Gulf Coast Phenology Trail 2021 Annual Report

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Mississippi Gulf Coast Community College Gautier Campus @ G. Bishop

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Executive Summary

The Gulf Coast Phenology Trail was established in 2016 by state and federal partners along coastal Mississippi and southeast Louisiana to learn about phenological changes occurring along the Gulf Coast. Five focal plants common to the area were selected as well as 29 other plants and 14 animals native to specific locations. The primary goal was to gather data to see if changes in climate impacted the initial growth time of species of concern. Since 2016, five years of data were collected by over 200 trained citizen scientists using *Nature's Notebook*, the USA National Phenology Network's phenology data collection platform. Over 249,500 observations were collected from 2017 to 2022 despite the closure of locations caused by tropical storm or hurricane damages and the Covid-19 Pandemic.

Our five years of data demonstrate that some species, such as red maple (*Acer rubrum*) and wax myrtle (*Myrica cerifera*) have generally consistent timing of leafing, flowering, and fruiting from one year to the next. Other species, including Chinese tallow (*Triadica sebifera*), redbay (*Pereia borbonia*), and yaupon holly (*Ilex vomitoria*) have more variability in these phenophases from year to year. We investigated whether invasive Chinese tallow has a longer leafing period than native red maple, but did not see evidence of a longer leafing period. Eastern baccharis, an important nectar plant, bloomed consistently in the late fall, and in the early spring in some years, likely providing a critical nectar source for monarchs migrating through the area during these periods. At western locations on the trail, typically several degrees warmer than eastern locations, red maple flowered several weeks earlier than at eastern locations. We also examined variability in leaf out of red maple between two different sites with similar habitat and found there was not a large difference in timing.

We continued to see anomalous weather across the Trail, with above average hurricane activity once again in 2021. The ongoing coronavirus pandemic provided further challenge to data collection efforts. Despite these challenges, we maintained high retention of long-term volunteers, and held multiple online and in person trainings. We anticipate holding additional workshops and/or field trips in August 2022 for current volunteer observers. These activities provide opportunities to network and maintain engagement in the program.

Introduction

The Gulf Coast contains rich and varied ecosystems including pine savannas, forests, shorelines, and open marshes. Phenology, or the study of timing of recurring life cycle events in plants and animals and their relationship to the environment, is an indicator of species response to climate change. The Gulf Coast Phenology Trail, (hereafter referred to as the Trail), was established in 2016 as a citizen science-driven, long-term monitoring program with the goal to gain a better understanding of the effects of climate change on plants and animals along the northern Gulf Coast from Louisiana to Alabama. Funding to establish the Trail and to monitor plants was provided by the U.S. Fish and Wildlife Service's Inventory and Monitoring Initiative. The staff at the USA National Phenology Network located at the University of Arizona provided support and coordination.

Project Description

The Trail considers both site-specific and larger-scale questions of interest. To address regional-scale questions, a set of core species, shared by most sites along the Trail, was selected in 2017. In addition, each of the 12 partners selected a list of species (Appendices B and C) for a total of 36 plants, 22 birds, 2 reptiles, 1 mammal, and 4 insects to monitor to address site-specific questions of interest. The Trail uses the USA National Phenology Network's *Nature's Notebook* as a tool for training, education, outreach, data collection, analysis and reporting.

The data collected by observers can be used by researchers and land managers who are interested in understanding the effects of climate change on plants and animals. To achieve educational and outreach objectives, we invited college students, school students, and local citizen scientists to participate in monitoring. Through their participation these groups gained field experience and knowledge of phenology data collection.

Each Trail Partner commits to:

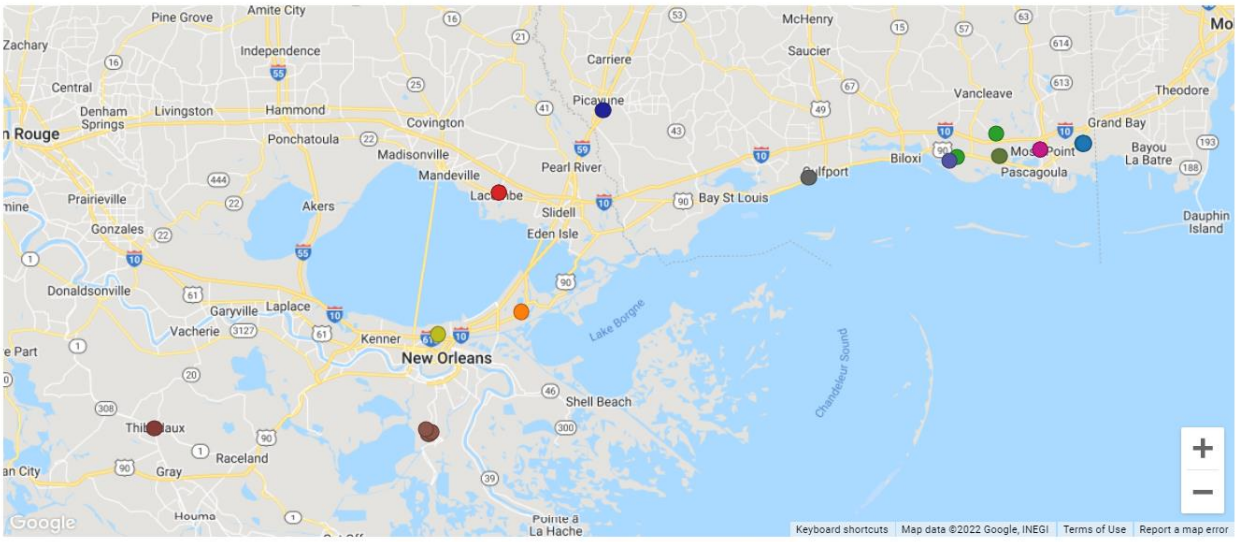
- Making repeat observations on the same individual plants or animal species at a site over time
- Making repeat observations at least once per week during the growing season
- Making observations for a least one growing season
- Making observations for more than one calendar year

Methods and Results

All partner sites along the Trail follow the protocols outlined by *Nature's Notebook* (www.naturesnotebook.org). We set up partner sites in the *Nature's Notebook* interface for citizen scientists to use when collecting phenology data along the Trail. Individual training on how to use the *Nature's Notebook* mobile application was provided upon request by the Local Phenology Leader or the Trail Coordinator. On rare occasions paper data collection was preferred and hard copies of data sheets were provided to citizen scientists for data collection.

Data sheets were turned in and the data were entered manually by the site lead as time permitted.

Locations of Gulf Coast Phenology Trail Partner sites active in 2021 are represented on the map below (Fig. 1).



Legend

- Grand Bay NWR/NERR
- Bayou Sauvage NWR
- Mississippi Sandhill Crane NWR
- Big Branch Marsh NWR
- Crosby Arboretum
- Pascagoula River Audubon Center
- Barataria Phenology Trail
- MGCCC Estaurine Education Center
- Bayou Lafourche Phenology Trail
- USM Marine Education Center
- USM Long Beach
- Couturie Forest Phenology Trail

Figure 1. Map of Gulf Coast Phenology Trail Partners active in 2021.

Primary Questions

Four primary questions were developed to guide phenology data collection on the Trail:

1-1. Does phenology of native Gulf Coast plants change over time under a changing climate?

Table 1. 2021 By the Numbers
68,586 Observations Records
21 Sites
35 Plant Species Observed
29 Animal Species Observed
58,168 Plant Observations
10,417 Animal Observations

2021 was the fifth year of data collection on the Trail, and we now have over 249,500 observations that have been collected by over 200 trained citizen scientists. We can now start to explore patterns in our data.

As in 2020, volunteer observers in 2021 were impacted by the Covid-19 Pandemic and Hurricane Ida that hit south of New Orleans on August 29, 2021 causing major damage to boardwalks and destroying a variety of plants. Louisiana sites including New Orleans City Park, National Park Sites, and National Wildlife Sites were closed because of storm damage. Some areas were damaged extensively and were shut down temporarily until some of the damages were repaired. Over 68,586 observations were made in 2021, exceeding the 63,870 records reported in 2020.

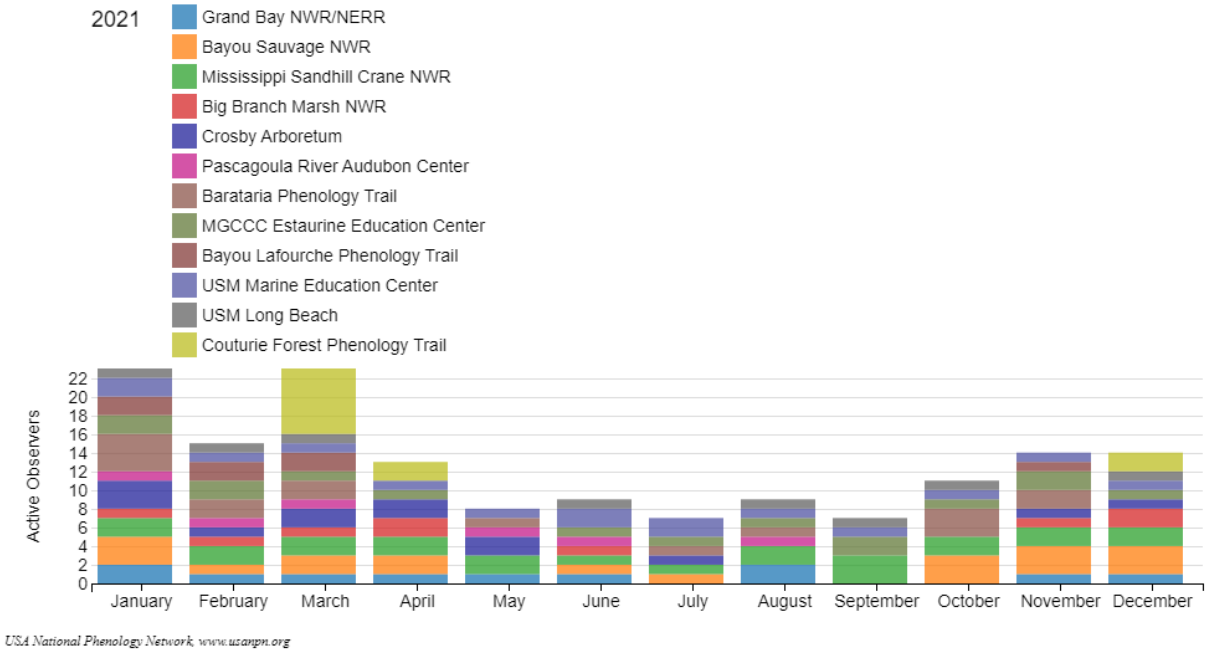


Figure 2. Number of *Nature's Notebook* observers active at each partner location by month in 2021.

