## Variables:

Response variable: Cone crop

explanatory variable: Calendar day and delta-t value

## Cone production records

We used seed production data for 10 mast-seeding species located in the Pacific Northwest from Franklin and Schulze (2023) annual ovulate cone production surveys. These surveys included the most consistent methodology of surveys and had the longest records available for several genera within the Pinaceae family. Their surveys were conducted for *Abies* spp. (*A. amabilis, A. concolor, A. grandis, A. lasiocarpa, A. magnifica, A. procera*), *Pinus* spp. (*P. engelmannii, P. lamberti, P. monticola*), and *Tsuga* spp. (*T. mertsiana*) (Franklin and Schulze, 2023). A total of 61 plots in 37 locations were collected in nine National Forests in Washington and Oregon from 1959 to 2023. These sites are part of the LTER network. At each site, a visual count was made of cone production in each of a number (20-30) trees in a stand of one tree species (Franklin and Schulze 2023). Many of these records have a year or sequence of years marked as N/a (no data collected). Our analysis only included the longest non-NA portion of any record, leaving a total of 36 records for our analysis (10 *A. amabilis,* 2 *A. concolor, 3 A. grandis, 1 A. lasiocarpa, 3 A. magnifica, 6 A. procera*), *Pinus* spp. ( *1 P. lamberti, 2 P. monticola*) and *Tsuga* spp. (7 *T. mertsiana*). Thus while the bulk of these records span >40 years, the record portions we used are typically more in the range of 15-30 years.

## Climate data

For all analyses, we used mean daily air temperature for March 1st through October 1st for a 33 year span (1981-2014) to match the available cone crop production records from the Franklin, J.F. and M.D. Schulze dataset. Temperature data from the nearest weather station was taken from the PRISM Climate Group at Oregon State University; see <https://prism.oregonstate.edu/>. Site location data was extracted from the Franklin and Schulze (2023) dataset and uploaded to the PRISM explorer for time series values with individual locations. The proximity of the PRISM weather station and site location did not exceed 4 kilometers.

## 

## Statistical Analysis

Prior to our analysis, we calculated Delta-t using daily temperature data for each year for the months of March through October. For the genera with a 2 year seed development time (*Abies and Tsuga*), we calculated Delta-T from daily temperature in year T2 minus daily temperature for T1. Then we modified the onset (start day) and duration (length of days) so that Delta-T could be calculated for different intervals. For example, onset 1 duration 30 would calculate the Delta-T values for March 1st through March 30th given the daily temperature means for 1983 minus the daily temperature means for 1982 (T2-T1).

Then, Pearson's correlation was calculated between the Delta-T values for each group of dates and the cone crop for each species annual cone crop record. For example, Delta-T for 1983-1982 predicts the ideal temperature cue for the 1984 cone crop. This was done in two ways: version. 2 was using the exponential of Delta-T and version. 3 was the exponential of delta-t/cone crop.

# 

## Background:

The Delta-T (ΔT) model uses both T n-1 and T n-2  to predict cone production. This model can be used to determine the temperature cue that initiates reproductive buds by the difference in summer temperature one year before the crop (T n-1) and the temperature in the preceding summer (T n-2 ) i.e ΔT= T n-1 -T n-2 (Kelly, 2013; LaMontagne 2020). The predicted cone crop size will respond to the magnitude of the difference between the two earlier summers (Kelly 2013; LaMontagne 2020; Vacchiano 2017) with large crops corresponding to large positive values of ΔT

We already calculated delta-t using month values and then correlated using the Pearson correlation test. Now, we see which month has the best correlation between delta-t and the cone crop values for that year. We speculated. We said that the onset date is the Julian calendar date and the assumed calendar date is 30 days but nature doesn't do that. We can make the assumption that it may be a certain month but we don't know After delta-t for the month, we will see which week has the best correlation and go through all of the weeks in that month with staggered on set dates (May 15- September 8th). We do exactly what we did before, we do delta-t weekly not monthly and we will do that for all of the weeks for May 15- september 8th. About 100 different onset date. Repeat the process with two weeks then three weeks and then., one month again and test the four different onset dates.

