

₁ Project Overview: The effects of false spring events on sapling buds

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₄ **Project Overview:**

₅ For my dissertation, I will be evaluating the effects of climate change — specifically late spring freezing events
₆ — on temperate forests. Late spring freezing events that occur after budburst are known as false springs
₇ and they are predicted to increase in intensity in certain regions as climate change progresses [1, 2]. It is
₈ anticipated that budburst will initiate earlier in the spring, however last freeze dates will not advance at the
₉ same rate [3]. This mismatch in timing could result in more intense false spring events for temperate tree
₁₀ species, especially species found in regions more at risk of these events. Individuals exposed to false spring events
₁₁ are at risk of leaf tissue loss, damage to the canopy, or even xylem embolism [4] and buds are most at
₁₂ risk between budburst and leafout, when frost tolerance is lowest [5, 6].

₁₃ Temperate plants have evolved to minimize false spring damage through a myriad of strategies, with the
₁₄ most effective being avoidance: plants must exhibit flexible spring phenologies in order to maximize growth
₁₅ and minimize frost risk by timing budburst effectively [7, 8]. Other species have evolved various methods to
₁₆ enhance protection against false spring events, rather than attempt to avoid spring frosts by initiating bud-
₁₇ burst later in the season and shortening the growing season. Temperate species utilize various morphological
₁₈ strategies to increase survivability against false springs: some have more serrations along the leaf margins
₁₉ in order to increase packability in winter buds, which accelerates the rate of budburst. Other species have
₂₀ more trichomes on juvenile leaves, which decreases the amount of intracellular ice formation and, therefore,
₂₁ minimizing damage risk. However, it is unclear how effective these protective strategies are against false
₂₂ springs. If the mismatch between spring onset and last freeze date amplifies with climate change, then the
₂₃ species that utilize avoidance strategies may be forced to employ less successful protective strategies.

₂₄ The main objective of this experiment is to evaluate the interspecific variation in frost tolerance and success
₂₅ of protective strategies among temperate forest individuals. In order to do this, I closely monitored the
₂₆ phenology from budburst to leafout of 45 individuals across three species at the bud level. Once the majority
₂₇ of the buds had bursted on an individual but before the buds reached leafout, I placed the sapling in a growth

28 chamber at -3°C for 24 hours to induce a false spring event. I then observed the individual until every bud
29 leafed out or died. Since frost tolerance is lowest between budburst and leafout, the primary focus of this
30 study is the rate of leafout, which we will call the duration of vegetative risk, and how false spring events
31 affect this rate. I will also assess the percentage of buds that reached full leafout. My hypothesis is that
32 the duration of vegetative risk will increase after a freeze event and the percent budburst will be lower for
33 individuals exposed to a false spring.

34 In order to assess the duration of vegetative risk, I used rstan and rstanarm to construct a one level hierachal
35 model in a bayesian format. I will refer to the duration of vegetative risk as ‘dvr’ when using it in a model
36 framework.

To test both models, I began by simulating fake data. My fake data simulation can be found in my ‘freezingexperiment’ repo on github ([cchambe12/freezingexperiment/analyses/scripts/FakeBudsGenerate.R](https://github.com/cchambe12/freezingexperiment/analyses/scripts/FakeBudsGenerate.R)) and it provides notes and data

37 **Overall Project Aim:**

38 The overall objective for this project is to build a functioning model for my future experiment plans. My
39 ultimate goal is to have 8-12 species included in the model and to somehow add another level of hierarchy at
40 the bud level. The full experimental model I wish to build would have the duration of vegetative risk as the
41 response variable with treatment, range limits, and wood anatomy as predictors, as well as number of leaf
42 serrations along the leaf margins and number of trichomes to include protect regimes in the model. However,
43 for this semester project, I only have two useable species and no information on wood anatomy. I will look
44 at just treatment and species as predictors, (β_{tx}) and (β_{sp}) for now and duration of vegetative risk (y) as the
45 response variable (Equation ??).

46 For my subsetted data, I have approximately 650 observations across three species. Each species has 7-8
47 individuals per treatment group and each individual has 3-38 buds. One species, *Sambucus racemosa*, was
48 infested by many pests after the phenology was assessed, however, the pest damage may have affected the
49 duration of vegetative risk. For this reason, *S. racemosa* may be removed from the study. If *S. racemosa* is
50 removed, there are 560 observations.

51 **Current Issues and Response to Feedback:**

52 Originally, I was hoping to look at the effects of freezing on each bud and assess two levels of hierachy: the
53 species level and then the individual level. However, after presenting in front of the class, there was a lot of
54 concern about the bud numbering system. Many classmates suggested I measure the distance of each bud
55 from the terminal bud and use that as another predictor value. I am hoping to somehow look at the varying
56 effects of the freezing temperatures on each bud in relation to budburst time. For example, if an axial bud
57 had initiated budburst before going in the growth chamber but the terminal bud did not, then I would expect

58 different effect sizes of the freezing treatment between these two buds. However, if I am looking at treatment
59 as a predictor than this would be pseudoreplicating. Should I focus on each bud as a unique case and use the
60 freezing date as an indicator for freezing treatment at the bud level? But then I would not include whole
61 individual effects. For now, I think the best way is to do two simpler models asking each of these questions
62 and then reevaluating. The simplest model may be to look at percent budburst as the response variable and
63 then have treatment as the predictor.