Despite the storm and pandemic circumstances in 2021, when possible, volunteers continued to observe the focal species and other species (Fig 2). Our native focal species are red maple (*Acer rubrum*), red bay (*Persia borbonia*), wax myrtle (*Morella cerifera*), and yaupon holly (*Ilex vomitoria*) and a non-native species, Chinese tallow (Sa*pium sebiferum*).

Our ability to answer the question of how phenology is changing depends on having observations on the same individual plants over many years. In 2021, 6 sites monitored Chinese tallow (*Triadica sebifera*), 16 sites monitored red maple (*Acer rubrum*), 11 sites monitored wax myrtle (*Morella cerifera*), 8 sites monitored red bay (*Persia borbonia*), and 9 sites monitored yaupon holly (*Ilex vomitoria)* (Table 2).

Table 2. Number of individual plants and sites for each focal species in 2017-2021

Plants	2017 # Plants/Sites	2018 # Plants/Sites	2019 # Plants/Sites	2020 # Plants/Sites	2021 # Plants/Sites
Chinese tallow	5/7	11/7	11/7	10/5	10/6
Red maple	36/7	29/10	50/15	42/11	51/16
Wax myrtle	29/5	26/8	39/13	25/7	29/11
Red bay	18/4	17/7	29/9	23/7	28/8
Yaupon holly	13/5	22/7	33/9	34/9	29/9

Chinese Tallow

Figure 3. From left to right, Chinese tallow catkins, immature seed pods and ripe seed pods. *Photos © G. Bishop*

Chinese tallow (Fig. 3), introduced to North America in the 1700s, displaces native plant species. The University of Arkansas Research and Extension Service reported in their website UAEx.edu that the Chinese tallow seeds can remain dormant for up to five years. Warren Conway from the Texas Tech University completed a 2002 study, “Avian use of Chinese Tallow Seeds in Coastal Texas” that includes information on the spread of seeds by Yellow-rumped Warblers (The Southwestern Naturalist 47(4):550 DOI:10.2307/3672658). Michael J. Baldwin from Louisiana Tech University completed his 2005 master’s thesis on “Winter Bird Use of the Chinese Tallow Tree in Louisiana,” that also looks at the dispersal of Chinese tallow seeds. We collect data on the timing of Chinese tallow seeds, because it is valuable to understand the phenology of Chinese tallow to better manage this species.

According to the U. S. Department of Agriculture, Chinese tallow is considered one of the most aggressive and widespread weeds that grows as a large shrub or a tree in the southeastern United States. This fast-growing invasive tree alters species composition, community structure, and ecosystem processes in many native habitats, and produces thousands of seeds and regrows from root stock despite management controls such as burning or cutting. Two species are under public review as biocontrol for Chinese tallow including *Bikasha collaris* (a small beetle) and *Gadirtha fusca* (a moth; "APHIS Announces Availability of Environmental Assessment on Agents to Biologically Control Chinese Tallow" Official USDA Animal and Plant Inspection Service website.aphis.usda.gov 2021).

Partners including Barataria Preserve, Acadian, Mississippi Sandhill Crane National Wildlife Refuge, Mississippi Gulf Coast Community College-Gautier Campus, and Grand Bay NERR are recording data on Chinese tallow phenology.

Initial shoot or leaf growth peaked in early February in 2017, mid-March in 2018 and 2019, in mid-April in 2020, and peaked between mid-April to mid- May in 2021 (Fig. 4). All years except 2019 saw continued reports of initial growth through the fall months. In all years, Chinese tallow flowering peaked in mid-May, though the proportion of yes records was much lower in 2019 (Fig. 5). First reported ripe fruit was variable in the five years, with observers reporting the earliest fruit in 2018 (Fig. 6).

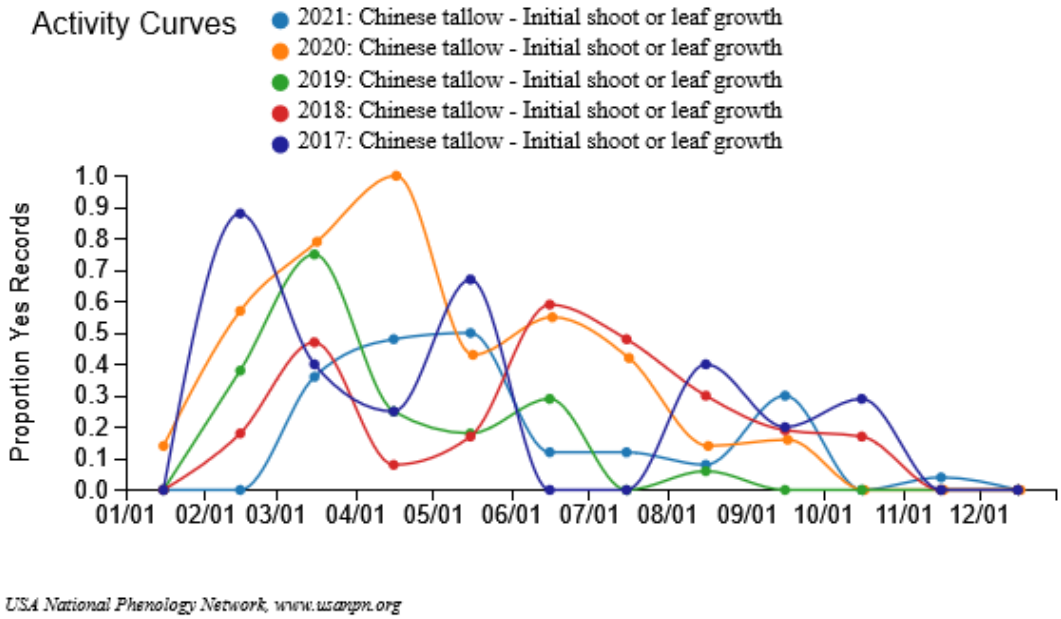


Figure 4. Activity curve showing the proportion of individual Chinese tallow with "yes" records reported for initial shoot or leaf growth 2017-2021.

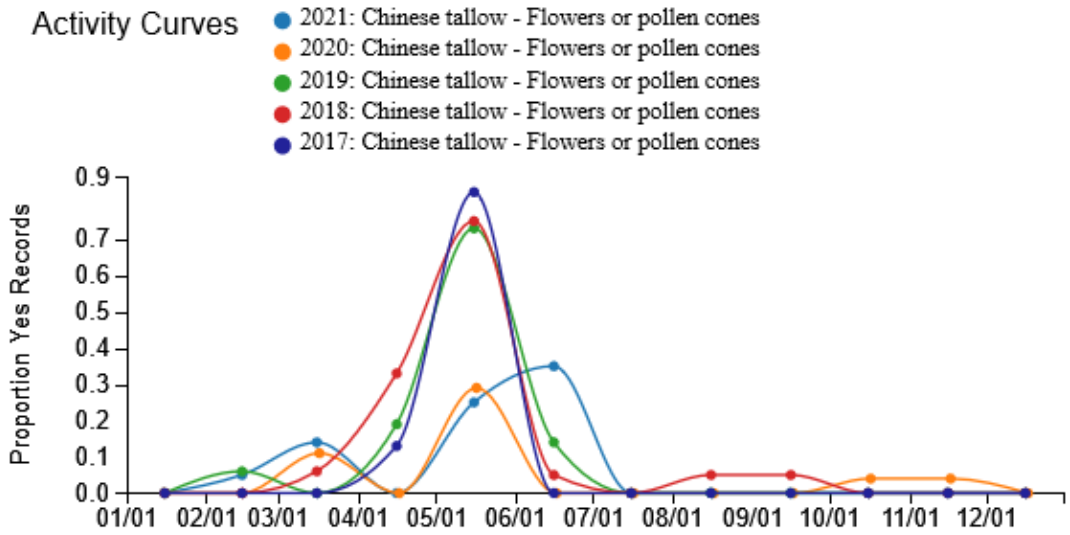


Figure 5. Activity curve showing the proportion of individual Chinese tallow with "yes" records reported for flowers or flower buds in 2017-2021.

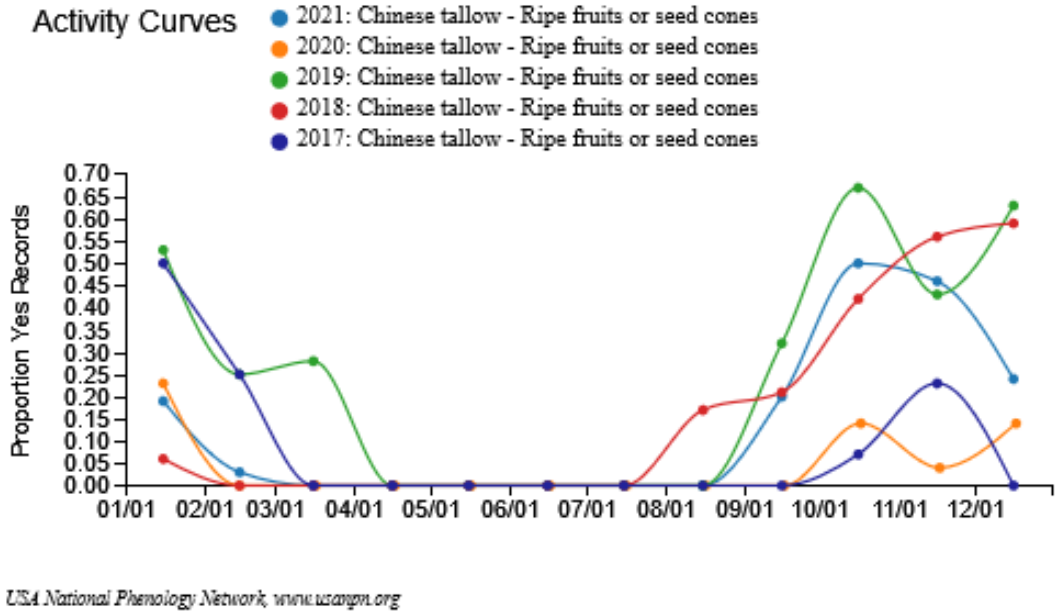


Figure 6. Activity curve showing the proportion of individual Chinese tallow trees with "yes" records report for ripe fruit in 2017-2021.