## Objective:

* Define the months or dates for specific species.
* Doesn't matter what we find because no one has done this
* Organizing the data;
  + Cone crop data- (this is the median values)
    - Only use consecutive values: that means exclude the values that are NA
    - Isolate the non-NA values for each species. Longest string of non-NA
    - Run both fragments
      * Ex : (Duration) 30, 20, 18, 6
  + Weather data-
    - relevant years that match with the consecutive cone crop data

## David Ranting at Emily and notes for the original program:

* Start with all the temperature dates as daily values and set duration
* First will be one week starting on may 15 to may 21st inclusive is 7 days so the very dist time you try the code you do it based on mean temp over the next seven days
* Now for each year you have mean temp from may 15 to 21 then correlation with seed crop size
* Then run it again and start with may 16 and run for seven days → may 17th → do until final onset date for september 8th
* Different onset with one week duration. Then do it for a two week duration for 14 days inclusive and then get correlation. And keep going until two weeks before September 18ths.
* Then do it again for three week durations from may 16
* Then one month but can only go until June.
* Then look at all correlations which species had the most consistent correlation and which onset and correlation

## Delta-T model explaination:

**Notes from Emily for the Delta-T function in R**

* Didnt use any main functions, only used ggplot for graphing, functions used are ones that are custom functions.
* Reading in the temperature data: storing all of the data in file temp1, then temp 1a takes specific col from temp 1.
* Delta T; Daily temperature for each year. Depending on when you wanted to start March 10 to October 1st. 8x30 = 240 days. Depending on the duration and interval you were looking at, 30 days, 1 week, 2 weeks. Code assigns groups to each of the days, if one week then March 10,11,12 then 7 of those days are assigned group 1. Across the year, the group 1s were averages and that would be the temp mean for 1981, then it repeats for 1982 and 1983 and so on. Youd have to do this for each group of days for all of the years (1982-2014). This is taking the temperature mean difference for the years. Calculate time step means: spits out the mean and another function takes in the means and takes difference between the years. Labeled col and order.

## Cross check dates with low cone production: Notes from David

* there is no unanimity on the delta t signal with regard to onset or duration because the cone crops themselves are not well synchronized. THAT had never occured to me as a potential problem. . . nonetheless with amabilis we can pick out one group of sites whose crop records are highly correlated with one another. It is true we have no clue why they are poorly correlated (something local. . . hail storm, local insect infestation. . .) but why not go with the highly correlated ones and see with that group only: how ell does delta t predict and what are the onset and duration.
* if you do the correlation matrix for the other species, then we can decide on a suitable cut-off; eg all conspecific records with a crop correlation of r>0.8 will be used.
* then you feed the selected records into the program as a large single record. eg we have 4 records totaling 120 years and that goes in as a single record (even though years are being repeated). that is what emily is supposed to be working on.
* I picked two sites well separated by latitude and correlated the first ten days of march for each. r=0.9. but the cone crop correlations show quite a bit of difference unrelated to latitude. ie presumably unrelated to weather. something other than weather is going on here. eg 1985 was a great crop at all sites for amabilis except ABAM36 where there were ZERO cones. ABAM35 should have a big crop in 91 but it doesnt. likewise, 97 is a great crop year for some amabilis sites but not for others. lots of examples. --this cant be due to weather; it is too similar for nearby sites. I think we will conclude there are limits to what delta t can do because there are non-weather drivers we dont understand. nonetheless we can still offer them something (onset/duration for each species that we expect to have an average r of about

## What we need now…

Picture a species with 8 records. Presently, each record has a set of cone crop values and delta t values, and we run each record separately. Is there a way to combine all the 8 records into a single record and then run the program on that? Ultimately we want to know the best onset and duration for the species (not just for each record). In other words, the records are currently broken up by site but instead we want to break them up by just the species. i.e all records that have ABAM for example, would be grouped together instead of separated by their location site.