64 For the question investigating the probability of leafout success, I will use a beta-binomial distribution model,
65 to provide a distribution for the probability of success, which is random. A beta-binomial distribution model
66 is crucial for this section of my project to provide a better fit to my model and limit overdispersion.

67 **Initial Results:**

68 The linear model (percentBB tx) suggests that a freezing treatment results in a lower budburst percentage,
69 however, the coefficient standar error, R-Squared value and residual standard deviation indicate low effect
70 sizes. There is an issue of statistical power across this entire experiment. Attached are a couple of figures
71 looking at the total data breakdown, the differences in duration of vegetative risk across bud number, and
72 percent budburst across the two birch species. I plan on investigating the bud dilemma further, looking at
73 different types of models and potentially adding more species, and also integrating these questions into a
74 bayesian framework.

75 Tables and Figures:

76

Table 1: Data Breakdown for Study.

Species	Individuals	Buds	Traits
BETPAP	14	9-27	DVR, SLA, Chlorophyll, Percent BB
BETPOP	15	8-38	DVR, SLA, Chlorophyll, Percent BB
SAMRAC	16	3-7	DVR, Percent BB
VIBCAS	26	NA	DVR, SLA, Chlorophyll
ACEPEN	15	NA	DVR, SLA, Chlorophyll
PRUPEN	12	NA	DVR, SLA, Chlorophyll

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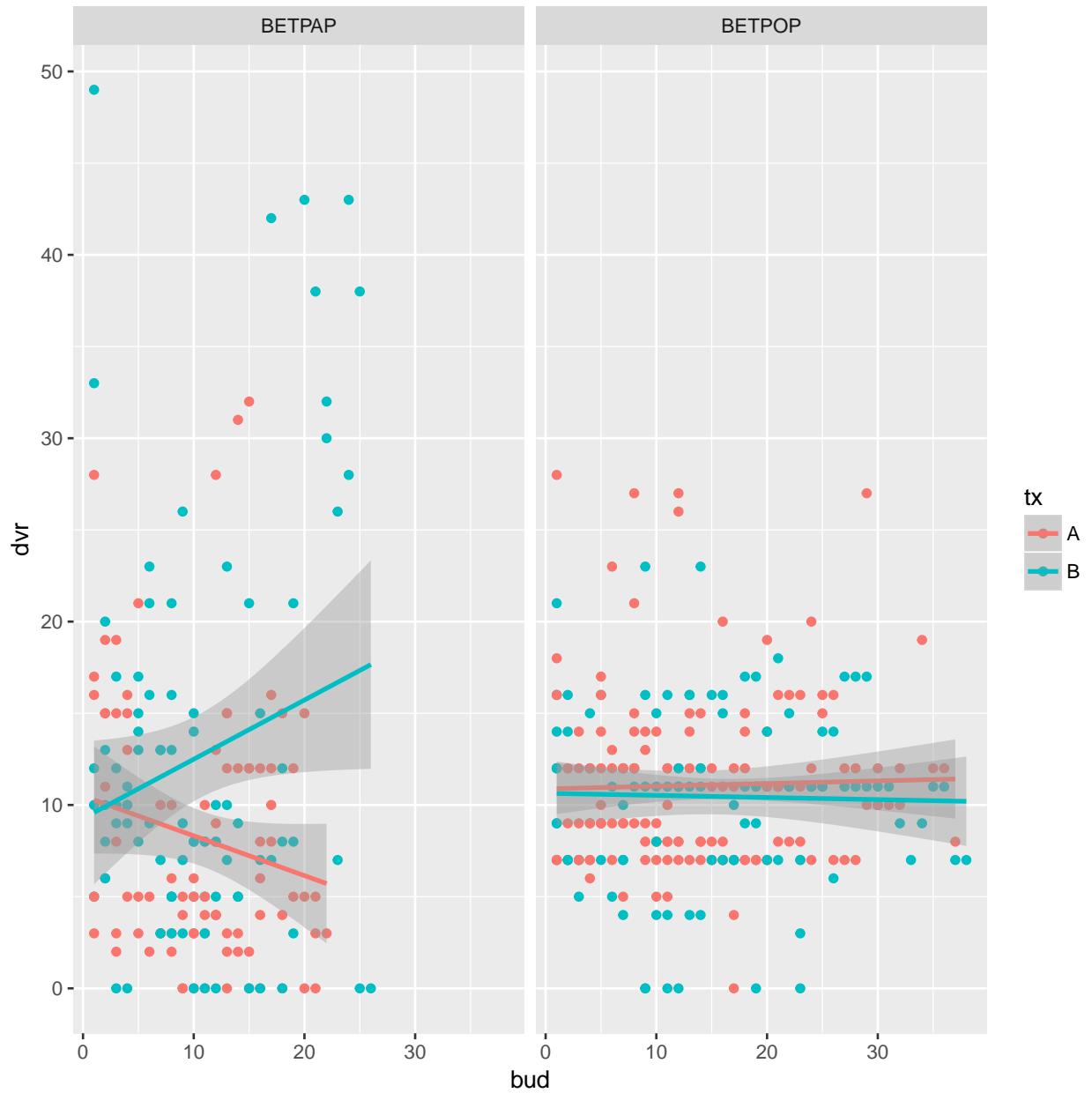


