Rethinking False Spring Risk

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June 6, 2017

Tables and Figures

1 Determining Spring Onset

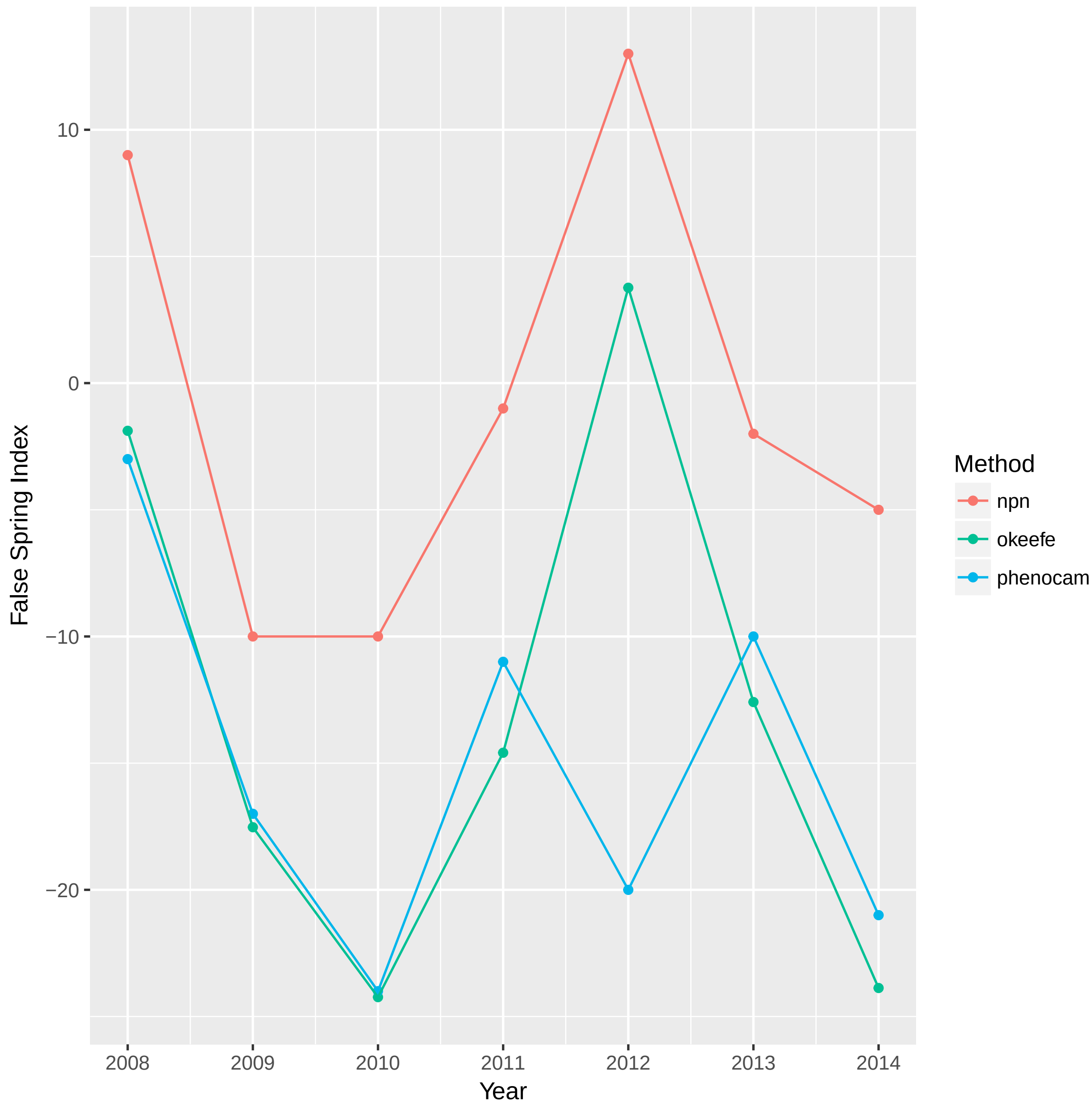
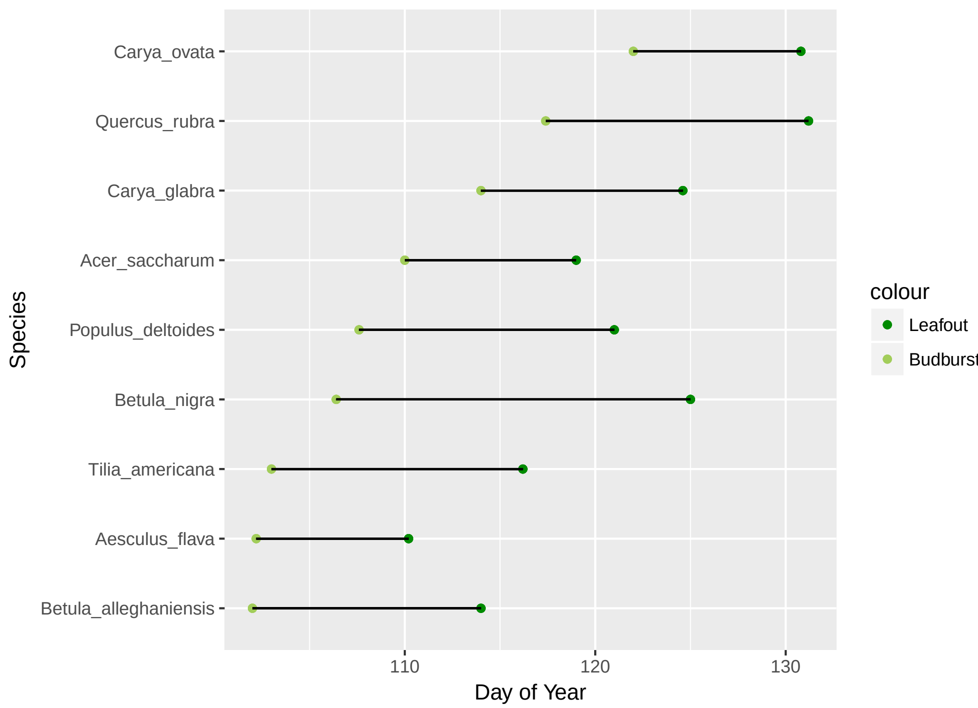


