Investigating The Variability of Urban Tree Phenology Using Volunteer-hosted Phenocams

Presented by Maya Hall

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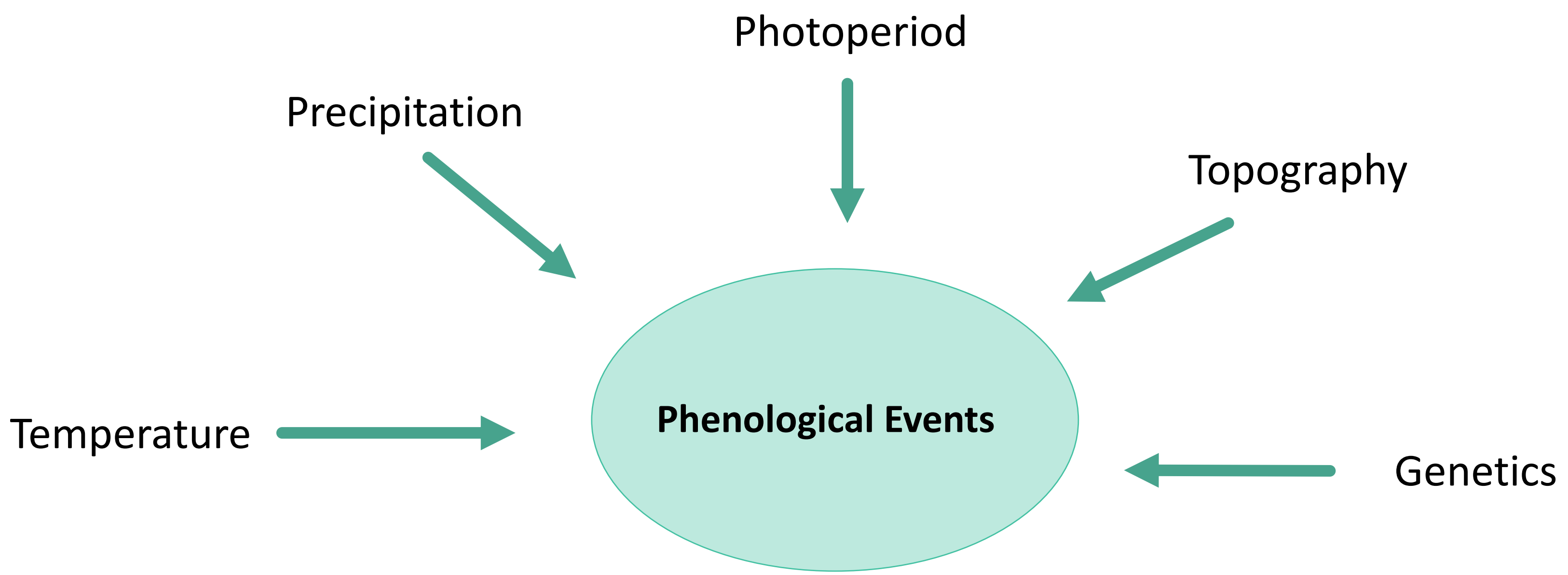
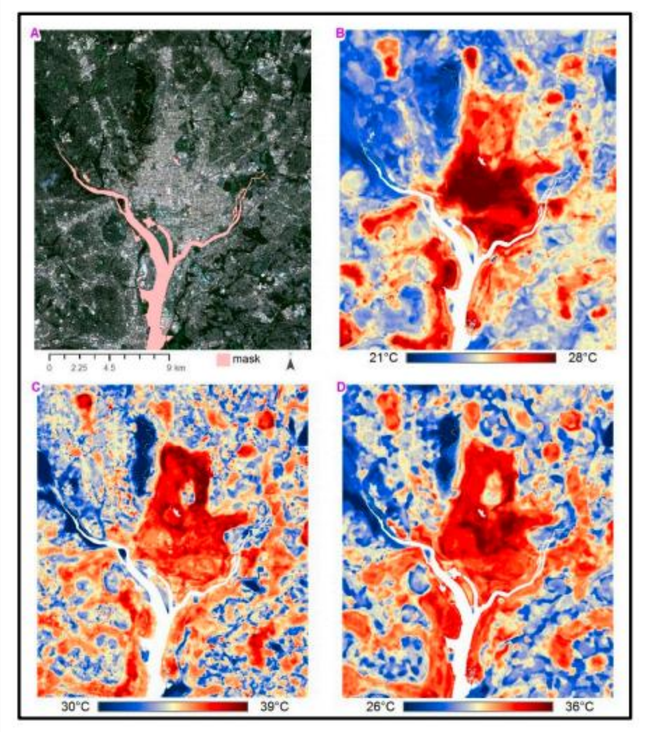
Background

Phenology: the study of cyclic and seasonal natural phenomena in the lives of plants and animals

Drivers Of Phenology



Urban Heat Island (UHI) Effect



Washington, D.C. (A) aerial imagery with major waterbodies masked; (B) morning UHI; (C) afternoon UHI; (D) evening UHI. *(Shandas et al. 2019)*