Figure 1: Duration of Vegetative Risk by bud number across the two betula species. As bud number increases, the further away from the terminal bud. The treatment effect on BETPAP appears to be much greater than on BETPOP from a first glance.

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78 lm(formula = perc.bb ~ tx + species, data = percent) coef.est coef.se
78 (Intercept) 74.20 5.29
78 txB -4.15 6.04
79 speciesBETPOP 2.13 6.04 — n = 29, k = 3 residual sd = 16.24, R-Squared = 0.02
  
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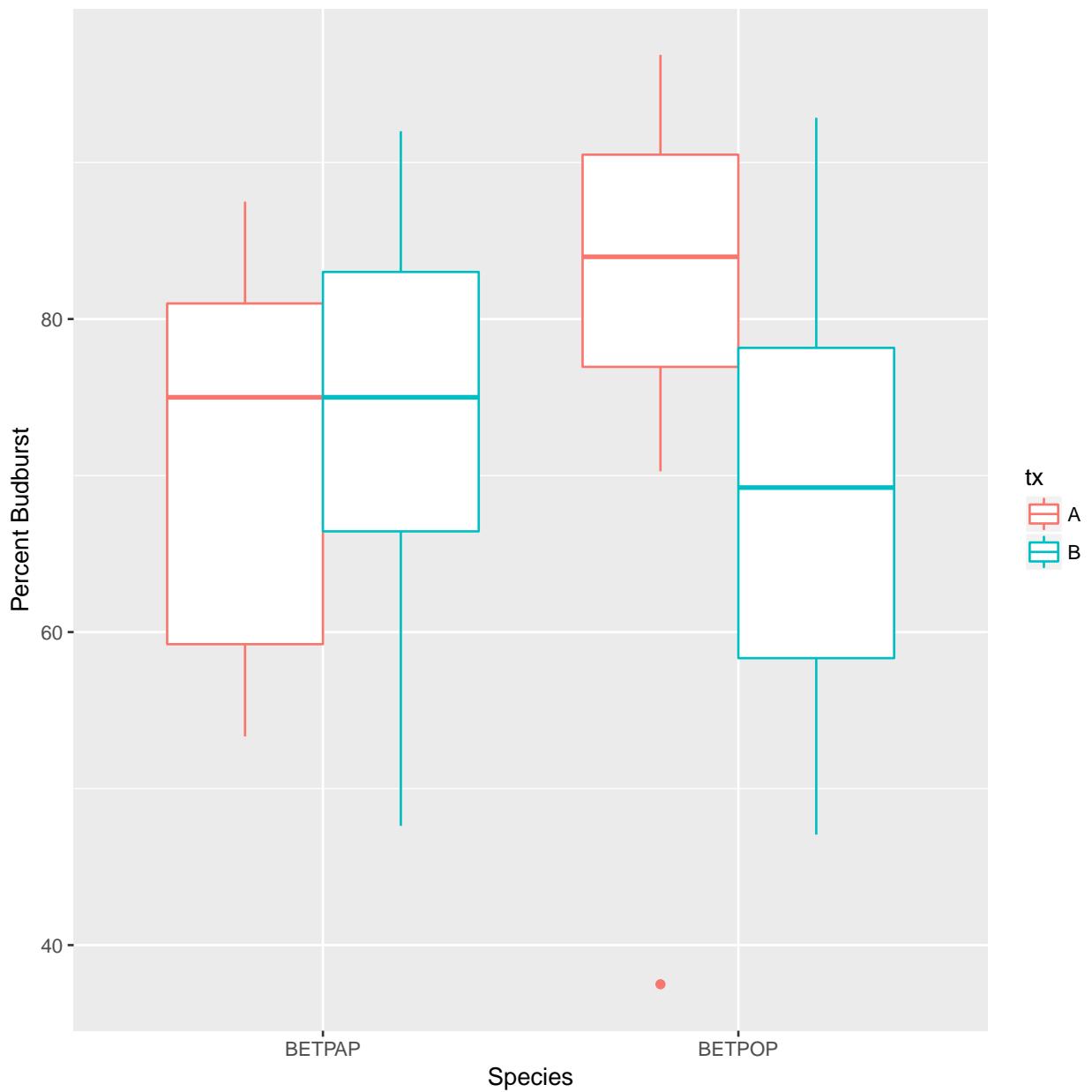


Figure 2: A boxplot looking at the percent budburst of individuals across treatment for each birch species

80 References

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