Abstract of Dissertation Research

Temperate tree and shrub species are at risk of damage from late spring freezing events, however the extent of damage and the frequency and intensity of these events is still largely unknown. Individuals that initiate budburst before the last spring freeze are at risk of leaf tissue loss, damage to the xylem, and slowed, or even stalled, canopy development. These damaging events are called false springs and have the potential to detrimentally affect forest growth and sustainability, which can result in highly adverse ecological and economic consequences. It is crucial for scientists and management teams to have a better understanding of false spring future trends in order to better conserve our forest ecosystems.

   Chapter 1: *Rethinking false spring risk*

Climate change has brought renewed interest to a major factor that shapes the life history of many non-tropical plant species: false spring events. While increased interest has led to a growing number of studies, much of the research takes a simplified view of these events, which—I argued—can lead to incorrect estimates and forecasting. Combining theory from ecology, climatology, physiology, biogeography and crop science we examined the effects of false springs, and the complexity of factors that drive plants' risk to frost damage.

   Chapter 2: *Climate change reshapes the drivers of false spring risk across European trees*

Here, I asked which climatic and geographic factors are the strongest predictors of false springs across six tree species, and how these predictors have shifted with recent climate change. By investigating leafout observations of six deciduous tree species from Europe, we unraveled the effects of species, spring temperature, elevation, distance from the coast and NAO index on false spring risk with climate change. We found that recent warming has reshaped the influence of these factors and magnified species-level variation in false spring risk.

   Chapter 3: *False spring damage to temperate tree saplings is amplified with winter warming*

For this experiment, I investigate the interplay of false spring events and warmer winters (generally expected to reduce chilling) across eight temperate deciduous tree species examining a suite of phenological, growth and leaf tissue traits. I found that false springs increased tissue damage, decreased leaf toughness and leaf thickness, and slowed budburst to leafout timing---extending the period of maximum freezing risk. Chilling, however, shortened this period of maximum risk, even under false spring conditions, thus compensating for some of the more adverse phenological effects of false springs. Despite major shifts in phenology from false springs and chilling I did not find evidence of phenological reordering within the community of species we studied. The results instead suggest climate change will reshape forest communities through impacts on growth and leaf traits from the coupled effects of false springs and warmer winters under future climate change.

   Chapter 4: *Assessing budburst phenology observations and simulations to better understand growing degree day models and methods*

Often we use mixed models to answer ecological questions, though we do not always understand the intricacies of the model output, nor do we investigate what is missing from the model output. Here, I work to understand mixed models using simulation data and test myriad hypotheses through these simulations. These methods can be applied to many ecological questions investigating climate data across global habitats but I specifically investigate spring plant phenology and how using different methods to measure climate can impact predictions. Understanding and predicting spring plant phenology is essential for determining growing season length and predicting and individual's risk of false spring under climate change.