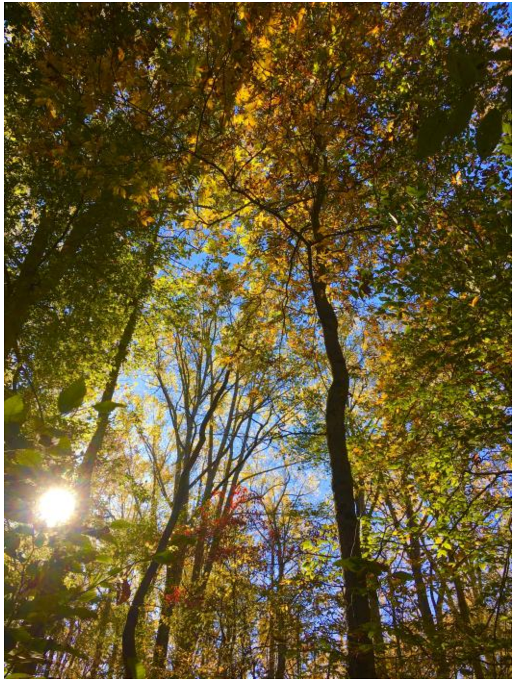
Advance in spring events

Delay in autumn events

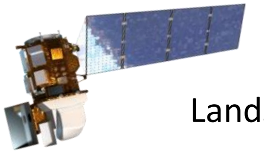
Extension of growing season

Motivation – Importance of Urban Phenology

- Ecosystem services
- Phenology as an indicator
- Proxy for future responses



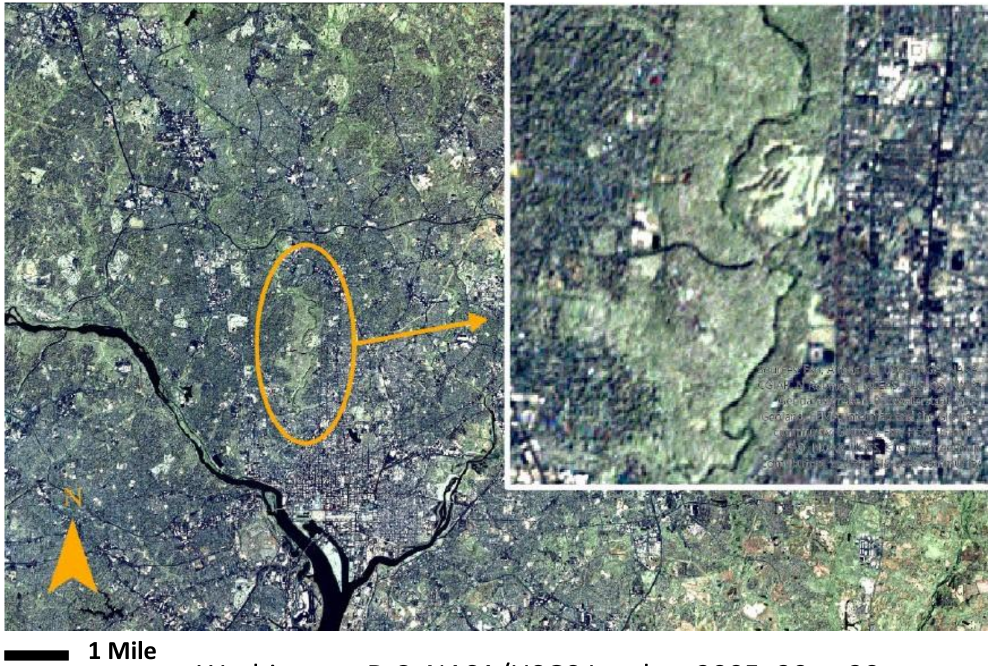
Methods of Phenological Data Collection



Landsat 8

- Ground-based Observations
- Satellite Remote Sensing

Satellite	Spatial Resolution	Temporal Resolution
MODIS	250m – 1000m	1-2 days
Landsat	30m	16 days
Harmonized Landsat Sentinel-2 (HLS)	30m	2-3 days



Washington, D.C. NASA/USGS Landsat 2005. 30mx30m

Phenocams

StarDot NetCam

Brinno Digital Camera

- Near-continuous
- Accessible and flexible
- Near-surface

Top: HoS EOS 2022; Bottom: Delaware Ave. SOS 2022

Aim 1: Test the extent to which phenocam imagery can track urban phenology changes influenced by regional air temperature and precipitation

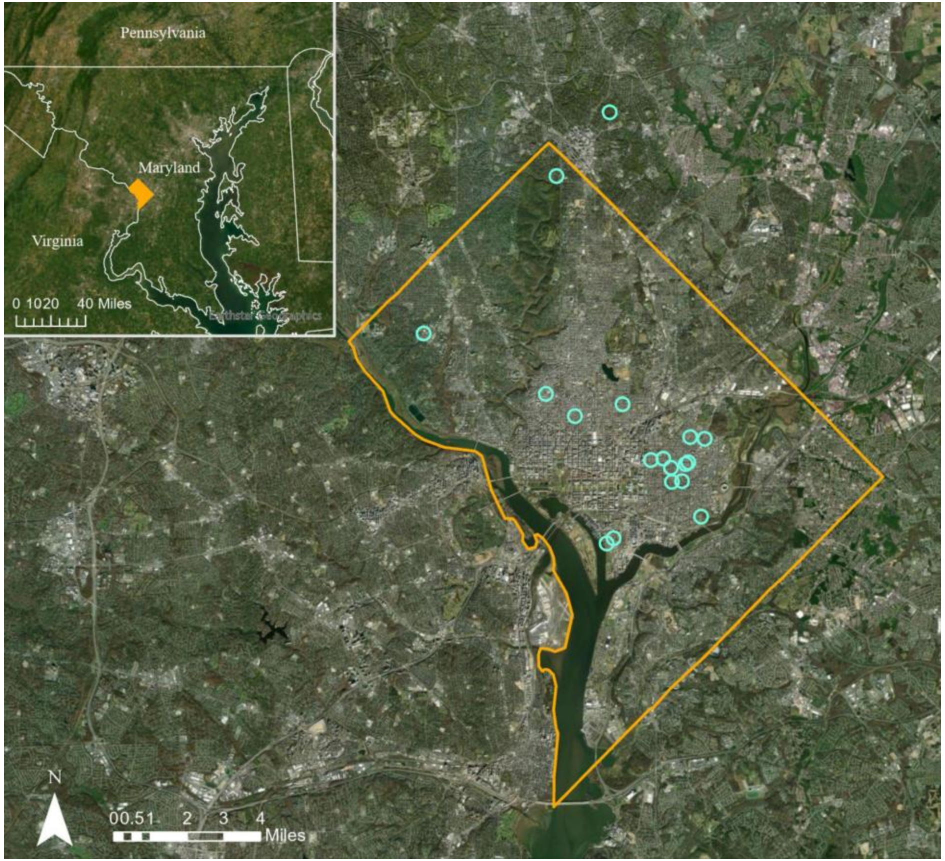
Aim 2: Explore the variability of urban tree phenological responses across phenocam site and genera

Aim 3: Examine the suitability of phenocams as reliable and practical tools for urban phenology studies and explore the implementation of volunteers as phenocam hosts

Study Site: Washington, D.C

- Humid subtropical climate
- 38% canopy cover
- 39% impervious surface cover

Phenocam locations based on Casey Trees volunteers



Washington, D.C. study site with district borders outlined in orange and each phenocam location symbolized as a bright blue circle

