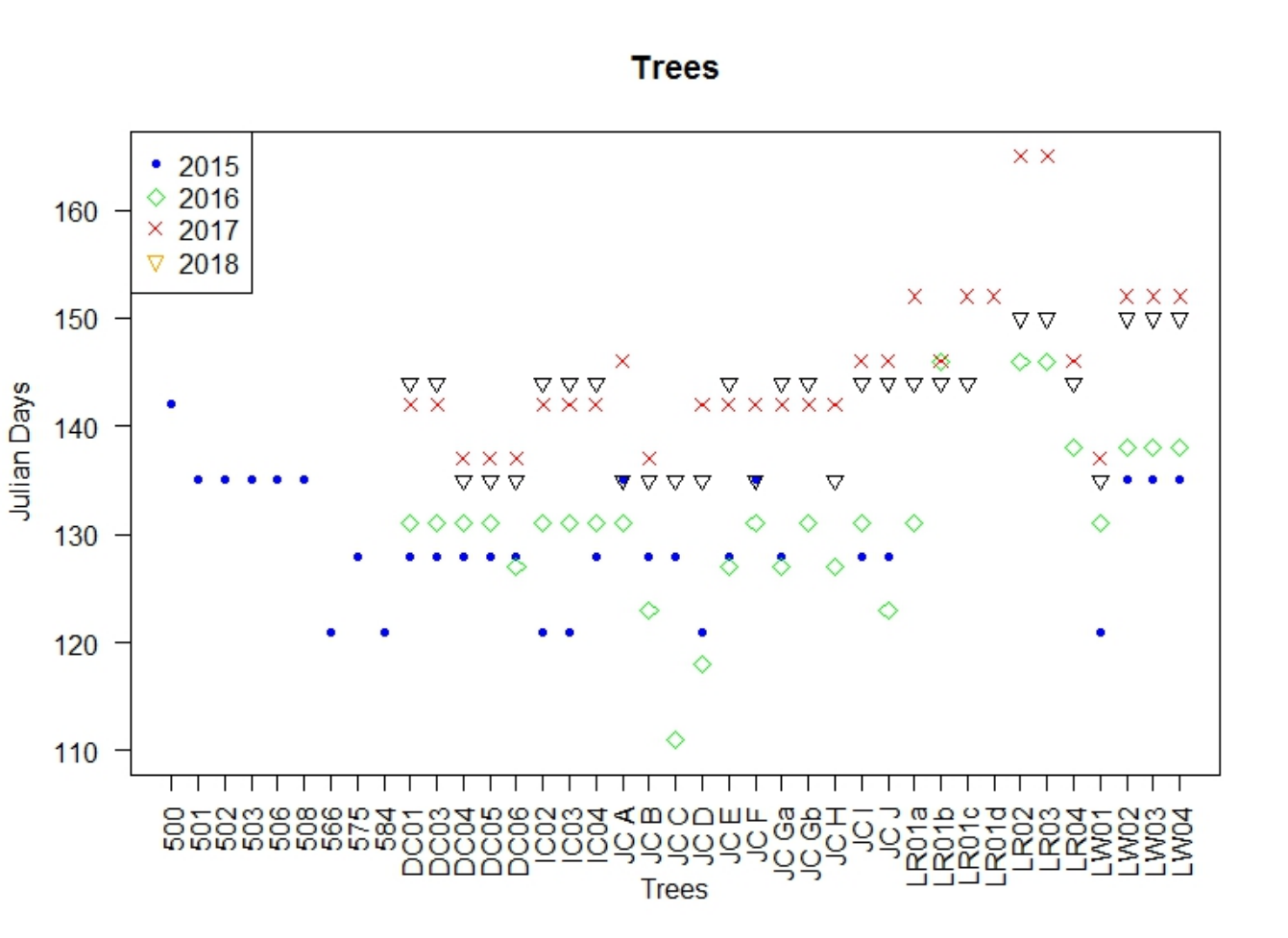
Beginning Julian Date of Peak Dispersal
Trees