Red Maple

Figure 7. From left to right, red maple buds, blossoms, and winged seeds. *Photos © G. Bishop*

Red maples (Fig. 7) are the top observed plant species in the United States among *Nature's Notebook* observers. Red maple is precocious, meaning it blooms before leaves emerge. Red maple seeds (samaras) are used by a number of wildlife species (USDA NRCS 2006). The peak in open flowers occurred in mid-February in 2017, 2018, 2019, and 2021, but peaked in early January in 2020 (Fig. 8). The peak of samara production was in mid-March in all four years (Fig. 9). Initial growth of leaves in red maples peaked in mid-March in all five years (Fig. 10). Red maples will leaf out primarily in mid-March but will leaf out again throughout the growing season in response to being burned or cut (Fig. 10).

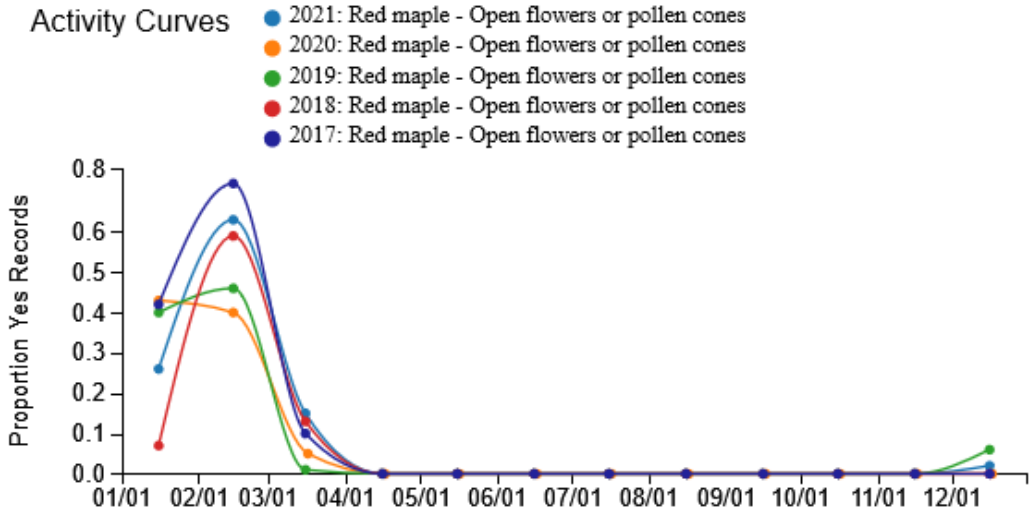


Figure 8. Activity curve showing the proportion of individual red maple trees with "yes" records reported for open flowers in 2017-2021.

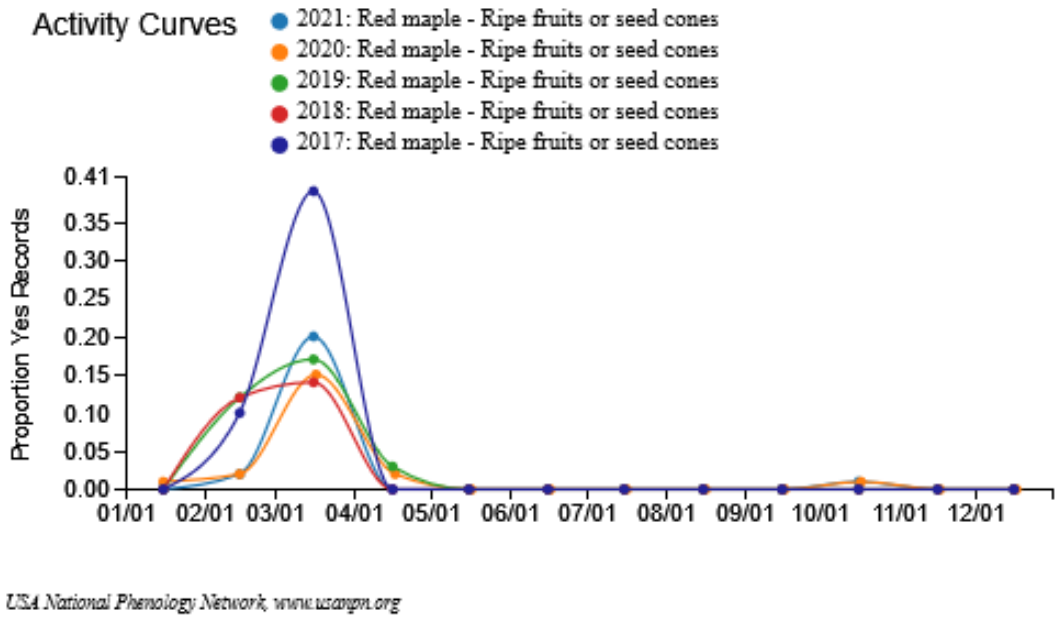


Figure 9. Activity curve showing the proportion of individual red maple trees with "yes" records reported for ripe fruits 2017-2021.

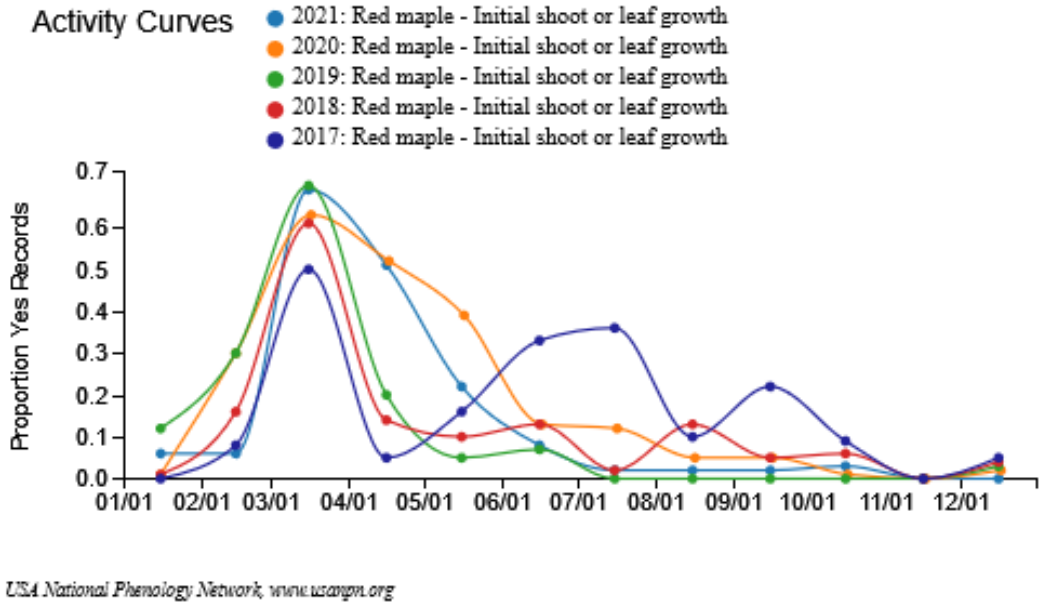


Figure 10. Activity curve showing the proportion of individual red maple trees with "yes" records reported for initial shoot or leaf growth 2017-2021.

Wax Myrtle

Figure 11. From left to right, wax myrtle male flower, female flower, immature berries, leaf buds. *Photos © G. Bishop*

Wax myrtle (Fig. 11) is dioecious, with male and female flowers occurring on different plants. Only the female flowers produce berries. On the Trail, leaf buds and new leaves emerged throughout the year especially when a terminal end is removed by browsers or by mechanical means. For that reason, we focus here on flower development and berry development. In all years (2017-2021) wax myrtle flowers peaked in mid-March (Fig. 12). The peak of wax myrtle ripe fruits development was mid-October in 2017, end of December in 2018 and 2021, and mid-November in 2019 and 2020. (Fig. 13).

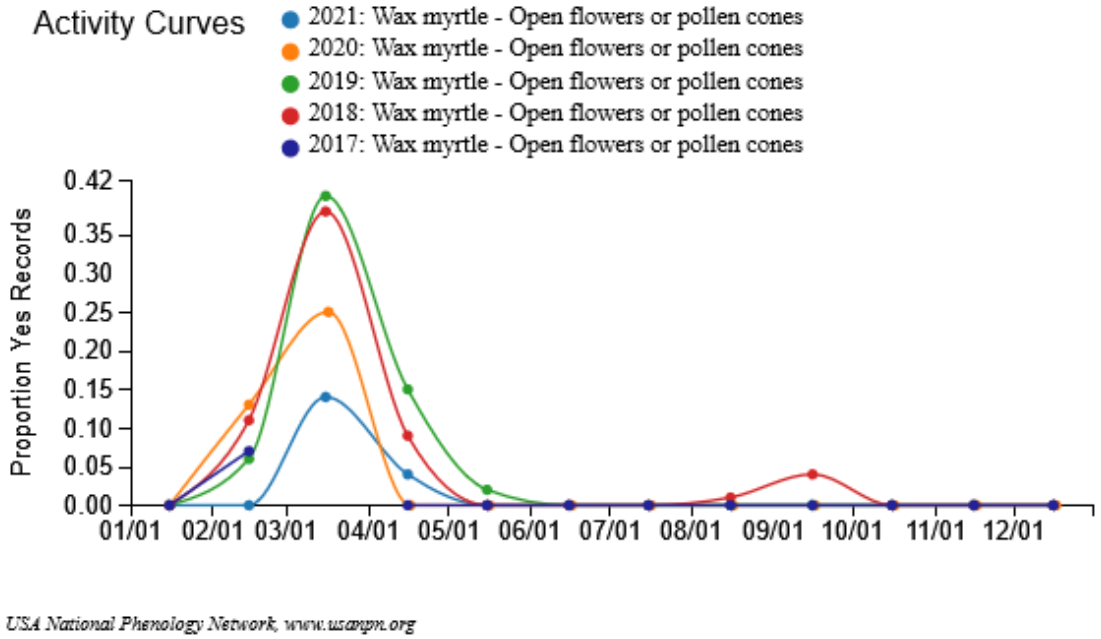


Figure 12. Activity curve showing the proportion of individual wax myrtle with "yes" records reported for flowers or flower buds 2017-2021.