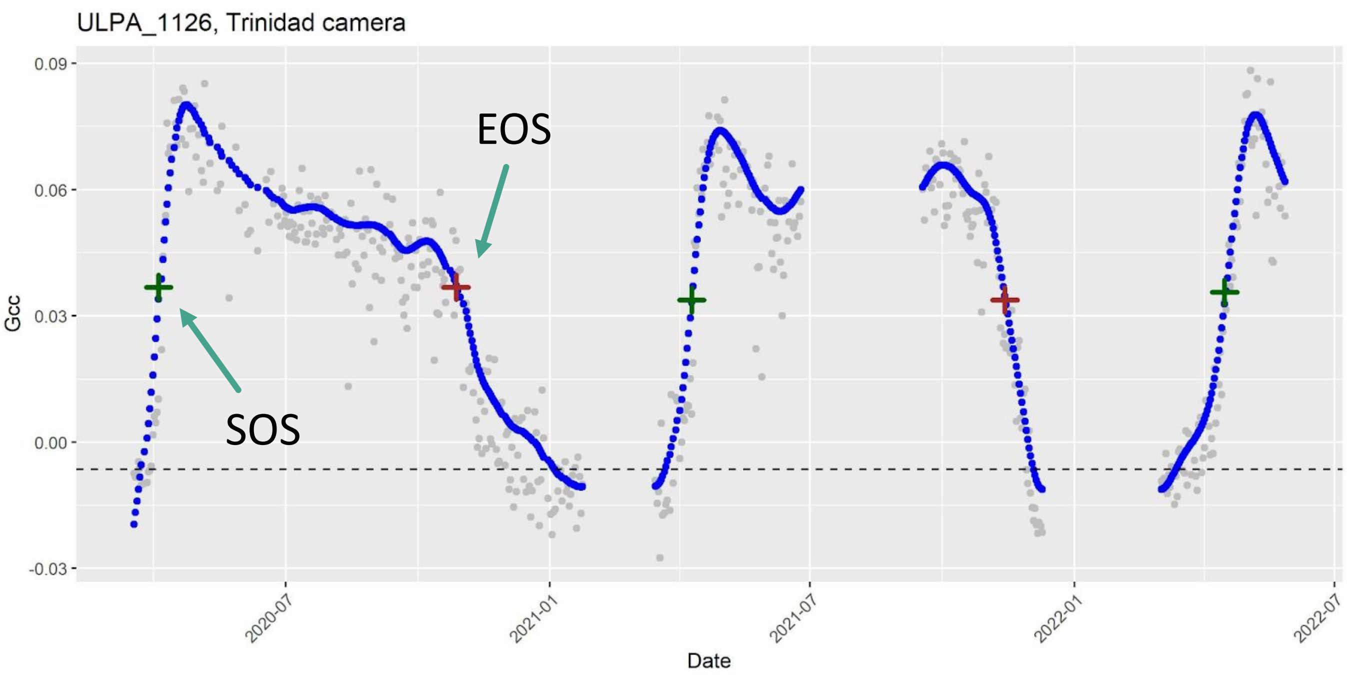
Phenocam Installation and Data Collection

Above: raw video from phenocam; Right: Examples of phenocam set-ups

Daily Images and xROI

Left: Example of an ROI in xROI GUI; Right: Example of drawn and labeled ROIs.

Spline Interpolation and Phenometrics



Example of spline interpolation

Interannual Differences in Phenometrics

Analysis of Variance (ANOVA)

- Start of season (SOS)
- End of season (EOS)
- Growing season length (GSL)

Tukey's Honest Significant Difference (HSD)

- Significant phenometrics

Visualize as Boxplots

- All phenometrics

Statistical Analyses

Aims 1 & 2 – Climate, Site, and Genus

- Hierarchical Mixed Effects modeling
- Ordinary Least Squares modeling
- Visualization of genera differences

Key Model Evaluation Steps

- MAD and R^2
- BIC minimization

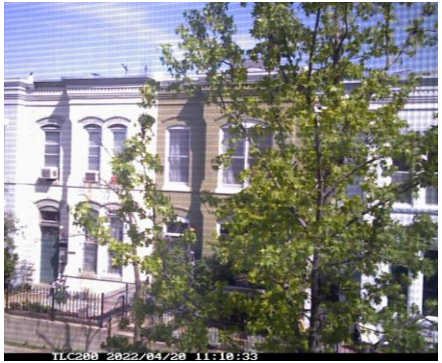
Model Variables

	Variable Name	Short Name	Description
Regional Variables	Temperature	TEMP	Monthly and daily minimums, maximums, and averages from NOAA
	Precipitation	PRECIP	Monthly averages and totals from NOAA
Site Variables	Impervious surface	IMP	Impervious surface from City of D.C. planimetric data
	Tree canopy	TCF	1 m tree canopy map derived from 2018 City of D.C. lidar data
	Elevation	ELEV	City of D.C. lidar Digital Terrain Model (2018)
Random Effects	Year	Year	2020 – 2022
	Phenocam	Phenocam	Individual phenocams
	Genus	Genus	Street tree identities provided by D.C.'s Urban Forestry Division (UFD)