Kruskal-Wallis Test: chi-squared = 52.86, df = 38, p-value = 0.06

Significant differences in the onset of seed dispersal

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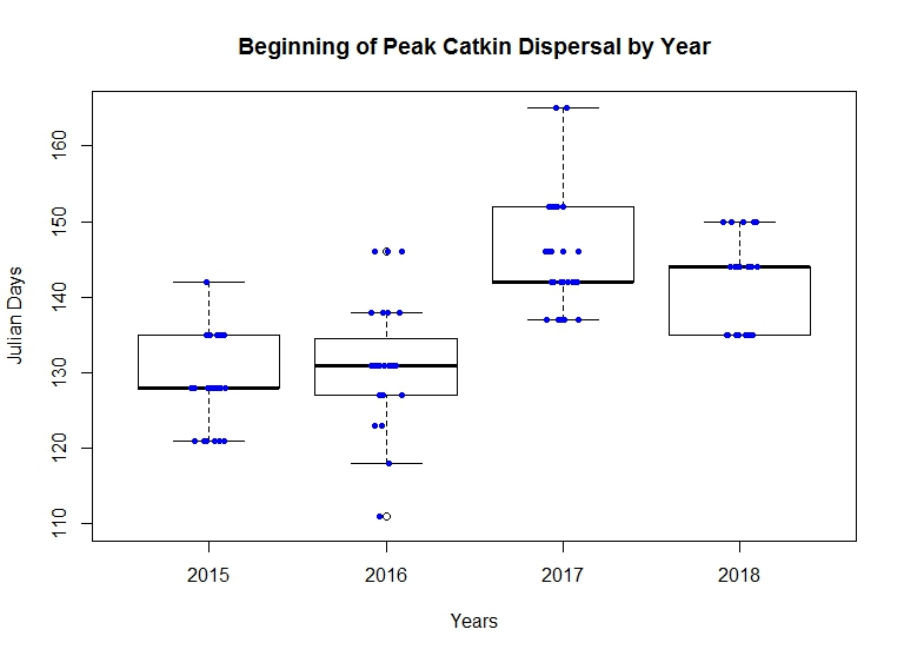
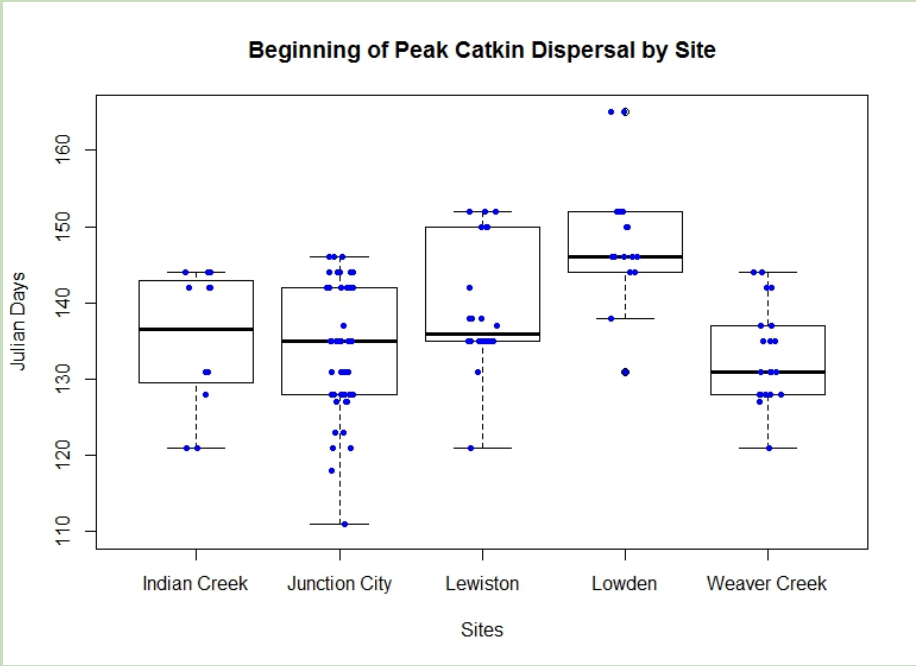
Box Plots Beginning Date of Peak Dispersal



Kruskal-Wallis Test: chi-squared = 64.74, df = 3, p-value = 0.00



Kruskal-Wallis Test: chi-squared = 33.96, df = 4, p-value = 0.00

- Peak dispersal defined as the first day that ≥ 75% of tree canopy is dispersing seeds.
- Blue dots are the Julian date at peak dispersal for each tree.
- Whiskers are the minimum and maximum values, unless min or max are out of interquartile range. Then whiskers are interquartile range and values outside of range are plotted as outliers (open circles).

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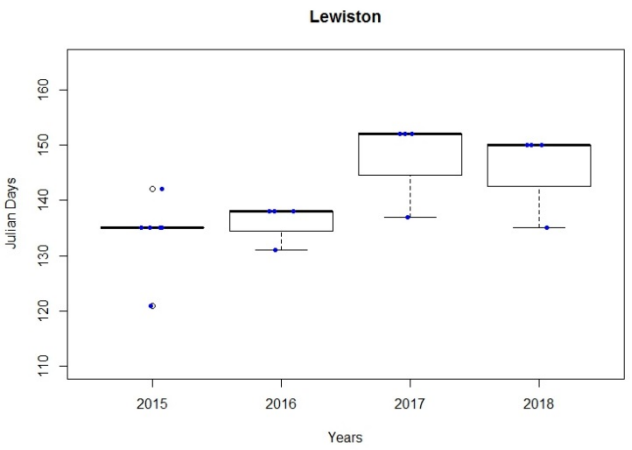
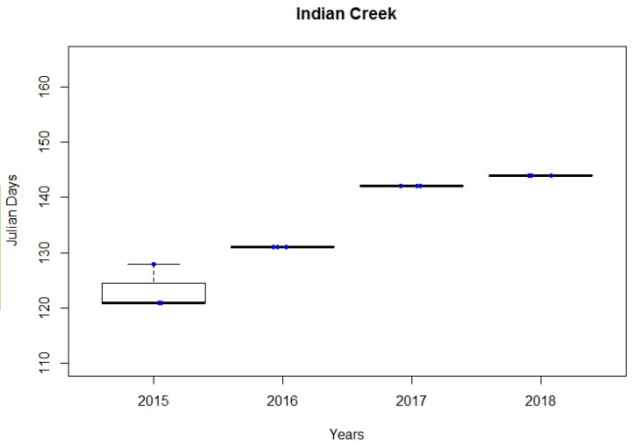
Box Plots Peak Dispersal