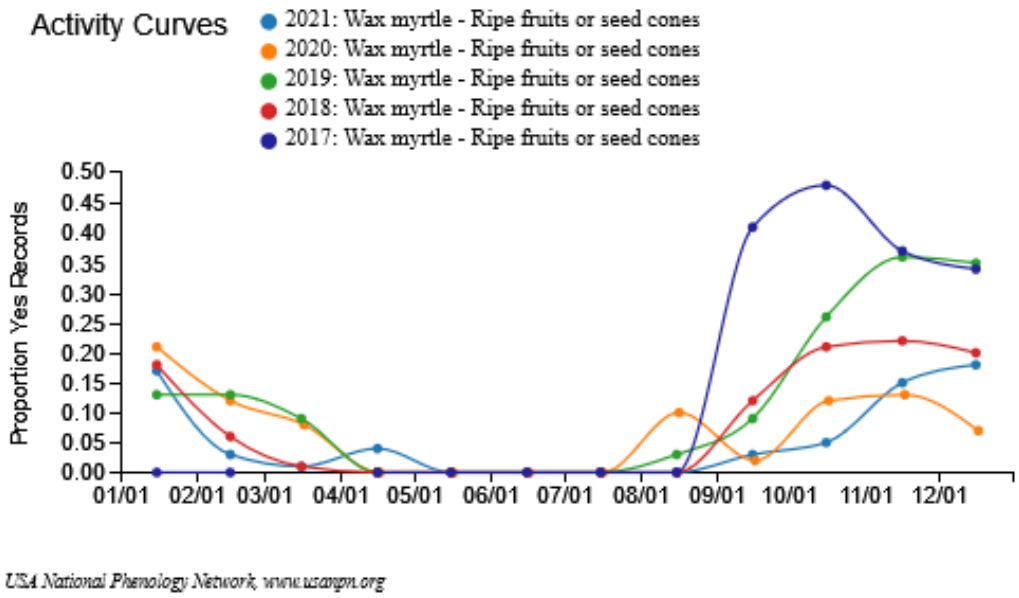


Figure 13. Activity curve showing the proportion of individual wax myrtle with "yes" records reported for ripe fruits and seeds in 2017 -2021.

Redbay

Figure 14. From left to right, redbay new leaves and breaking leaf buds, redbay leaf galls. *Photos © G. Bishop*

Our phenology observations of redbay (Fig. 14) will help us to see what trees are affected by laurel wilt, which is caused by a fungal symbiont of the exotic red bay ambrosia beetle. One individual redbay, infected with laurel wilt, died on the Pine Forest Restoration Trail in Gautier,

Mississippi so another mature red bay was added. The peak in initial growth for redbay occurred in mid-March in 2018, 2019, 2020, and in mid- April in 2021; the information was incomplete for 2017 (Fig. 15). We observed a peak in flowering in mid-April in 2017, 2018, 2020, 2021, the end of May in 2019 (Fig. 16). The peak of redbay fruits (drupes) for 2017, 2018, and 2019 was mid-October, occurred in mid-August for 2020, and mid-December in 2021 (Fig. 17). While laurel wilt is present at Grand Bay NWR/NERR, in 2020 and 2021 redbay plants produced over 100 fruits on plants there as well as at other Trail locations.

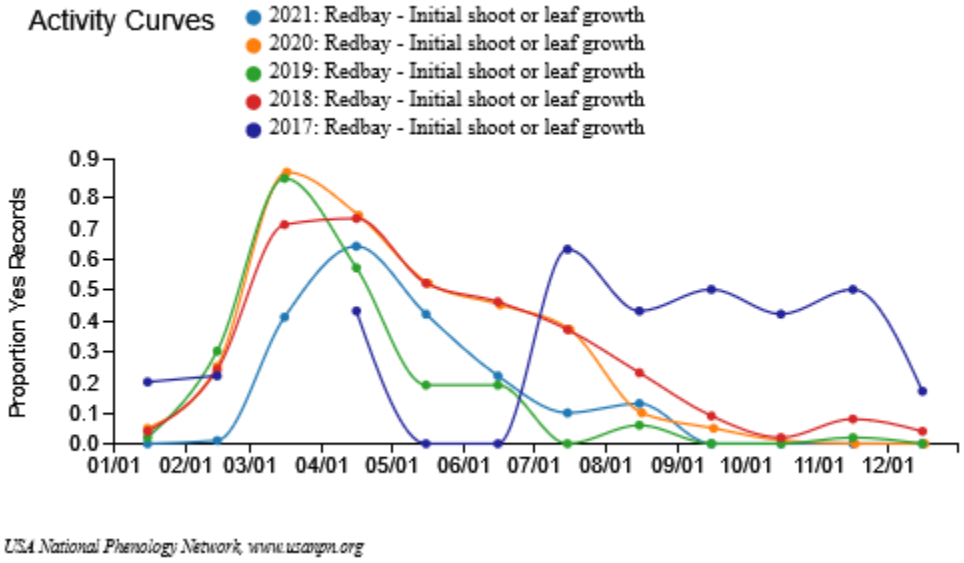


Fig. 15. Activity curve showing the proportion of individual redbay with “yes” records reported for initial growth in 2017 -2021.

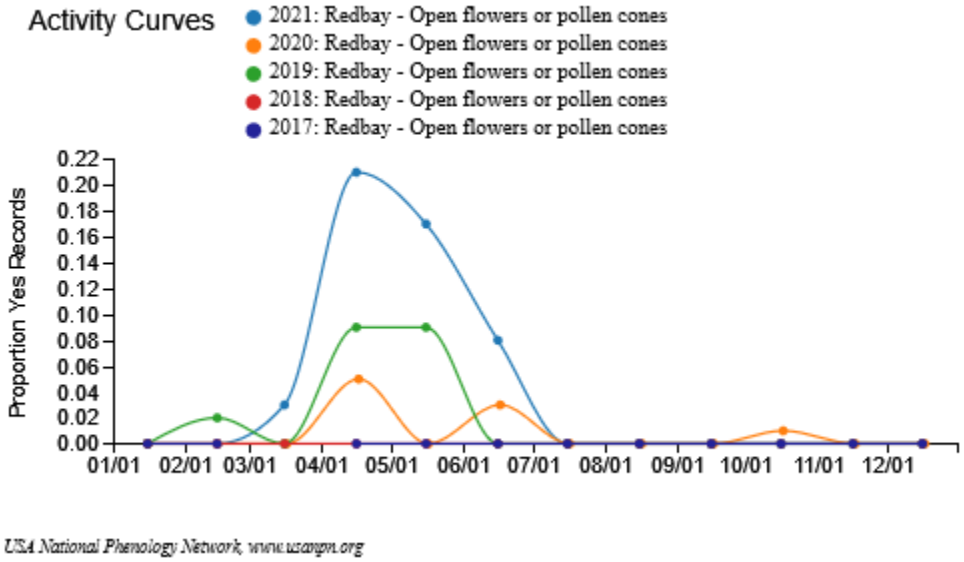


Figure 16. Activity curve showing the proportion of individual redbay with “yes” records reported for flowers or flower buds in 2017 -2021.

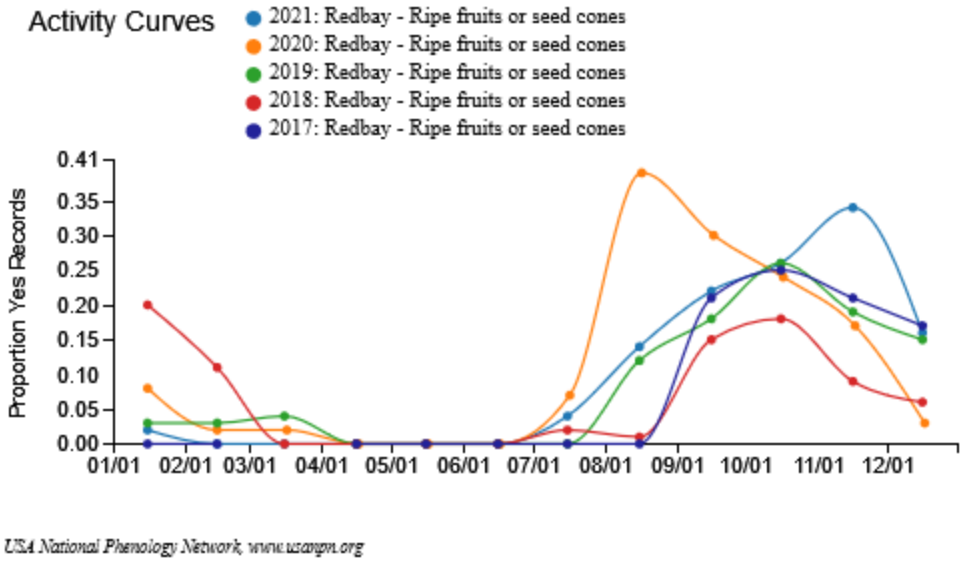


Figure 17. Activity curve showing the proportion of individual redbay with "yes" records reported for ripe fruits in 2017 -2021.

Yaupon Holly

Figure 18. From left to right, female yaupon holly in bloom and with ripe berries. *Photos © G. Bishop*

Another dioecious focal plant on the Trail is yaupon holly (Fig. 18). Yaupon holly leaf development can occur almost year-round. Yaupon galls, caused by the insect *Gypropsylla ileci* (BugGuide.net) have been mistaken for leaf buds. For our reports, we focused on timing of development of flowers and berries. Yaupon holly flowers peaked at the end of April in 2017, 2018, 2021 and in early March in 2019 and 2020. (Fig. 19). The peak of ripe fruits was from mid-January to mid-February in all five years. (Fig. 20).

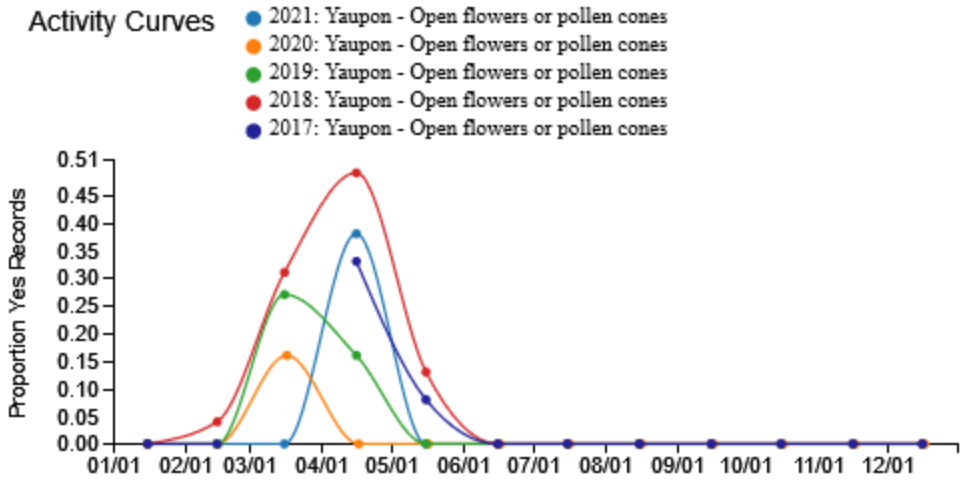


Figure 19. Activity curve showing the proportion of individual yaupon holly trees with “yes” records reported for flowers or flower buds in 2017 -2021.