Method Evaluation

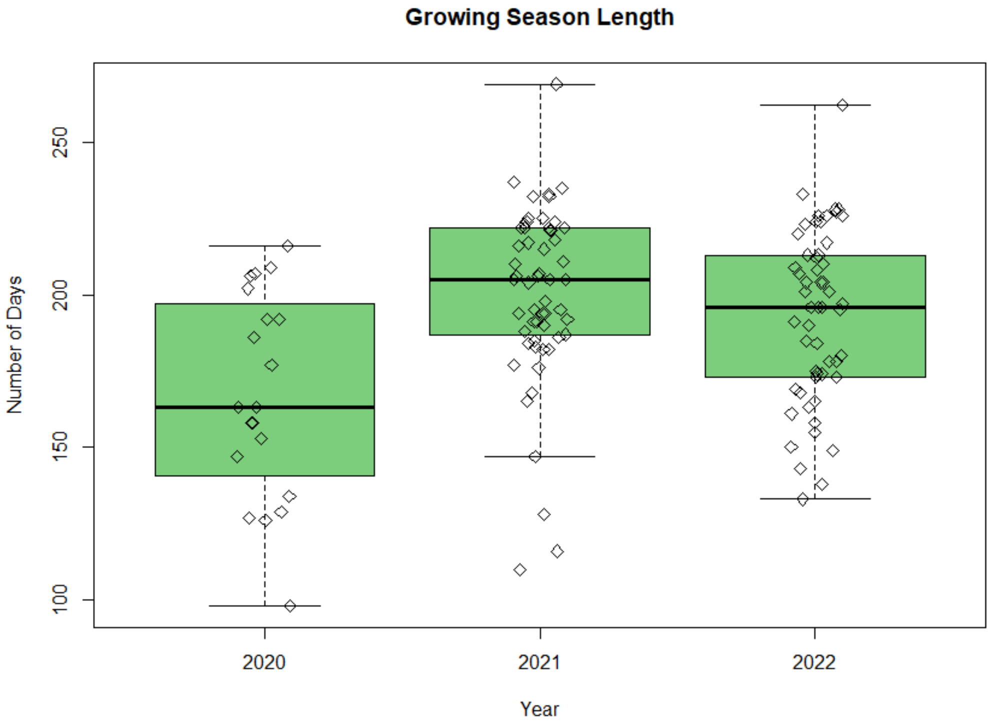
Aim 3 – Volunteer-hosted Phenocams

- Assess benefits and complexities of phenocams
- Evaluate influence of volunteer-based sites
- Provide recommendations