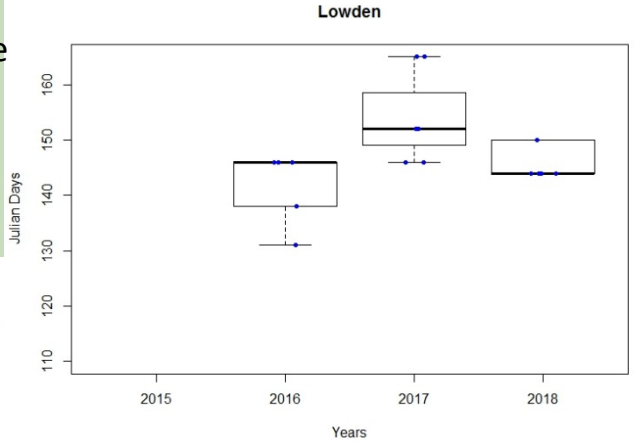


Kruskal-Wallis Test:
chi-squared = 11.38, df = 3, p-value = 0.00

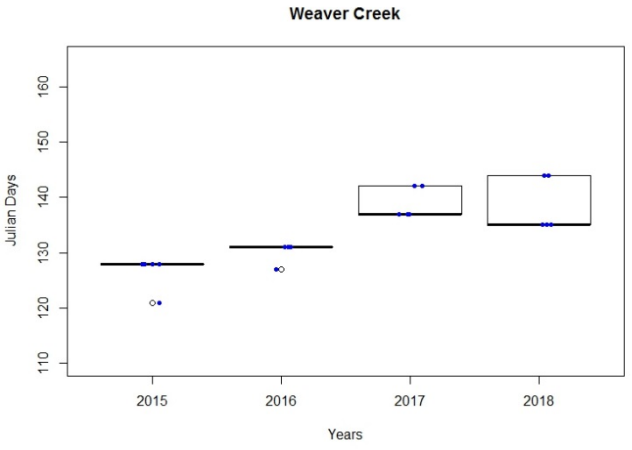
Peak dispersal defined as ≥ 75% of tree canopy dispersing seeds. Therefore, peak dispersal can occur over several weeks.



Kruskal-Wallis Test:
chi-squared = 10.88, df = 3, p-value = 0.01

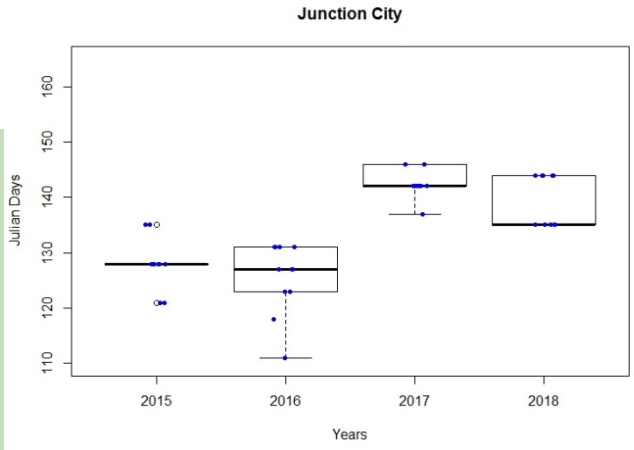


Kruskal-Wallis Test:
chi-squared = 8.59, df = 2, p-value = 0.01



Kruskal-Wallis Test:
chi-squared = 16.44, df = 3, p-value = 0.00

WY2004 WET
WY2015 DRY
WY2016 WET
WY2017 EXT WET
WY2018 CRIT DRY



Kruskal-Wallis Test:
chi-squared = 31.38, df = 3, p-value = 0.00

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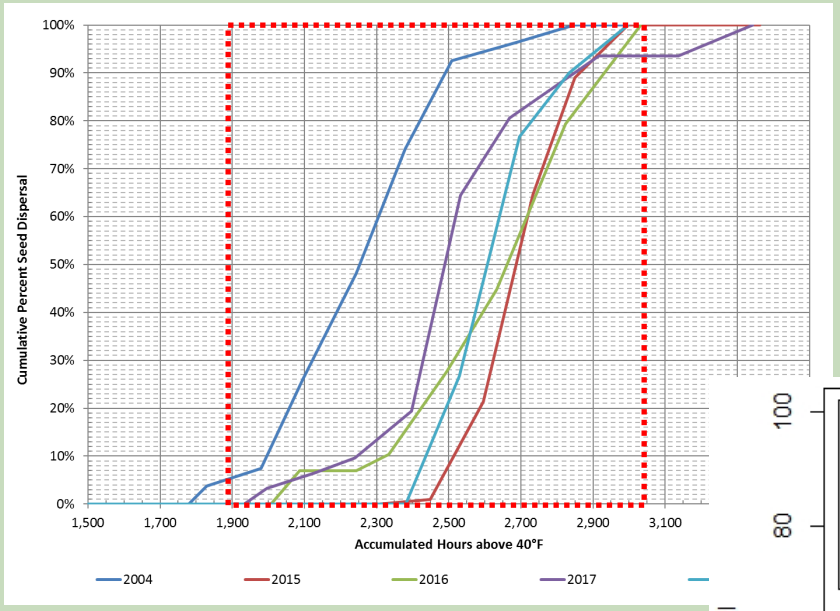
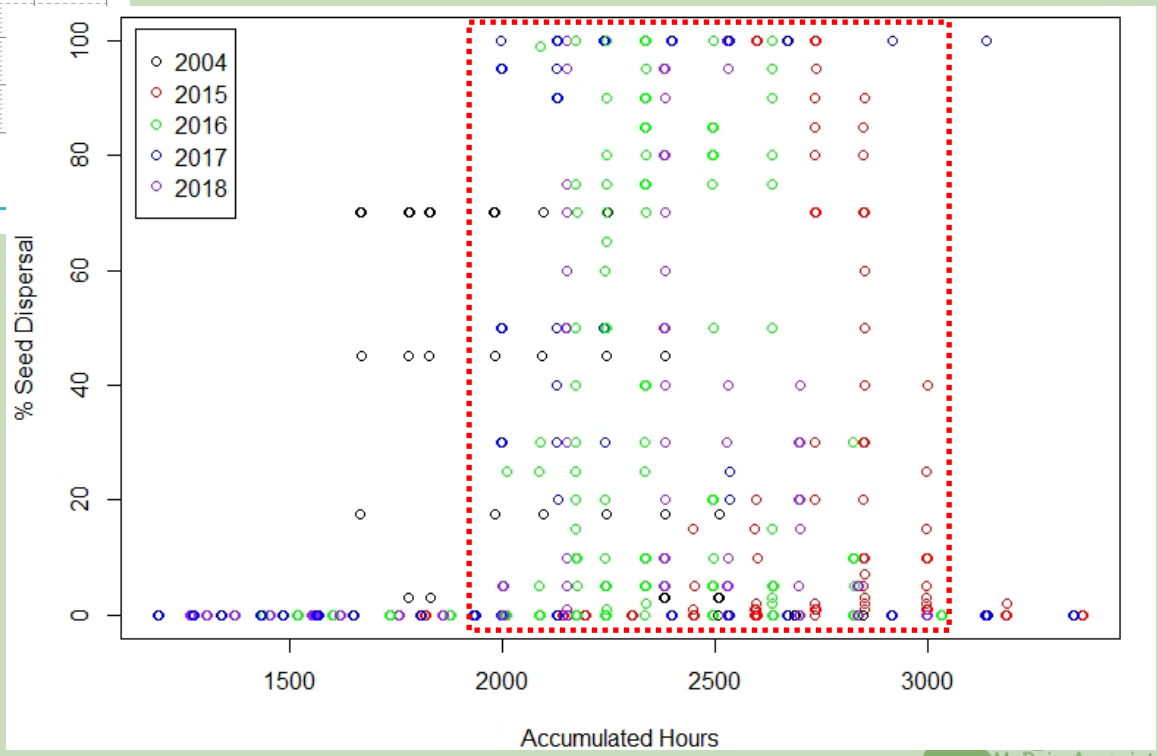
Secondary Analysis Descriptions