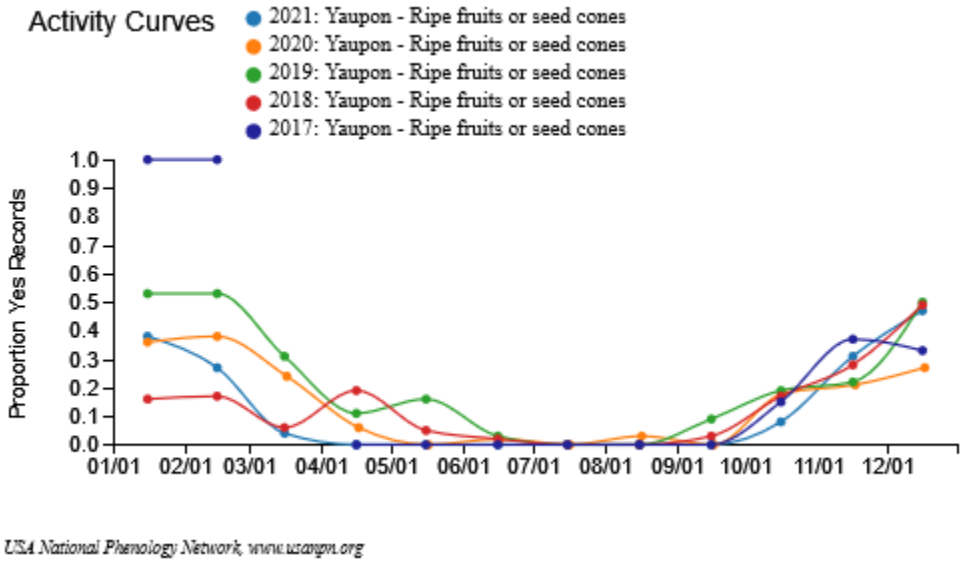


Figure 20. Activity curve showing the proportion of individual yaupon holly trees with “yes” records reported for ripe fruit in 2017 -2021.

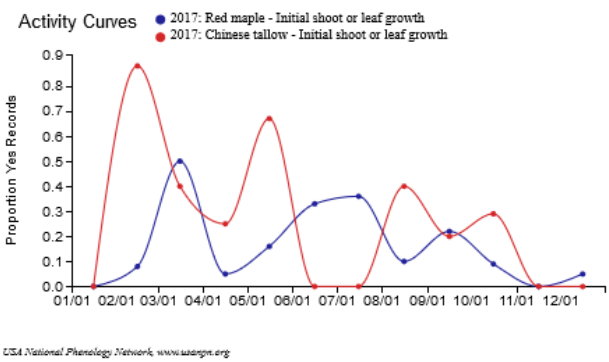
1-2. Does phenology of Gulf Coast plants differ between native and non-native plants?

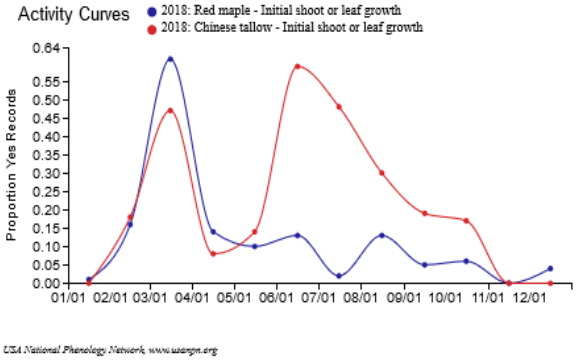
Figure 21. From left to right, red maple leaves, Chinese tallow leaves. *Photos © G. Bishop*

Native red maple trees and Chinese tallow trees are two focal species monitored on the Trail that are deciduous (Fig. 21). We explored data from these species to attempt to answer the question: *Is there a difference in some phenological cycles between native and non-native plants*? Some invasive species have a competitive advantage over native plants in that they can leaf out earlier in the spring than native plants and hold onto their leaves longer; this phenomenon is known as e*xtended leaf phenology*.

In three of the five years, Chinese tallow leafed out 1-3 weeks earlier than red maples (Fig. 22). In all years, both plants also showed initial leaf growth later in the year after the first initial flush of leaves. This is likely because several of the red maples and Chinese tallow were either impacted by prescribed fire or cut back by staff, after which they sprouted new leaves.

Initial Leaf Growth





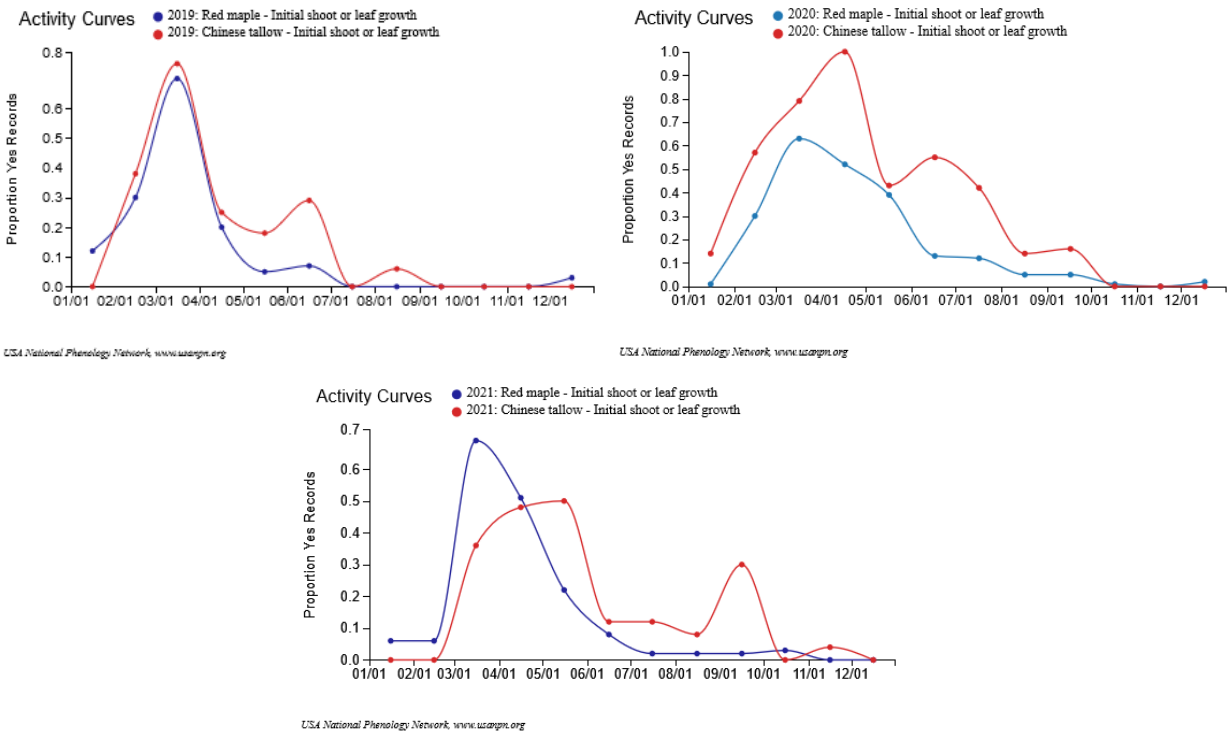
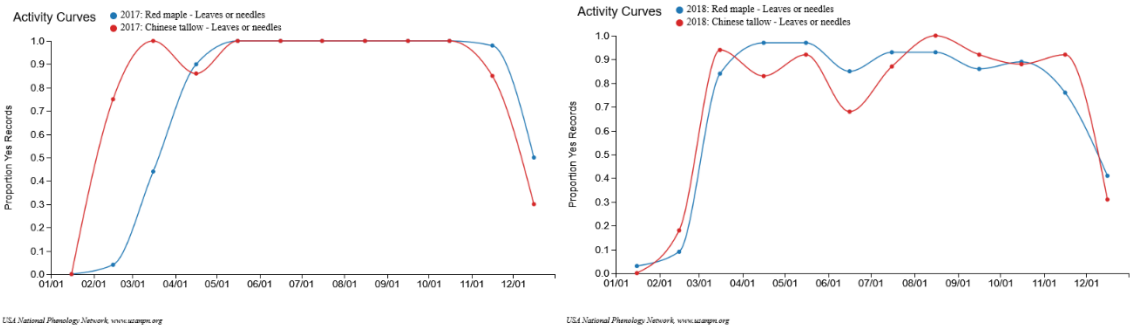


Figure 22. Activity curves showing the proportion of individual Chinese tallow trees with "yes" records reported for initial shoot or leaf growth compared to red maple in 2017-21.

The timing of when leaves are present on red maple and Chinese tallow is quite similar in all years (Fig. 23). We did not see evidence of a longer leafing period in Chinese tallow than red maple.