Figure 1: A scatterplot indicating FSI values from 2008 to 2014 for each methdology used in this study. PhenoCam FSI values are red, Observed FSI values are blue, and USA-NPN FSI values are green.

Species Differences and Vegetative Risk

Treespotters Data

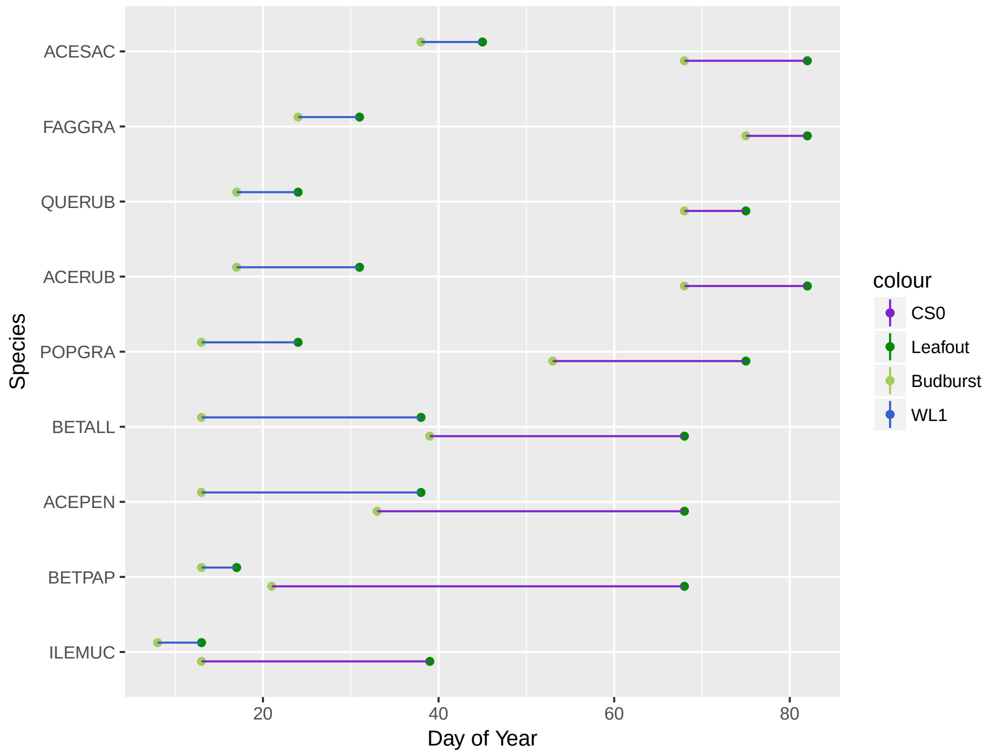
Figure 2: Duration of vegetative risk for 9 native tree species in New England. Data was downloaded from the US-NPN data download tool (http://data.usanpn.org/observations/get-started) and observations were collected from the Arnold Aboretum - Tree Spotters program.