- Line charts of median dispersal: Looks at median % dispersal for each accumulated degree-hour during survey period.
- Generalized Linear Model (GLM): the non-parametric equivalent to linear regression. Determines if variables have an effect on data.
  - GLM (Binomial): Looks at the probability of a tree dispersing seeds rather than percent of dispersal.
  - A GLM (Poisson) was performed on the original data. More on that on the last slide.
  - Goodness-of-fit testing: Tests which model was the most appropriate for the data.
    - p-value = 1 – pchisq (residual deviance, residual degrees of freedom)
    - Pchisq is a function in R that calculates the probability distribution of χ^2

Cottonwood Seed Dispersal and Degree Hour Accumulation



WY2004 WET
WY2015 DRY
WY2016 WET
WY2017 EXT WET
WY2018 CRIT DRY



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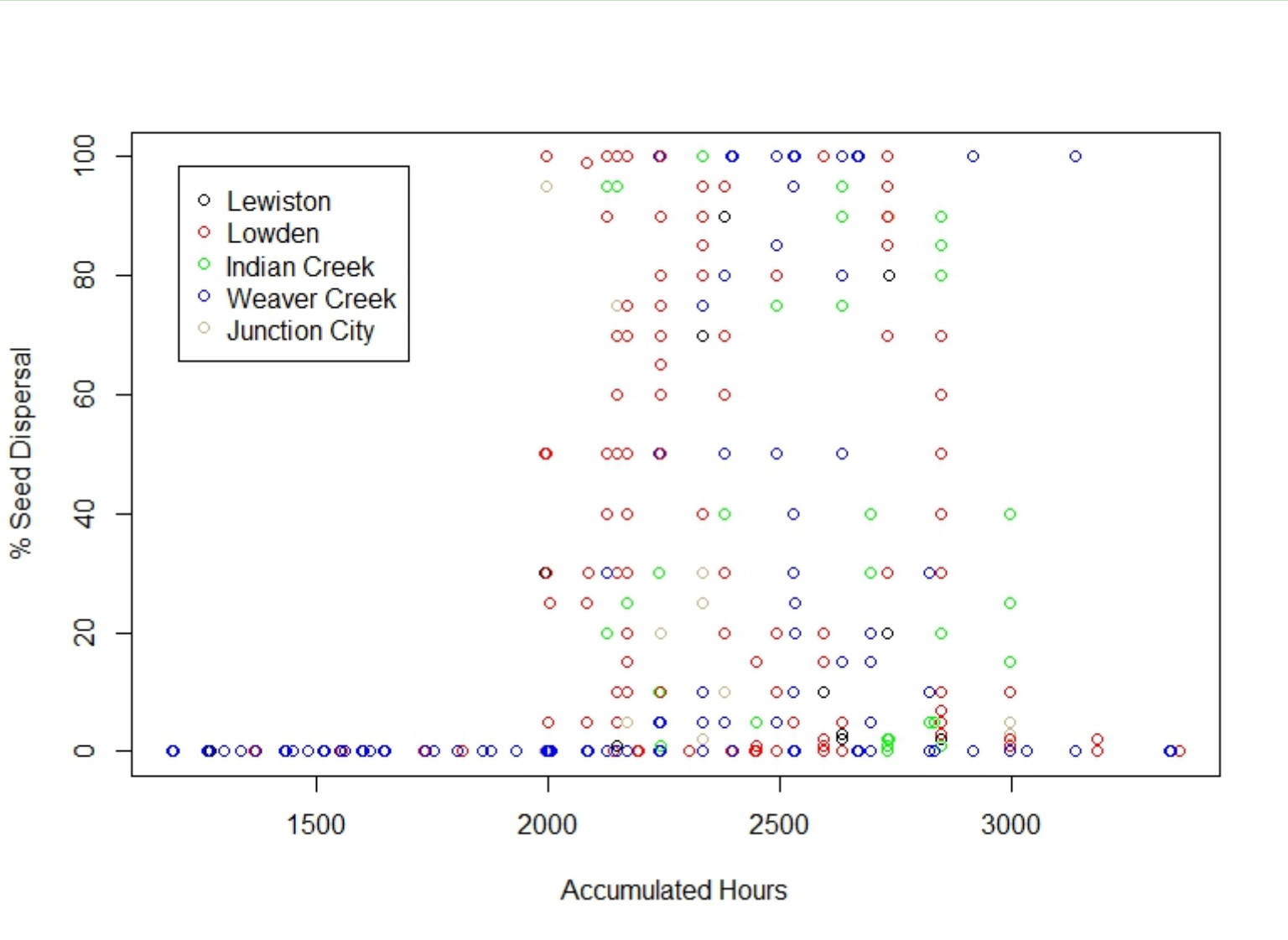
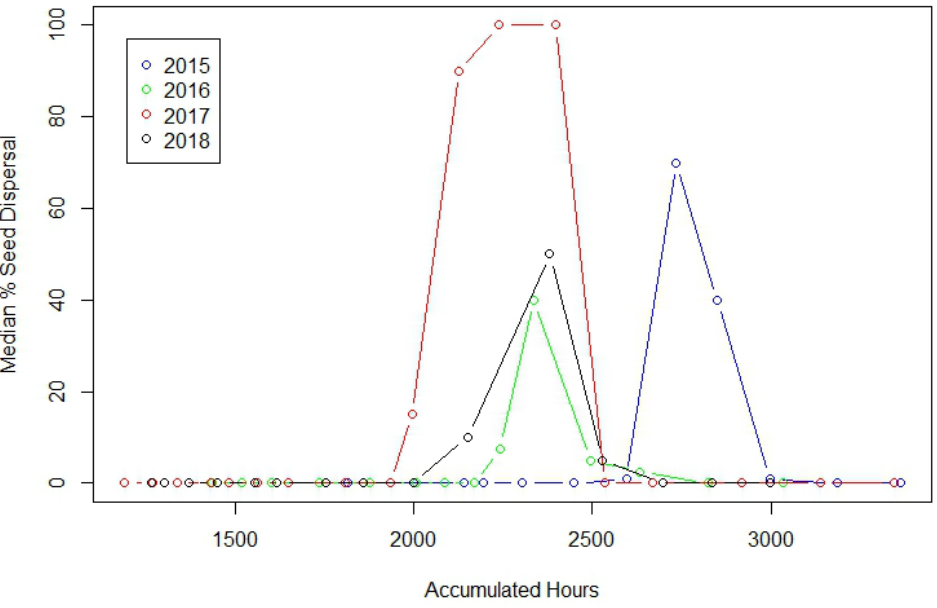
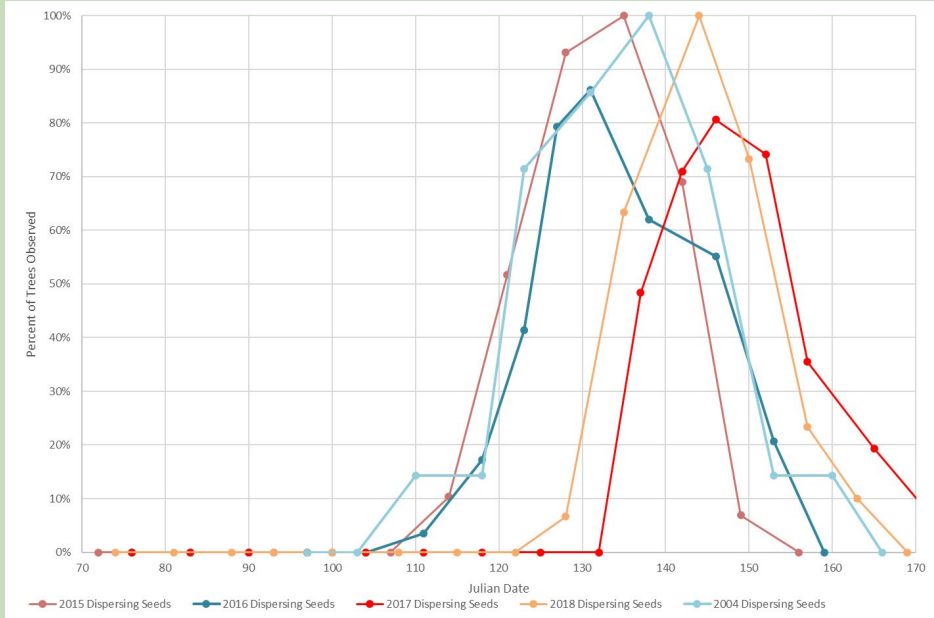
Site Dispersal by Accumulated Degree-Hour



Median Percent Dispersal Line Chart

The median percent seed dispersal for all trees dispersing seeds for each observation date. Accumulated hours are shown for each survey date.





When seed dispersal is dependent on degree hours

- 2015 is different in terms of timing
- 2017 is different in terms of median percent seed dispersal