Leaves



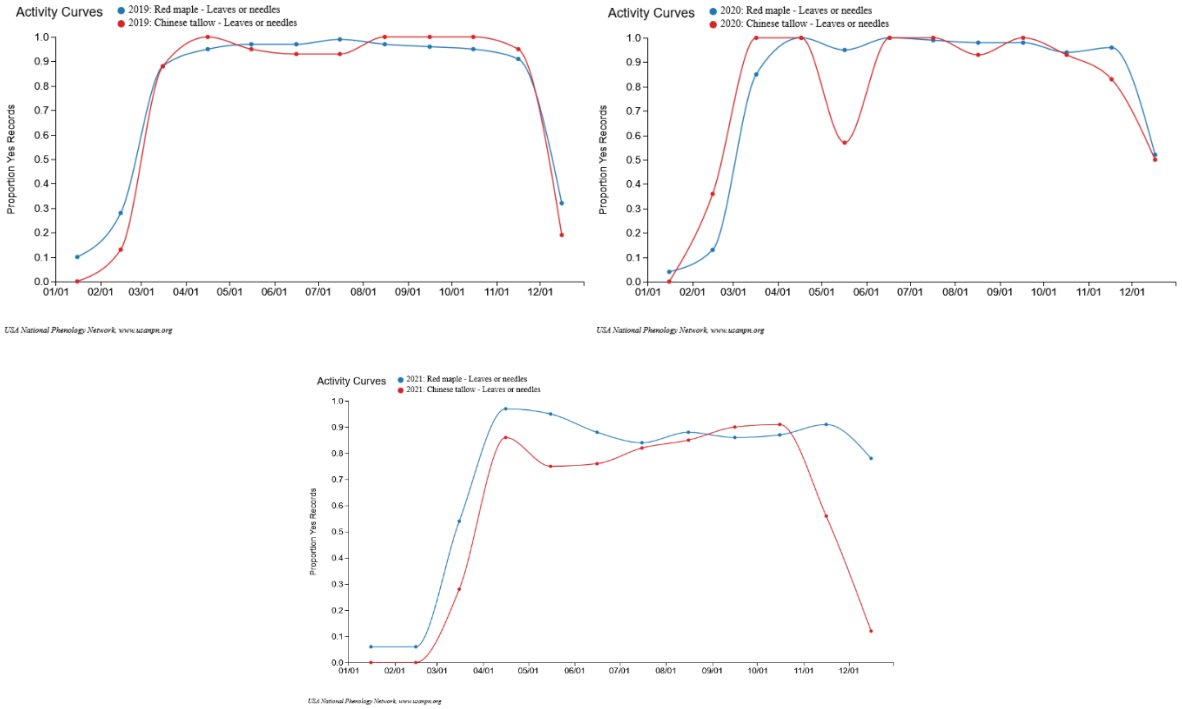
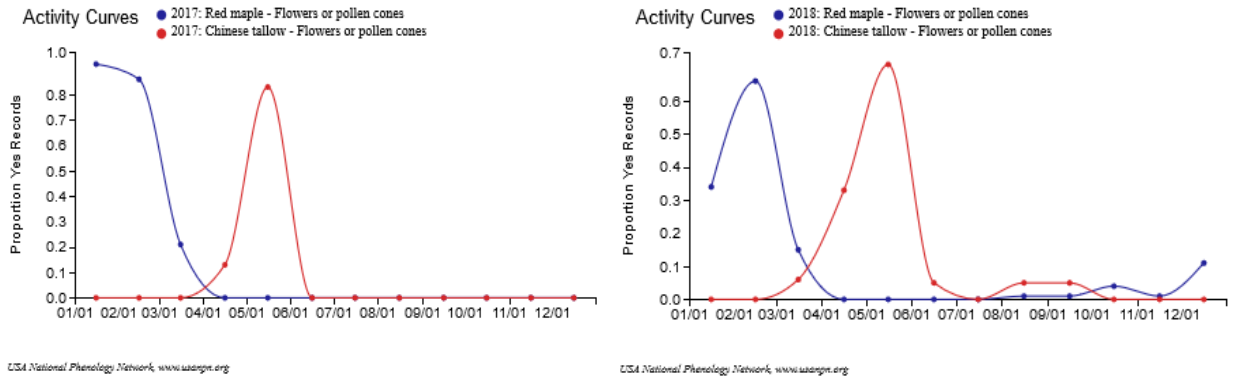


Figure 23. Activity curves showing the proportion of trees with a "yes" reported for leaves for Chinese tallow and red maple in 2017-21.

We see a larger difference in the timing of flowering between Chinese tallow and red maple, with the peak in red maple trees flowering occurring two months earlier than in Chinese tallow (Fig. 24). Red maple flowers peaked in early January (2017, 2019, 2020) or mid-February (2018, 2021) while Chinese tallow flowers peaked in mid-May for 2017-2020 but in 2021 first peak was in mid-March.

Flowers



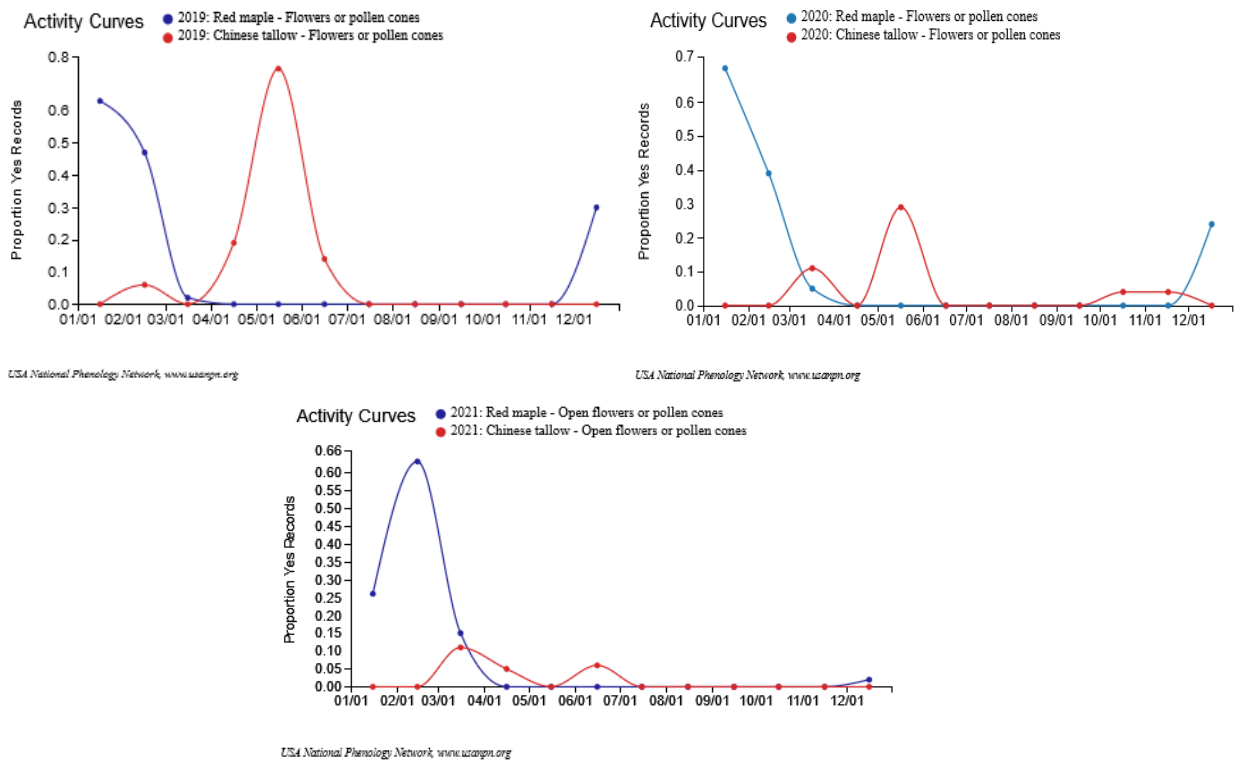
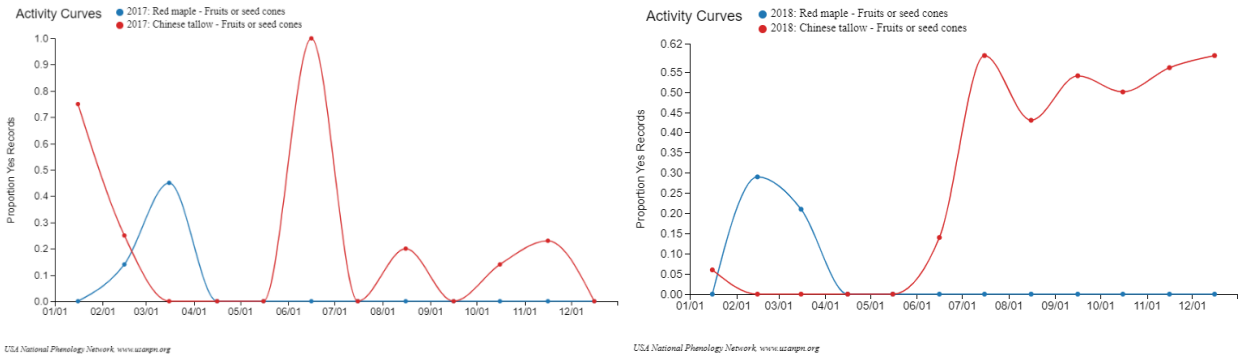


Figure 24. Activity curves showing the proportion of trees with a "yes" reported for flowers or flower buds for Chinese tallow and red maple in 2017-21.

Fruit production for red maples generally occurred from February to mid-March while Chinese tallow started fruiting in June.

Fruits



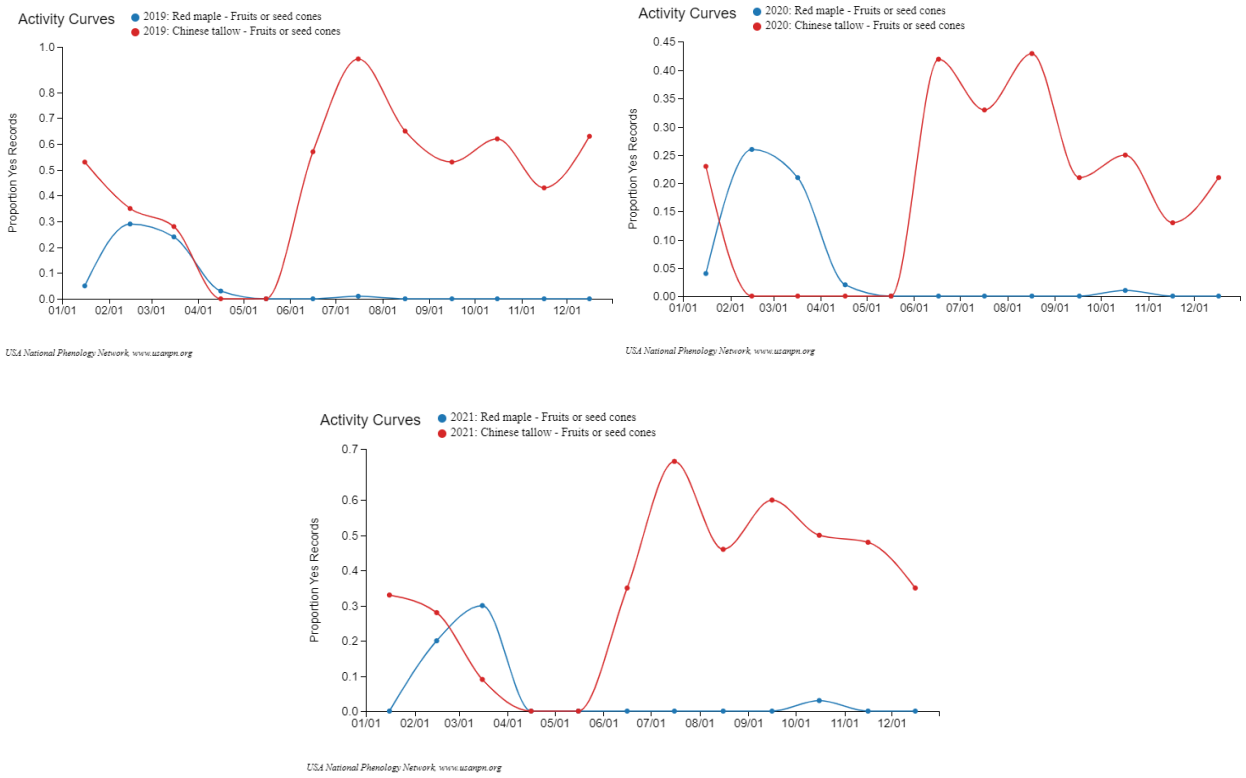


Figure 25. Activity curves showing the proportion of trees with a "yes" reported for fruits (seeds) for Chinese tallow and red maple in 2017-21.