	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	7.0456	9.4102	0.75	0.4575
Budburst	0.0549	0.0858	0.64	0.5250

Dan's Data

Figure 3: Day of budburst and the day of leaf out for native tree species in New England. Data was collected from a growth chamber experiment using any combination of two photoperiod treatments, two forcing treatments, and three chilling treatments. The standard deviation is represented in blue for budburst and green for leaf out.



Harvard Forest Data

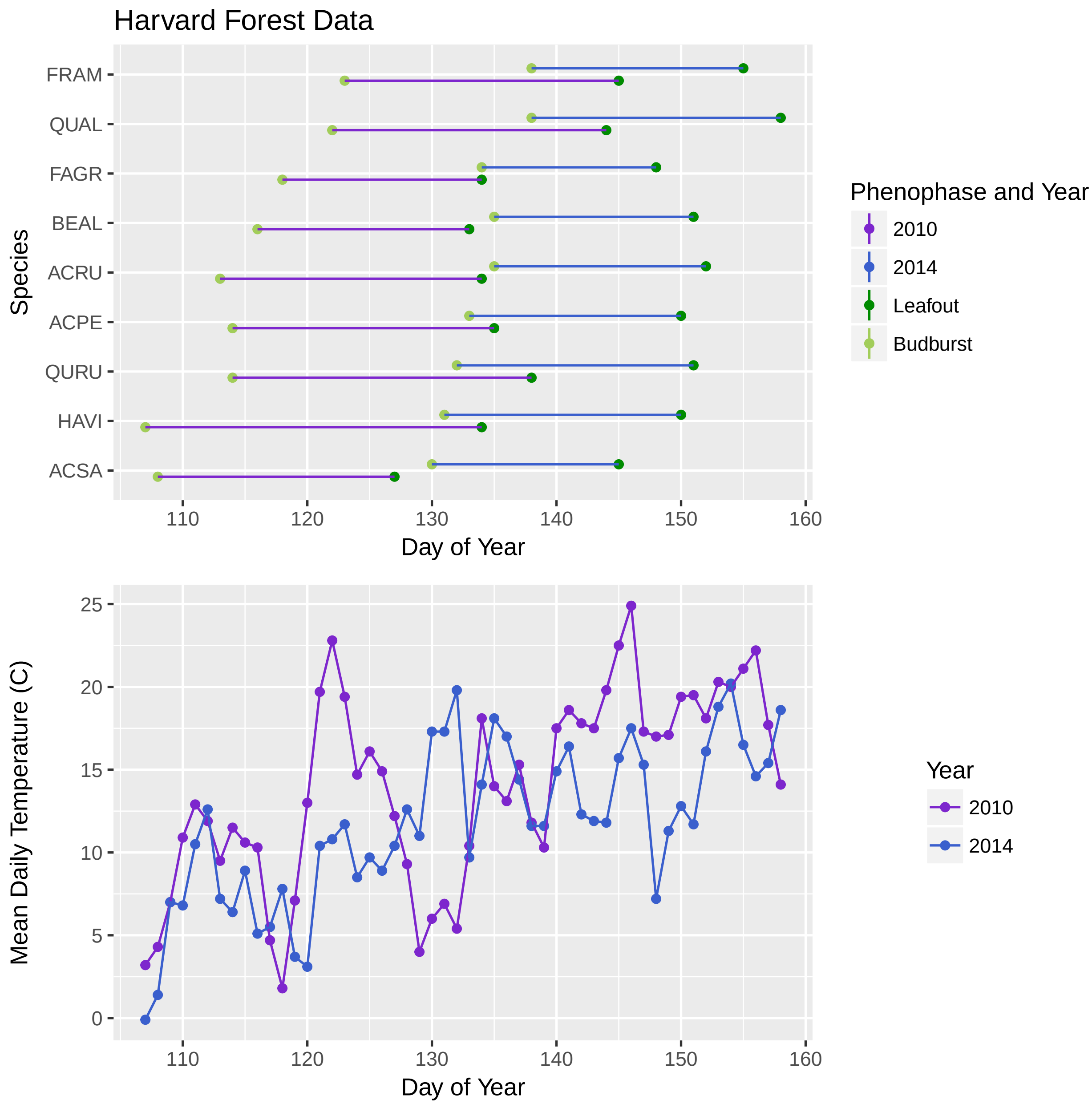
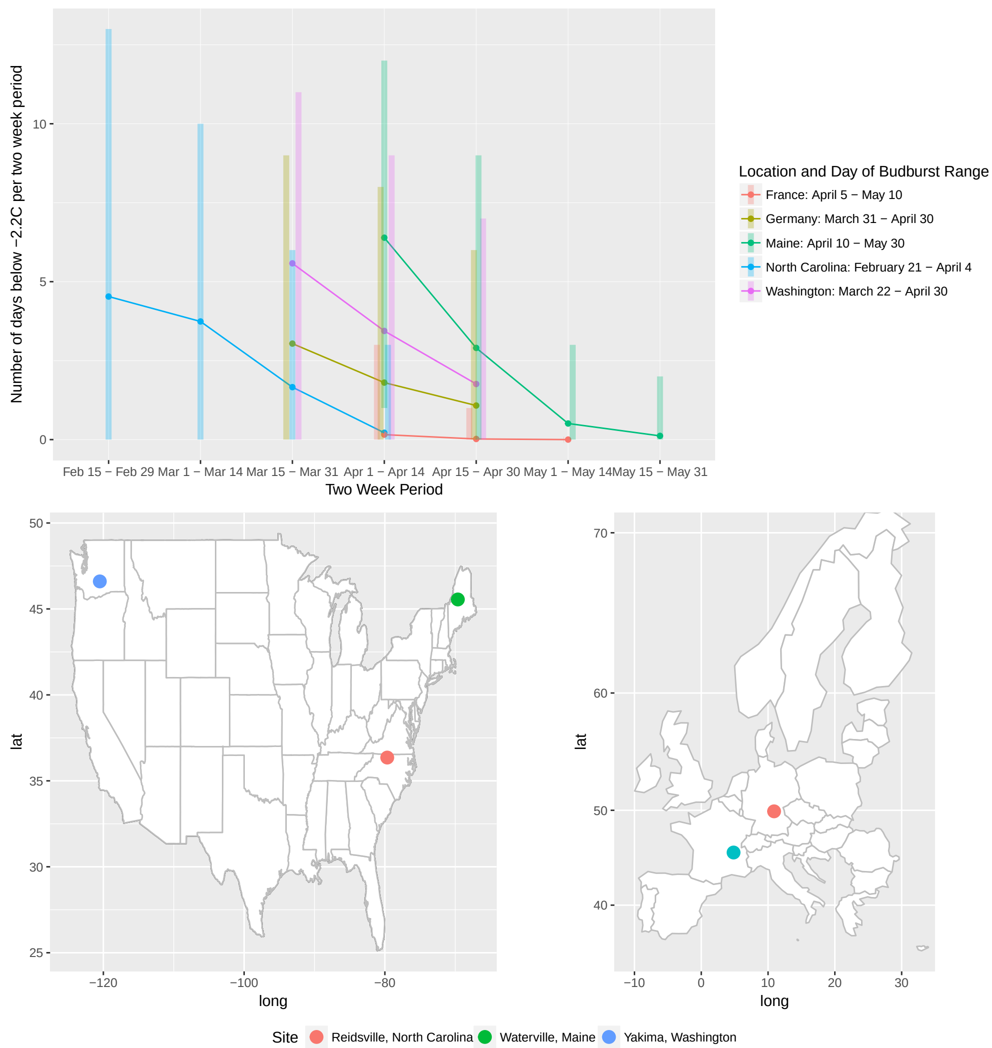


Figure 4: A timeline plot indicating the duration of vegetative risk for each species from collected from Harvard Forest.

Regional Differences in Vegetative Risk?