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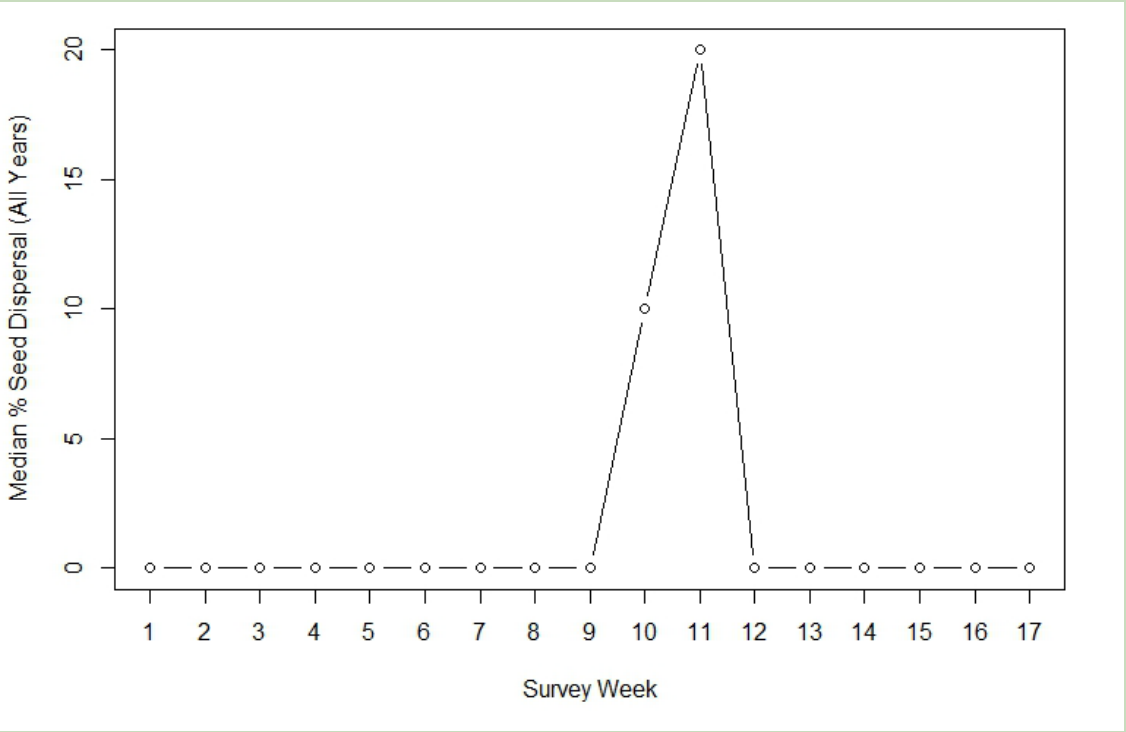
Median Dispersal Line Chart



Survey Week	2015	2016	2017	2018
1	3/13/2015	3/16/2016	3/17/2017	3/15/2018
2	n/a	3/23/2016	3/24/2017	3/22/2018
3	n/a	3/30/2016	3/31/2017	3/29/2018
4	4/3/2015	4/6/2016	4/7/2017	4/3/2018
5	4/10/2015	4/13/2016	4/14/2017	4/10/2018
6	4/17/2015	4/20/2016	4/21/2017	4/18/2018
7	4/24/2015	4/27/2016	4/28/2017	4/25/2018
8	5/1/2015	5/2/2016, 5/6/16	5/5/2017	5/2/2018
9	5/8/2015	5/10/2016	5/12/2017	5/8/2018
10	5/15/2015	5/17/2016	5/17/2017	5/15/2018
11	5/22/2015	5/25/2016	5/22/2017, 5/26/17	5/24/2018
12	5/29/2015	6/1/2016	6/1/2017	5/30/2018
13	6/5/2015	6/7/2016	6/6/2017	6/6/2018
14	n/a	n/a	6/14/2017	6/12/2018
15	n/a	n/a	6/21/2017	6/18/2018
16	n/a	n/a	6/27/2017	n/a
17	n/a	n/a	7/3/2017	n/a

- The highest median % seed dispersal occurs during survey weeks 10 and 11.
- The survey dates across all years were only different by 2 days for week 10.
- *This suggests that we can target May 15 through May 31 as our priority seed dispersal window.*

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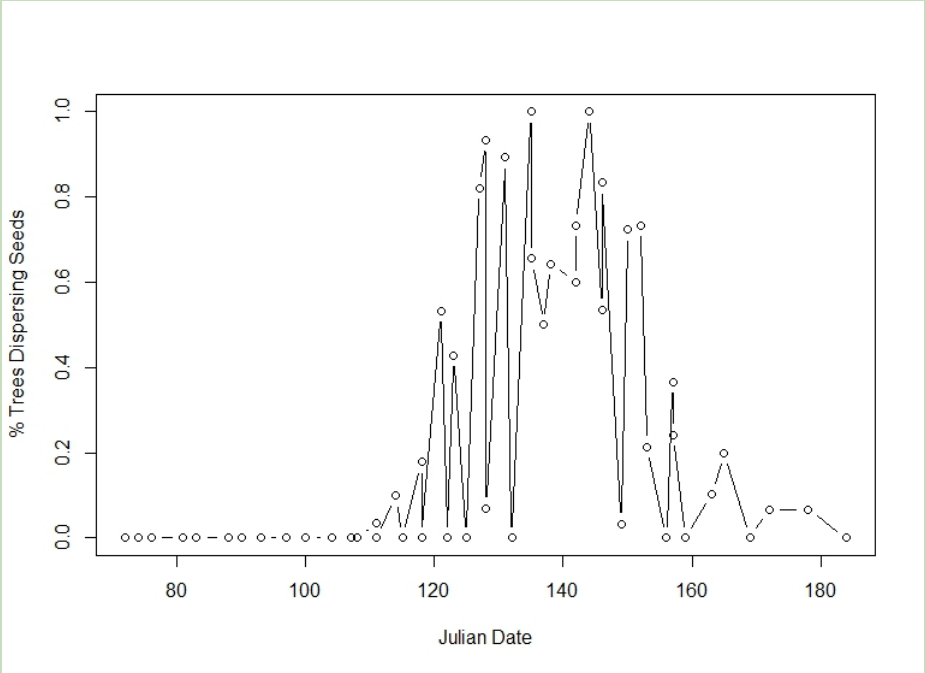
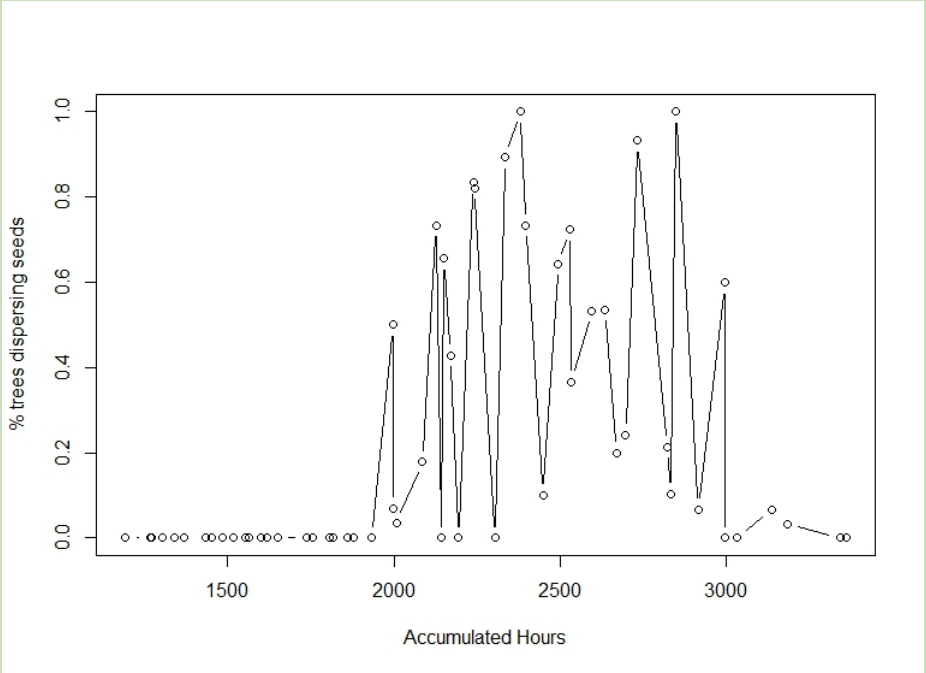
Dispersal vs. Julian Date and Accumulated Degree-Hour