1-3. Does the phenology of native plant pollinators match native plant phenology over time under a changing climate?

Figure 26. From left to right, Monarch butterflies on eastern baccharis. Photo ©Chris Feurt at Grand Bay NWR/NERR on November 3, 2019. Eastern Baccharis in bloom. Photo @Gbishop

We selected monarch butterflies and eastern baccharis (Fig. 26) to answer the question: *does the phenology of native plant pollinators match native plant phenology over time under a changing climate?* In 2018- 2021 we recorded the fall flowering of eastern baccharis (*Baccharis hamlimifolia*) and the activity of monarch butterflies (*Danaus plexippus*) at Bayou Sauvage National Wildlife Refuge, Mississippi Sandhill Crane National Wildlife Refuge, and the Barataria National Preserve. Additional sites, including Big Branch NWR, Grand Bay NEER, Crosby Arboretum were added in 2020. The fall peak in flowering of eastern baccharis overlaps with the fall activity of monarch butterflies (Fig. 27), though we did not record flowers in the monarchs' summer period of activity. No sightings of monarchs were recorded in 2020. However, it was reported in 2021 that monarch visitation occurred in mid-March when eastern bacharris flowers were blooming early and again in mid-November. This early spring and late fall flowering of eastern baccharis is likely a critical source of nectar for monarchs that migrate through the area during these times of the year.

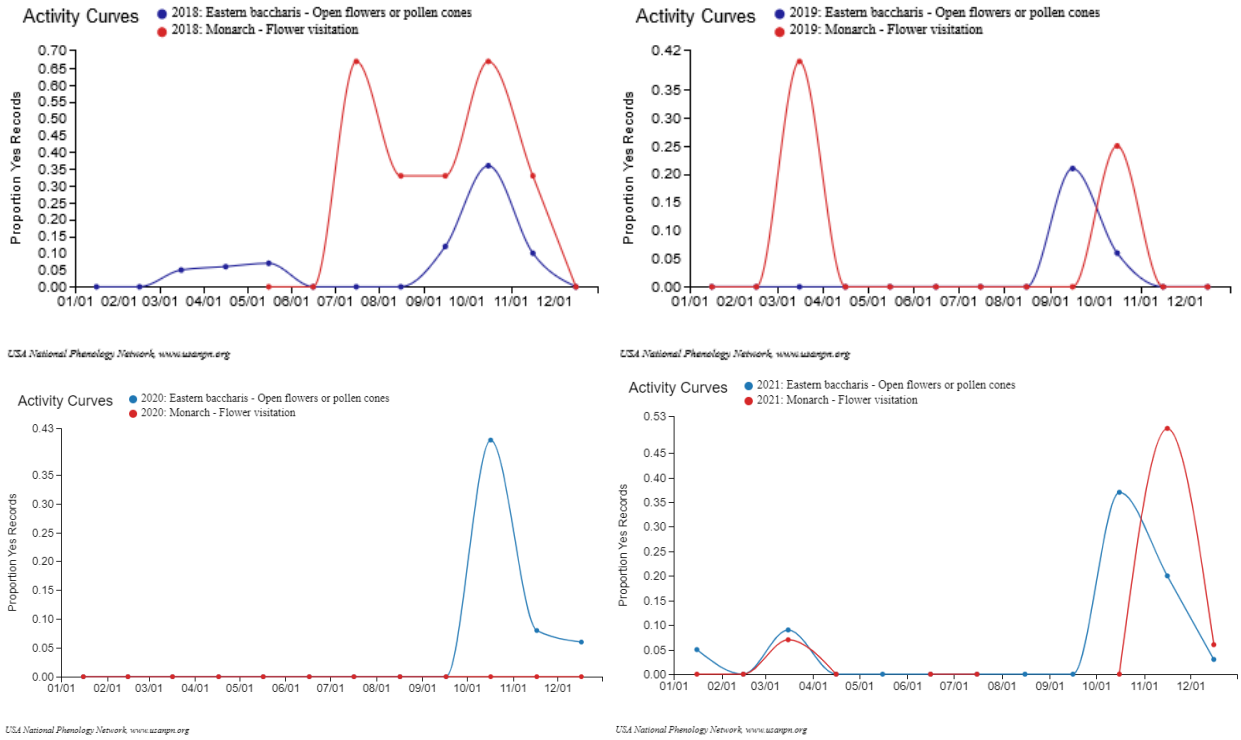


Figure 27. Activity curve showing the proportion of "yes" records for monarch butterflies and open eastern baccharis flowers in 2018-21.

1-4. Is there an East-West gradient in the timing of certain focal species from Louisiana to Alabama?

Western locations on the Trail typically have warmer winter temperatures than those at eastern locations, as reflected in the weather summary from the New Orleans National Weather Station compared with the Gulfport, Mississippi or Mobile, Alabama Weather Station. At Louisiana sites, red maple flowering peaked in early January in 2017, 2019, 2020, and 2021,

and in mid-February in 2018 (Fig. 28). At Mississippi sites, red maple flowering peaked in mid-February in 2017, 2018, 2019, and 2021 and peaked in early January in 2020 (Fig. 28).

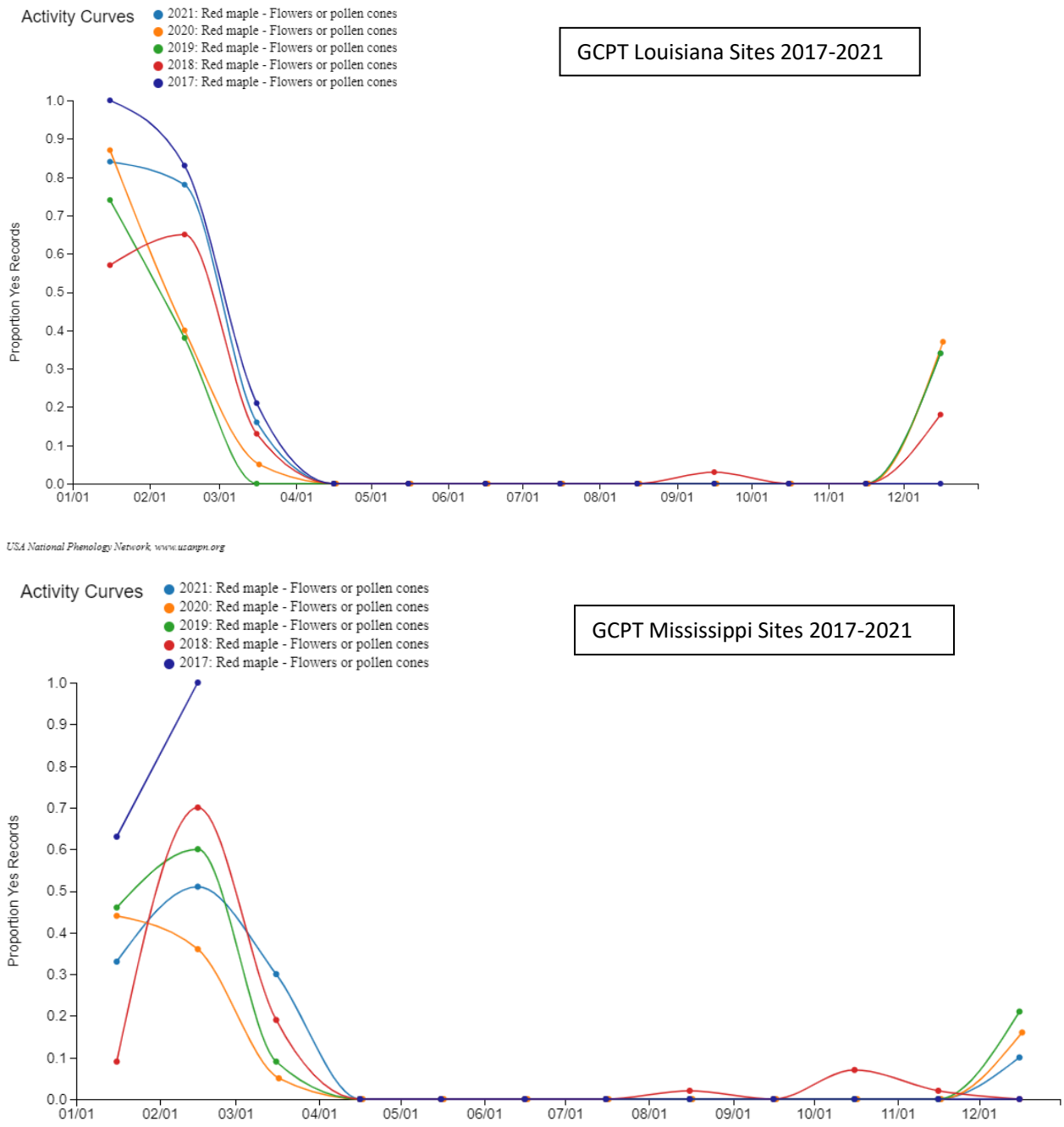


Figure 28. West-East comparison of the proportion of "yes" records reported for red maple flowers or flower buds in 2017-2021 for Louisiana sites (top) and Mississippi sites (bottom).

Secondary Questions

Figure 29. Mississippi Sandhill Cranes and colts at Mississippi Sandhill Crane National Wildlife Refuge. Photo by @LMcLauren 4-2022

2-1. What is the variation in phenology in similar habitats across the Trail?