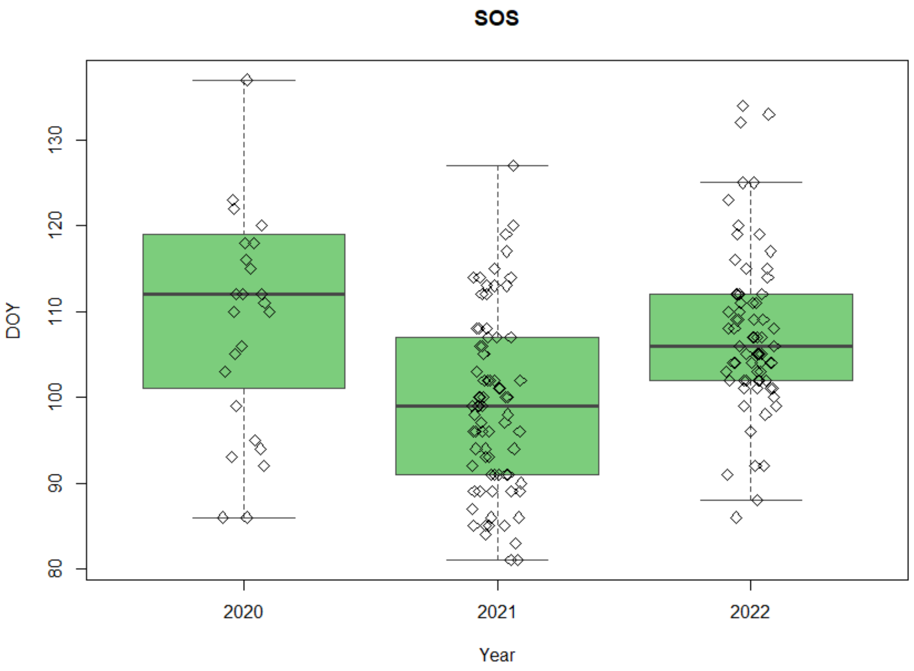


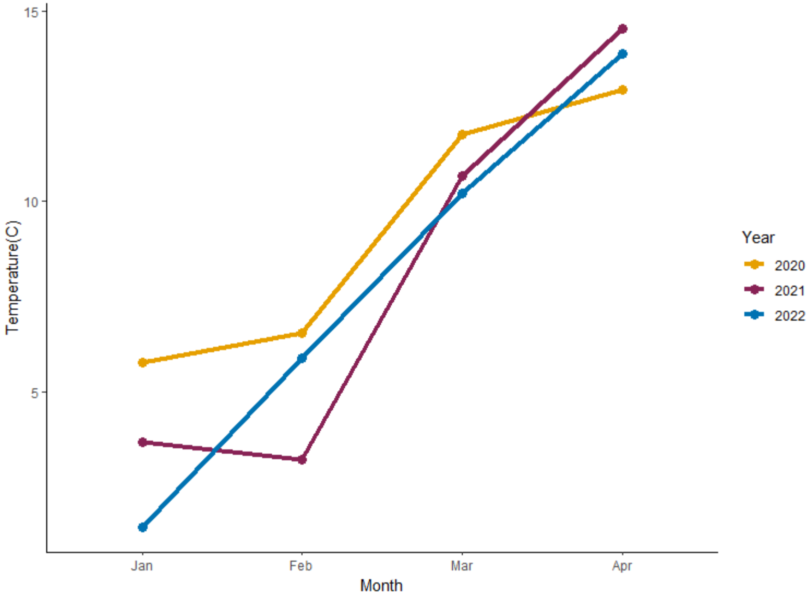
Results

Interannual Variation



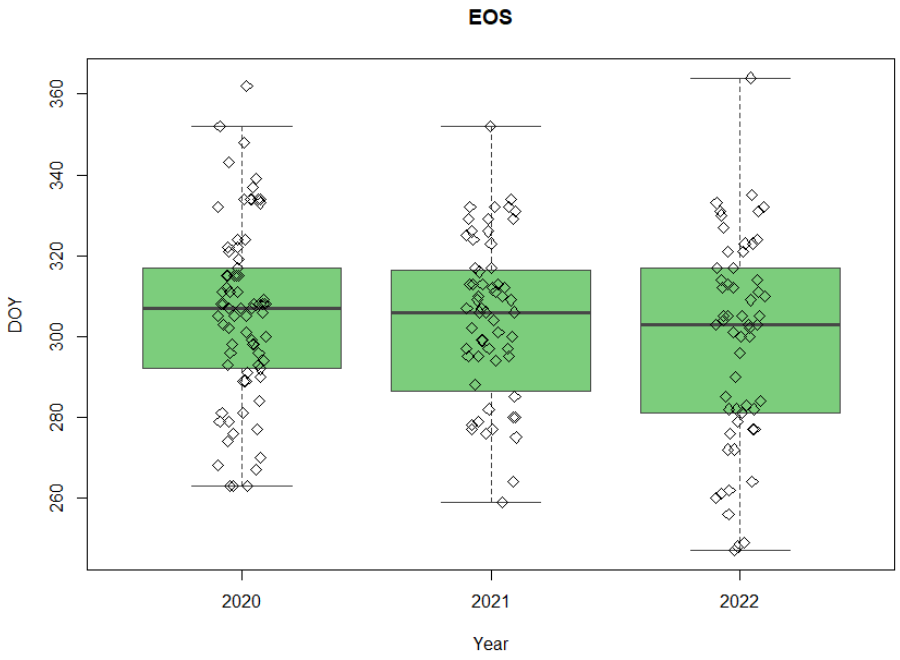
Interannual Variation

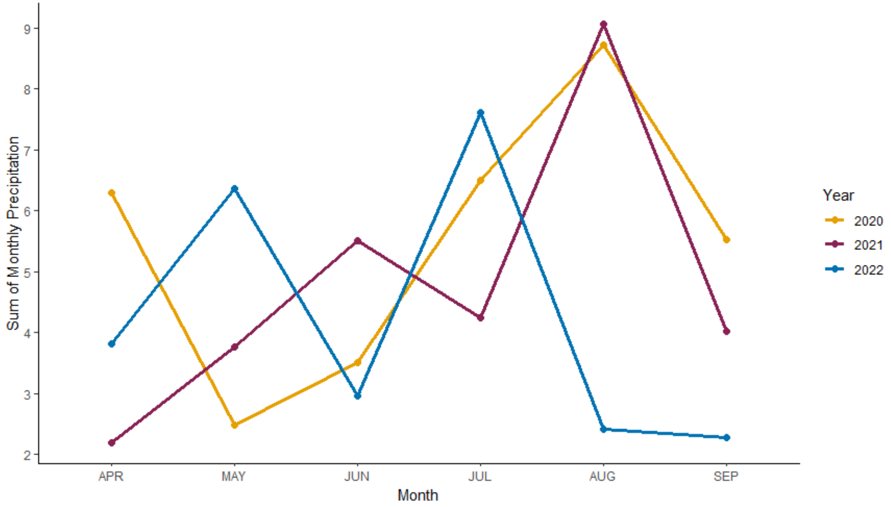




Results

Interannual Variation





Hierarchical Mixed Effects Models

$$\boldsymbol{SOS = \%IMP + \%TCF + ELEV + TEMP + \ (1|Phenocam)}$$

R^2 = 0.38
MAD = 5.03

$$\boldsymbol{EOS = \%IMP + \%TCF + ELEV + TEMP + PRECIP + \ (1|Phenocam)}$$

R^2 = 0.36
MAD = 10.26

Hierarchical Mixed Effects Model: SOS

	IMP	TCF	ELEV	TEMP
Coefficient	33.12	13.64	-0.06	25.72
Std. Error	60.23	63.82	0.16	9.01
t-value	0.55	0.21	-0.34	2.85
p-value	0.60	0.84	0.71	**4.86e-3***

**statistical significance at the 99% level*

Ordinary Least Squares Models

$$\boldsymbol{SOS = \%IMP + \%TCF + ELEV + TEMP}$$

R^2 = 0.14
MAD = 5.19

$$\boldsymbol{EOS = \%IMP + \%TCF + ELEV + TEMP + PRECIP}$$

R^2 = 0.04
MAD = 13.58

Ordinary Least Squares Model: SOS

	IMP	TEMP	TCF	DTM
Coefficient	-14.94	17.73	9.89	-0.03
Std. Error	12.13	3.97	13.90	0.03
t-value	-1.23	4.47	0.71	-1.10
p-value	0.22	**1.45e-05***	0.48	0.28

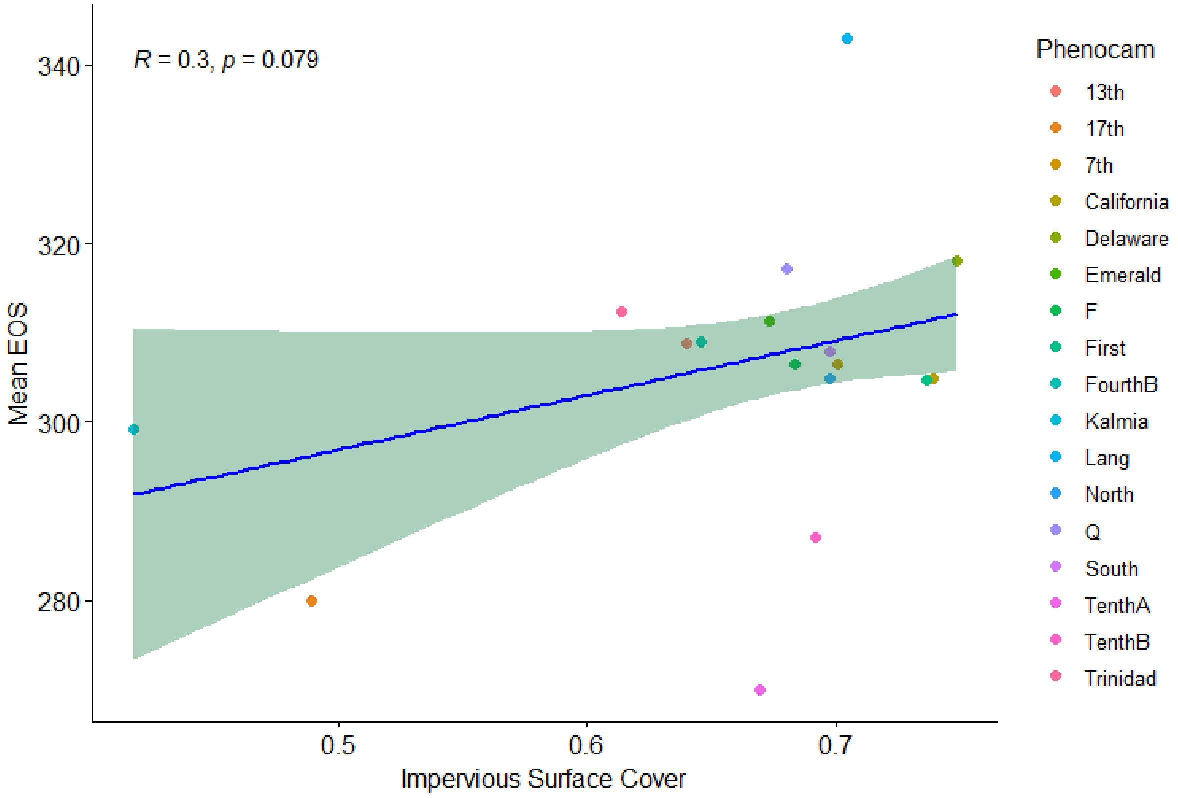
**statistical significance at 99% level*