Using the binomial data, the percent of trees dispersing seeds was calculated for each Julian date or accumulated degree hour.

$$\%\ of\ trees\ dispersing\ seeds = \frac{\sum trees\ dispersing\ seeds\ (trees\ with\ "1"\ value)}{\sum all\ trees\ surveyed}$$

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Goodness-of-Fit Testing

The residual deviance of the model can be used to test whether the logistic regression model provides an adequate fit for the data.

A p-value is calculated in R using this equation:

p-value = 1 – pchisq (residual deviance, residual degrees of freedom)

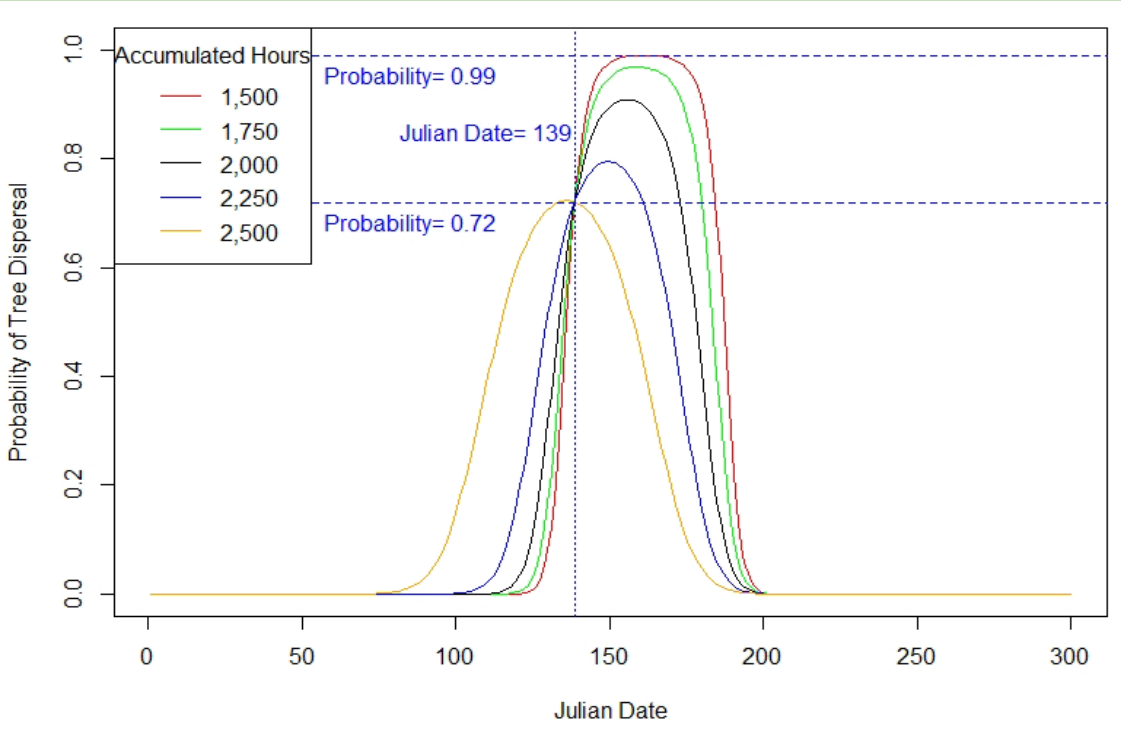
If the p-value result is ≤ 0.05, then there is a significant lack of evidence to support the null hypothesis i.e. the model is not a good fit.