Figure 5: Risk of a false spring event across five archetypal climate regions. The data was subsetted for each region based on earliest historical spring onset date to the latest historical leafout date and was divided into biweekly time periods (USA-NPN, 2016; Soudani *et al.*, 2012; Schaber & Badeck, 2005). We calculated the mean number of days that were -2.2°C (Ault *et al.*, 2015; Schwartz *et al.*, 2006; Schwartz, 1993) or below for each two week period that fell within the budburst to leafout timeframe in each region.



Temperature Thresholds for Damage: Agricultural vs Ecological

Table 1: Comparing damaging spring temperature thresholds in ecological and agronomical studies across various species and phenophases.

Sector	**BBCH**	**Species**	**Temperature (°C)**	**Type**	**Source**
Ecological	9-15	Sorbus aucuparia	-7.4	50% lethality	Lenz *et al.* (2016)
Ecological	9-15	Prunus avium	-8.5	50% lethality	Lenz *et al.* (2016)
Ecological	9-15	Tilia platyphyllos	-7.4	50% lethality	Lenz *et al.* (2016)
Ecological	9-15	Acer pseudoplatanus	-6.7	50% lethality	Lenz *et al.* (2016)
Ecological	9-15	Fagus sylvatica	-4.8	50% lethality	Lenz *et al.* (2016)
Ecological	9+	All	-2.2	hard	Schwartz (1993)
Ecological	9+	All	-1.7	soft	Augspurger (2013)
Ecological	All	All	2 SD below winter TAVG	cold-air outbreaks	Vavrus *et al.* (2006)
Ecological	9+	Eucalyptus pauciflora	-5.8	elevated CO2 and temperature threshold	Barker *et al.* (2005)
Ecological	9+	All	-2.2	7 day threshold	Peterson & Abatzoglou (2014)
Agrinomical	9+	All	2	Risk threshold for clear nights	Cannell & Smith (1986)
Agrinomical	Floral	Vaccinium spp.	-4.4 to 0	sprinkler protection threshold	Longstroth (2012)
Agrinomical	9	Rosaceae	-7.2	10% lethality	Longstroth (2013)
Agrinomical	9	Rosaceae	-13.3	90% lethality	Longstroth (2013)
Agrinomical	All	All	Varies	Radiation Frost	Barlow *et al.* (2015)
Agrinomical	Floral	Wheat	-4 to -5	10-90% lethality	Barlow *et al.* (2015)
Agrinomical	Vegetative	Wheat	-7 for 2hrs	100% lethality	Barlow *et al.* (2015)
Agrinomical	Vegetative	Rice	4.7	lethal limit	Sánchez *et al.* (2013)
Agrinomical	Vegetative	Corn	-1.8	lethal limit	Sánchez *et al.* (2013)
Agrinomical	Vegetative	Wheat	-17.2	lethal limit	Sánchez *et al.* (2013)

Conclusion - Box

Box 1: Key Indicators for Modeling False Spring Risk and Damage
In order to properly evaluate the expected level of damage sustained from a false spring event key indicators should be included in the model.

I. Life Stage of the Individual(s) (Caffarra & Donnelly, 2011)
   (i) Seedlings and saplings will begin budburst earlier than adults
   (ii) The duration of vegetative risk may vary between life stages
   (iii) Long-term effects may vary

II. Location Within a Forest (Augspurger, 2013)
   (i) Individuals along the forest edge are more likely to experience a false spring
   (ii) Level of damage is likely to be higher at forest edges

III. Amount of Winter Chilling (Flynn & Wolkovich, 2017?)
   (i) Will affect the timing of budburst in the spring
   (ii) Will affect the duration of vegetative risk

IV. Proximity to Water
   (i) Large bodies of water are expected to act as a buffer to spring freezes

V. Precipitation Prior to Budburst (Anderegg *et al.*, 2013)
   (i) Will a drought increase cavitation and heighten damage from a false spring?
   (ii) Or will a drought decrease the risk of damage due to a lower chance of intracellular frost damage?

VI. Freeze Duration and Intensity
   (i) How should we define freezing temperatures?
   (ii) At what point is a freezing event severely damaging and xylem embolism occurs?
   (iii) How long must a false spring be to cause xylem embolism?

VII. Range of the Species
   (i) Species that have a more northern range may be more photoperiod than temperature sensitive

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