Ordinary Least Squares Model: EOS

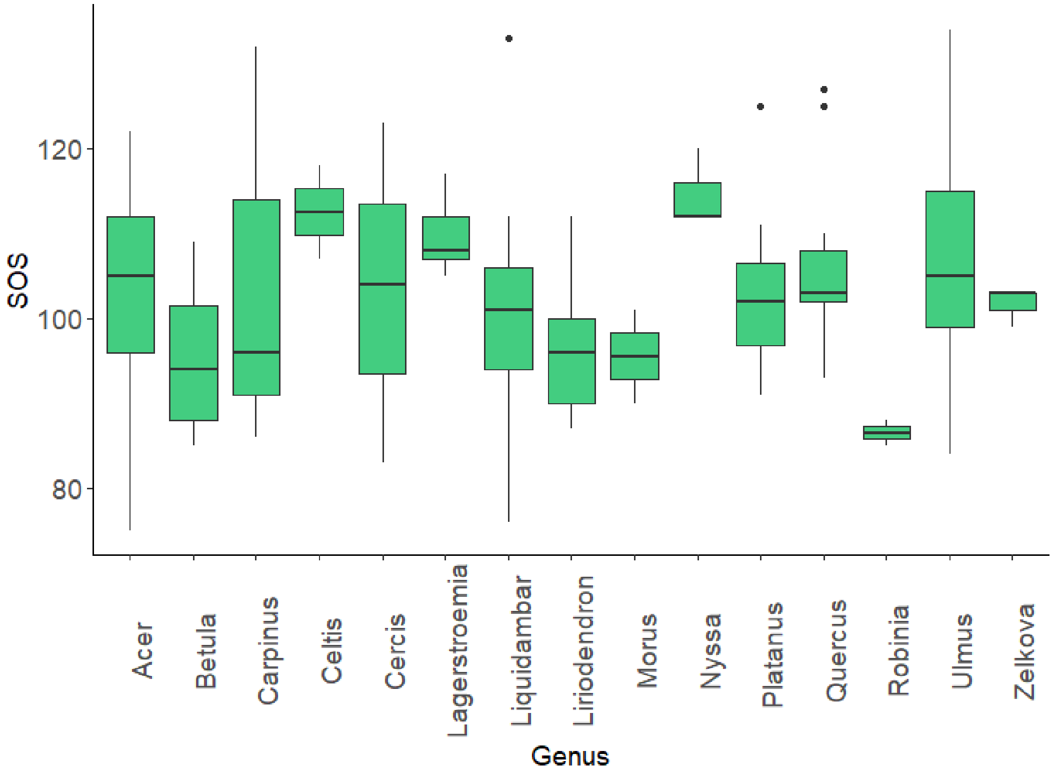
	IMP	TEMP	TCF	DTM	PRECIP
Coefficient	58.75	-2.43	5.03	-0.03	0.35
Std. Error	24.90	5.97	25.71	0.05	0.44
t-value	2.36	-0.41	0.20	-0.66	0.76
p-value	**0.02***	0.68	0.85	0.51	0.43

**statistical significance at 95% level*

Ordinary Least Squares Model: EOS & Impervious Surface Cover



Phenometric Differences in Genera



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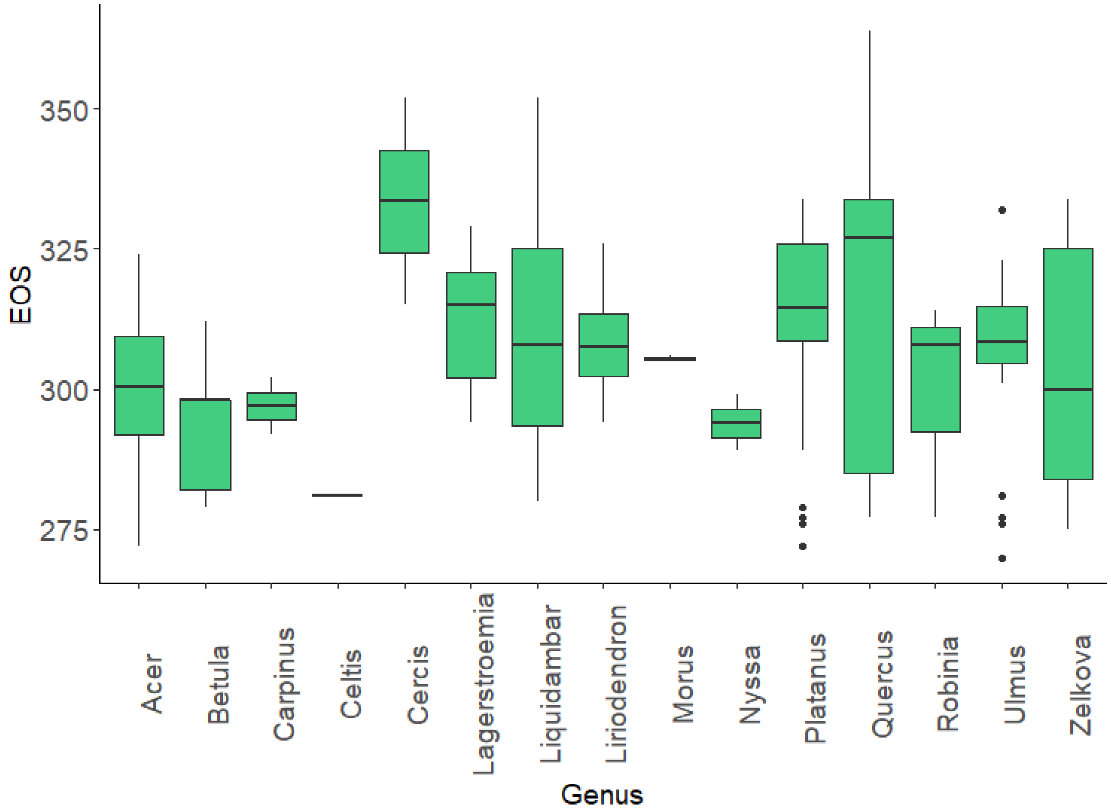
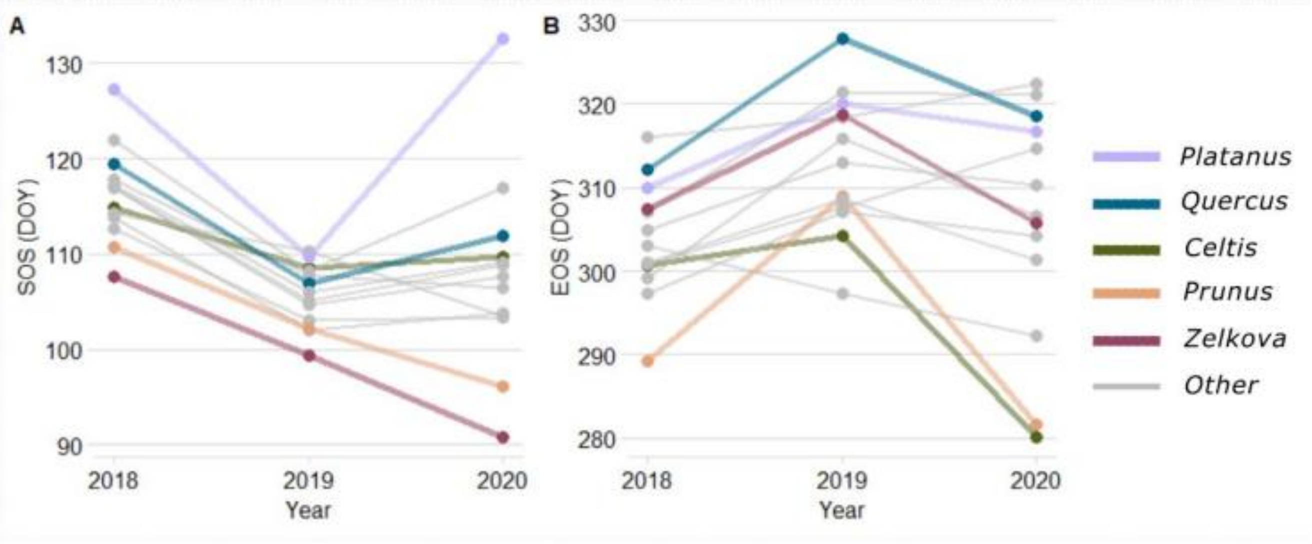