	Equation	Residual deviance	Residual degrees of freedom	P-value
Model 1	Capsules dispersing seeds (binomial) = Trees	1795.00	1658	0.01
Model 2	Capsules dispersing seeds (binomial) = Years	1803.80	1693	0.03
Model 3	Capsules dispersing seeds (binomial) = Sites	1814.50	1692	0.02
Model 4	Capsules dispersing seeds (binomial) = Julian Date + Accumulated Hours	1670.90	1694	0.65
Model 5	Capsules dispersing seeds (binomial) = Julian Date * Accumulated Hour	933.08	1693	1.00

Good Fit

Binomial GLM Model 5

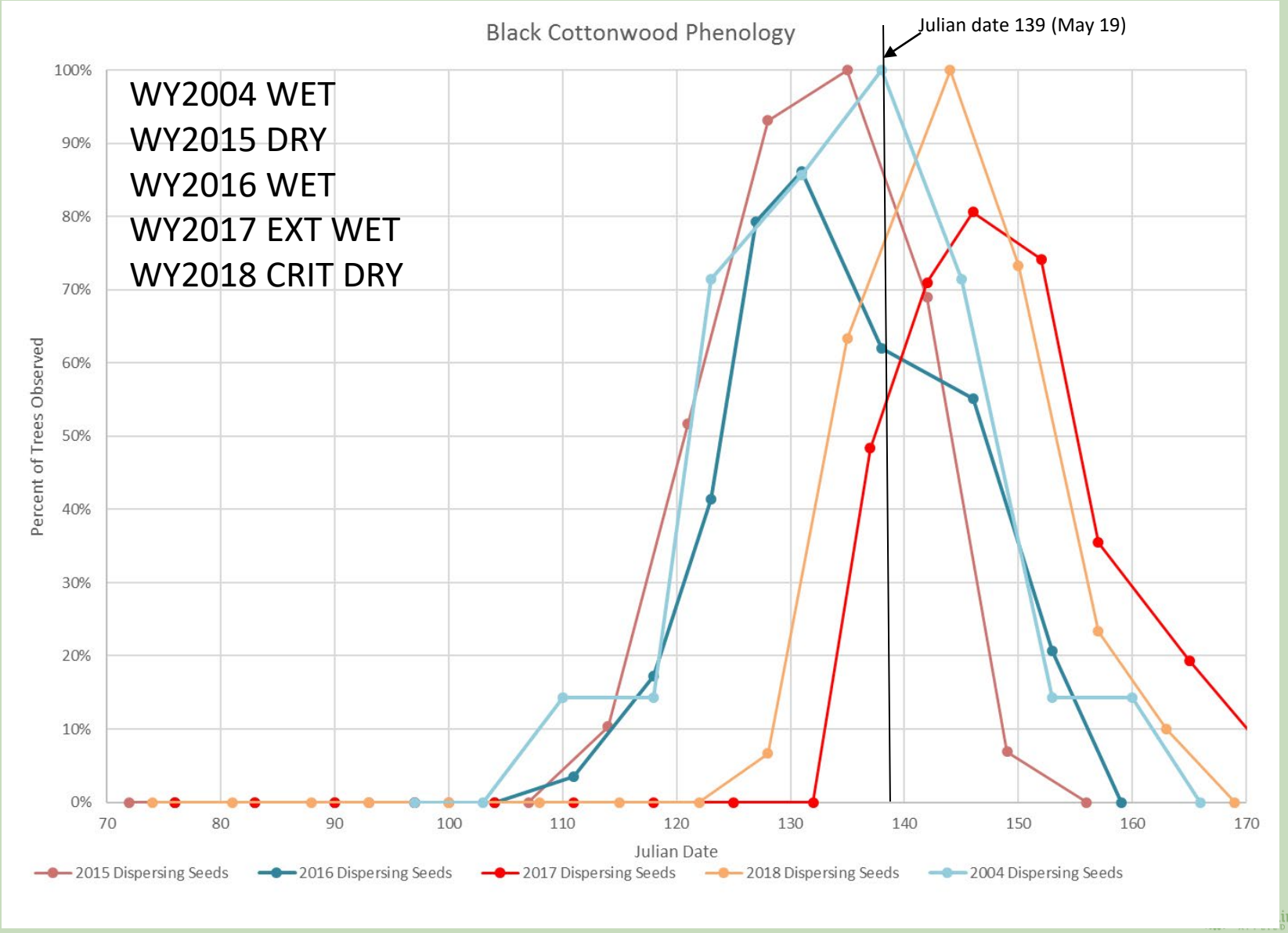
- To try and predict when seed dispersal might begin, Model 5 was used and the predict function in R, to calculate the probability of seed dispersal for a range of Julian Dates (0-300) under 5 different Accumulated Hours scenarios: 1500, 1750, 2000, 2250, 2400.
- The results were plotted to see how the probabilities change for the different scenarios.
- All lines intersect at Julian Date = 139 (May 19), and Probability = 0.72



Accumulated Hours	Highest Probability of Dispersal	Range of Julian Days	Associated Calendar Date*
1,500	0.99	154–169	June 3–18
1,750	0.97	155–163	June 4–12
2,000	0.91	153–159	June 2–8
2,250	0.79	146–154	May 26–June 3
2,500	0.72	132–140	May 12–20

* non-leap year

2015-2018 Seed Dispersal



Conclusions

- Does seed dispersal timing differ among trees, years, and/or sites?
  - Seed dispersal does not differ between trees or sites.

- Examine the timing of seed dispersal from year to year.
  - There is variability in the timing of seed dispersal, but median peak seed dispersal occurred in calendar weeks 10 and 11 in 2004, 2015-2018; (May 15 through May 29)

- Examine the relationship of Julian date and accumulated degree-hours with seed dispersal timing.
  - Julian Date and Accumulated Degree Hours interact. The interaction effect of one variable on the other will change seed dispersal.

Next Steps

- Next steps could include:
  - Examine the relationship of seed dispersal with other environmental factors using binomial GLM.
  - Conduct a cluster analysis of individual trees using tree-specific environmental variables to identify groupings of trees based on currently unknown characteristics. (i.e. are there trees at different sites that are characteristically similar to each other, like early-seeders vs. late-seeders).
  - Develop a gaming tool to help strategize timing of flow release modifications to target seed dispersal.

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