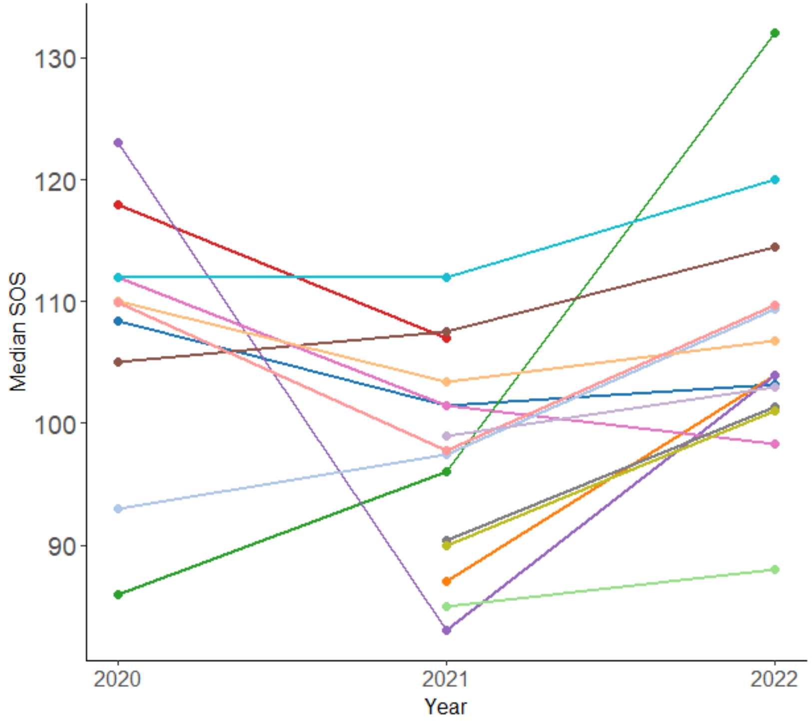
Interannual Genera Differences

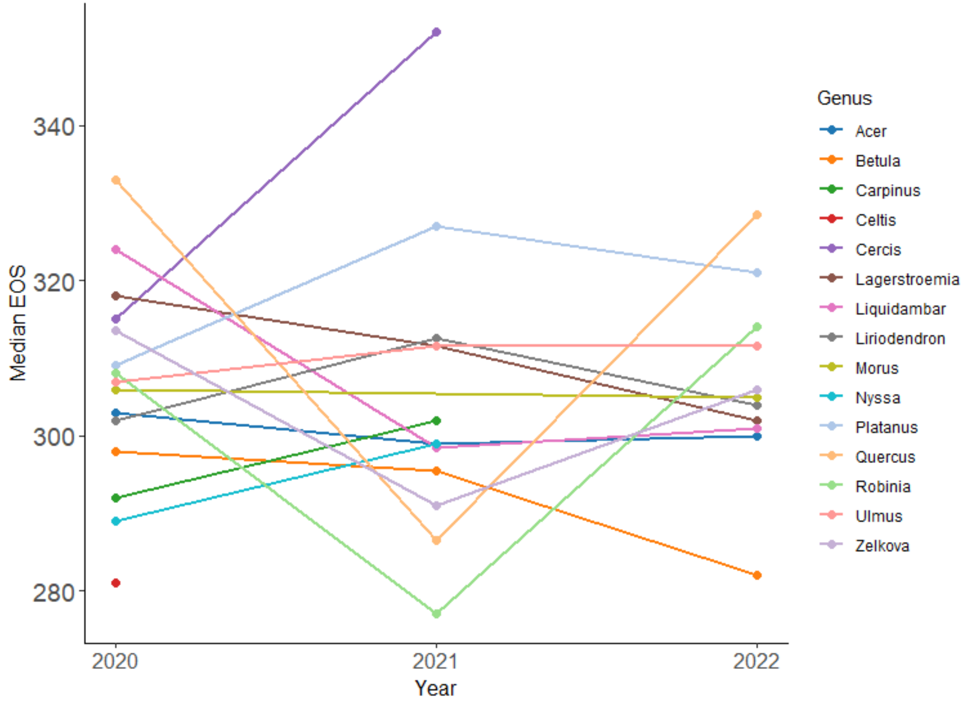


Median phenometric values for each genera plotted across three years. A) SOS, B) EOS (Alonzo et al. *accepted*).

Results

Interannual Genera Differences





Results

Assessing Phenocams

Phenocam	SOS 2020	EOS 2020	SOS 2021	EOS 2021	SOS 2022	EOS 2022
Trinidad Ave	Active	Active	Active	Active	Active	Active
17th St.	Active	Active	Active	Active	Inactive	Inactive
First St.	Active	Active	Active	Active	Active	Active
Lang Pl.	Active	Active	Active	Active	Active	Active
A 10th St.	Active	Active	Inactive	Inactive	Inactive	Inactive
A 4th St.	Active	Inactive	Inactive	Inactive	Inactive	Inactive
B 10th St.	Active	Active	Active	Active	Active	Active
B 4th St.	Active	Inactive	Inactive	Inactive	Inactive	Inactive
Delaware Ave		Active	Active	Active	Active	Active
13th St.		Active	Active	Active	Active	Active

Phenocam	SOS 2020	EOS 2020	SOS 2021	EOS 2021	SOS 2022	EOS 2022
California St.		Active	Active	Active	Active	Active
Emerald St.		Active	Active	Active	Active	Active
Q St.		Active	Active	Active	Active	Active
7th St.		Active	Active	Active	Active	Active
F St.		Active	Active	Active	Active	Active
Pershing Dr.		Active	Active	Active	Active	Active
HoS North		Active	Active	Active	Active	Active
HoS South		Active	Active	Active	Active	Active
Kalmia Rd.		Active	Active	Active	Active	Active

Aim 1:

- Significant SOS differences between years
- SOS delayed by **~ 1.8 to 2.6** days as temperature increases

Aim 2:

- Significant phenometric differences across genera
- EOS delayed by **~ 5.9** days for every 10% increase in impervious surface cover

Aim 3:

- Urban locations add complexity to phenocam set-ups
- Type of phenocam matters
- Volunteers as phenocam hosts increase educational reach of project, but site variation adds noise

Recommendations

- Continuous power source
- Prioritize high installation
- High selectivity of phenocam model and mount type

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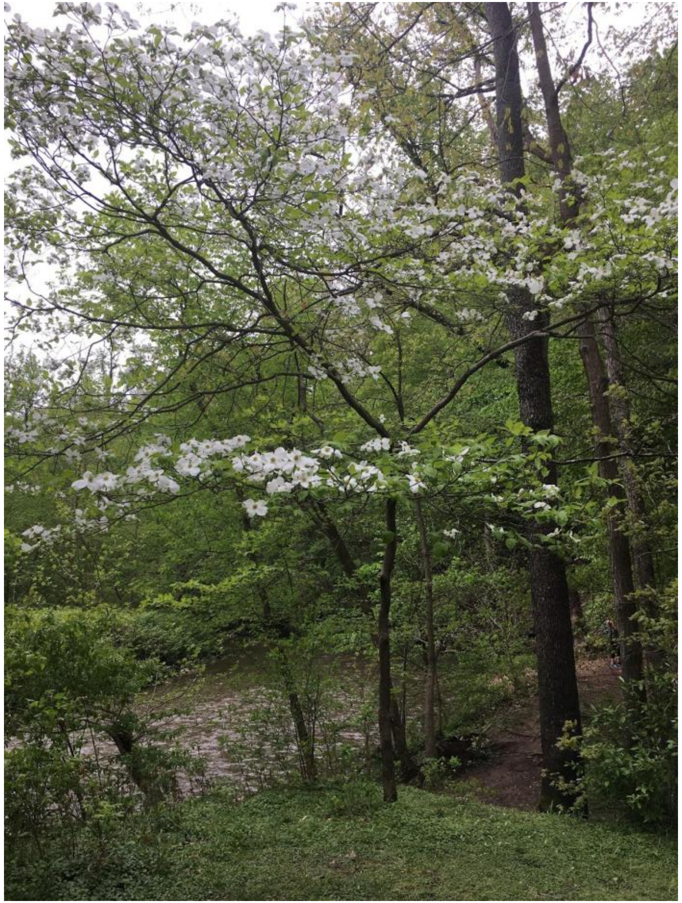

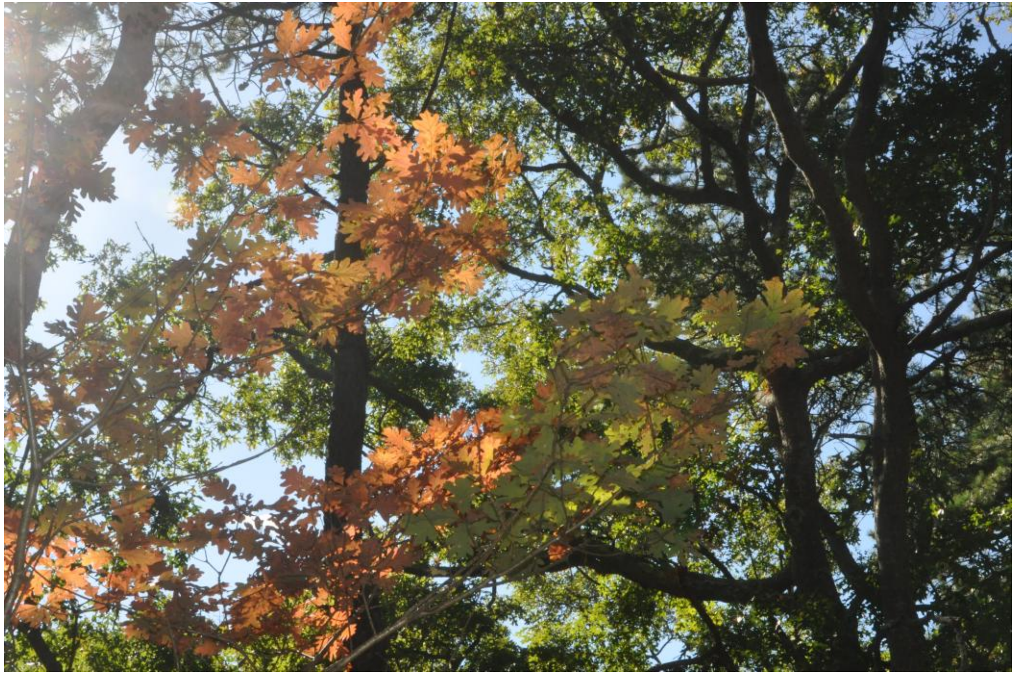

Any Questions?

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