We are interested in the amount of variation in life cycle events including breaking leaf buds and open flowers across individual plants and sites on the Trail. A comparison of two Trail sites with savannah habitat – Grand Bay NWR/NERR and Mississippi Sandhill Crane NWR – shows that the peak in initial growth in Chinese tallow varied by several months at the two different sites in 2019 and was slightly more similar between the two sites in 2020 (Fig. 30). In 2021, the peak was similar in the spring, but Grand Bay NERR did not have a secondary peak in the fall (Fig. 30).

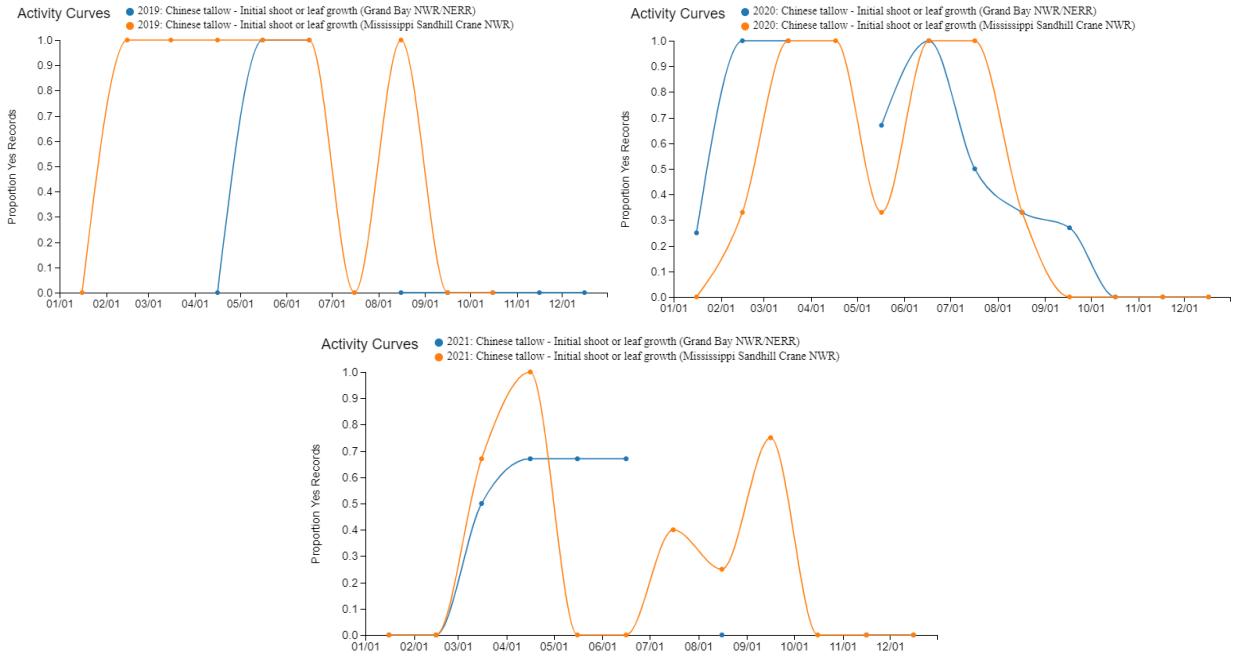


Figure 30. Activity curve showing the proportion of trees with a "yes" reported for initial growth in Chinese tallow at Grand Bay NWR/NERR and Mississippi Sandhill Crane NWR in 2019-21.

For red maple, the peak in initial growth was very different between the Grand Bay NERR/NWR and Mississippi Sandhill Crane NWR sites in 2019, and more similar in 2020 and 2021 (Fig. 31).

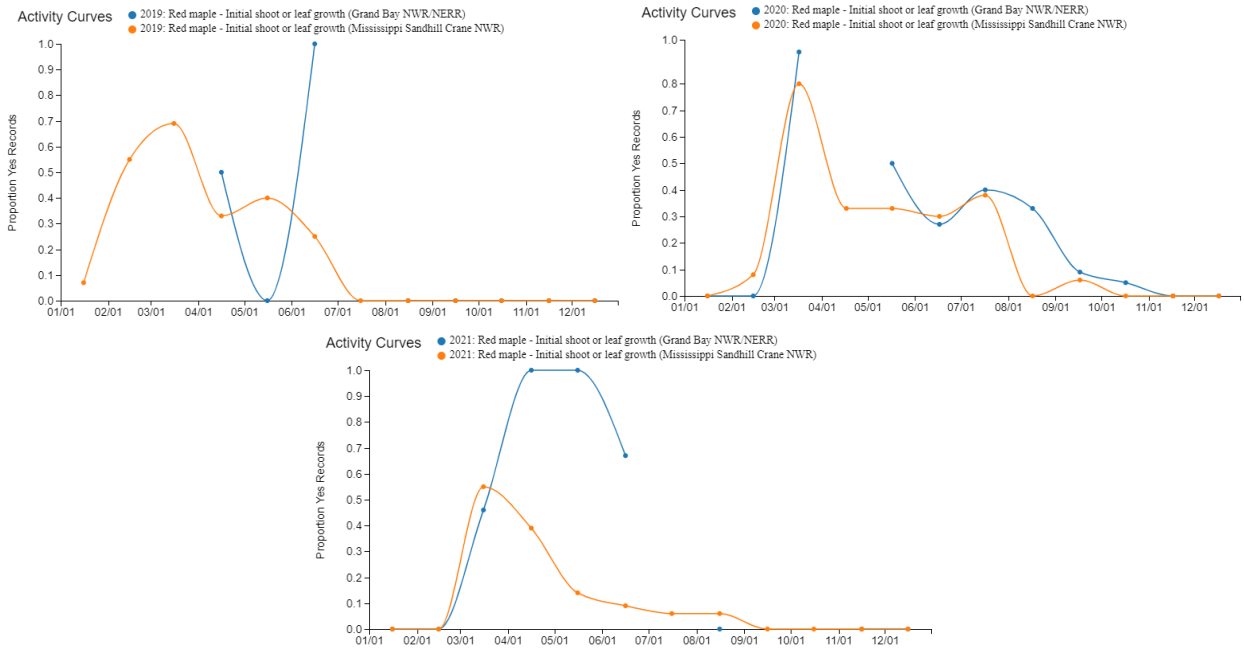


Figure 31. Activity curve showing the proportion of trees with a "yes" reported for initial growth in red maple at Grand Bay NWR/NERR and Mississippi Sandhill Crane NWR in 2019-21.

2-2. Does phenology of focal species differ between areas that have been disturbed by fire, storm, etc.?

Figure 32. From left to right, initial look after prescribed fire at Mississippi Sandhill Crane NWR photo taken June 9, 2021 and view on July 8, 2021. Photos @gbishop

Three of the sites, Grand Bay NWR/NERR, Mississippi Sandhill Crane NWR, and the Crosby Arboretum, manage savannah habitats which include prescribed fires and mechanical clearing. There was one prescribed firs at the Mississippi Sandhill Crane NWR in late June of 2021 (Fig. 32). Two of the species tracked at that site, wax myrtle and redbay, show increased activity in new leaf growth after June (Fig. 33).

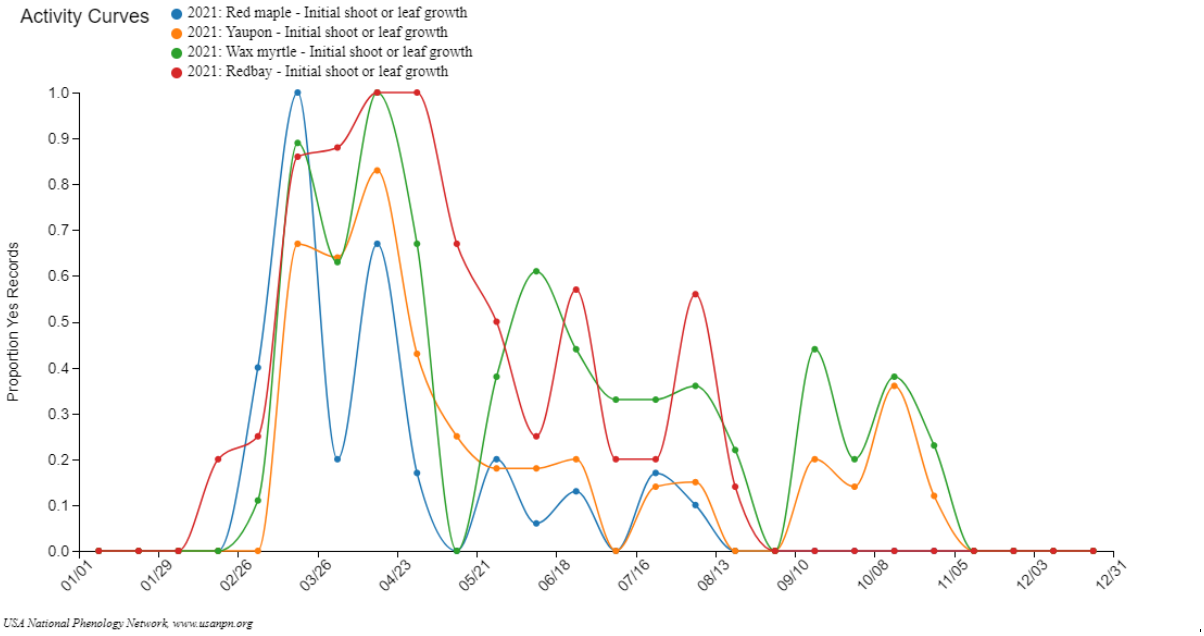


Figure 33. Activity curve showing the proportion of trees with a "yes" reported for initial growth in red maple, yaupon, wax myrtle, and redbay at Mississippi Sandhill Crane NWR in 2021.

2-3. How is the arrival and departure of migrating animals, such as Purple Martin, shifting in response to a changing climate?

According to the Audubon website, Purple Martins migrate from the Amazon River basin in South America returning in February to the Southeast United States (Fig. 34). There they depend on human supplied housing, including gourds, to build their nests

We observe Purple Martins at the Grand Bay NWR/NERR where a stationary pole with gourds is located. Currently our limited data still do not present a clear picture for answering this question about Purple Martins. However, based on the graph (Fig. 35) Purple Martins were recorded in mid-February in 2017, 2018, 2019 and 2021. Of the past four years, the longest duration of Purple Martin activity was recorded in 2018.

Figure 34. Migration of Purple Martin to the North (courtesy Bing.com/images)

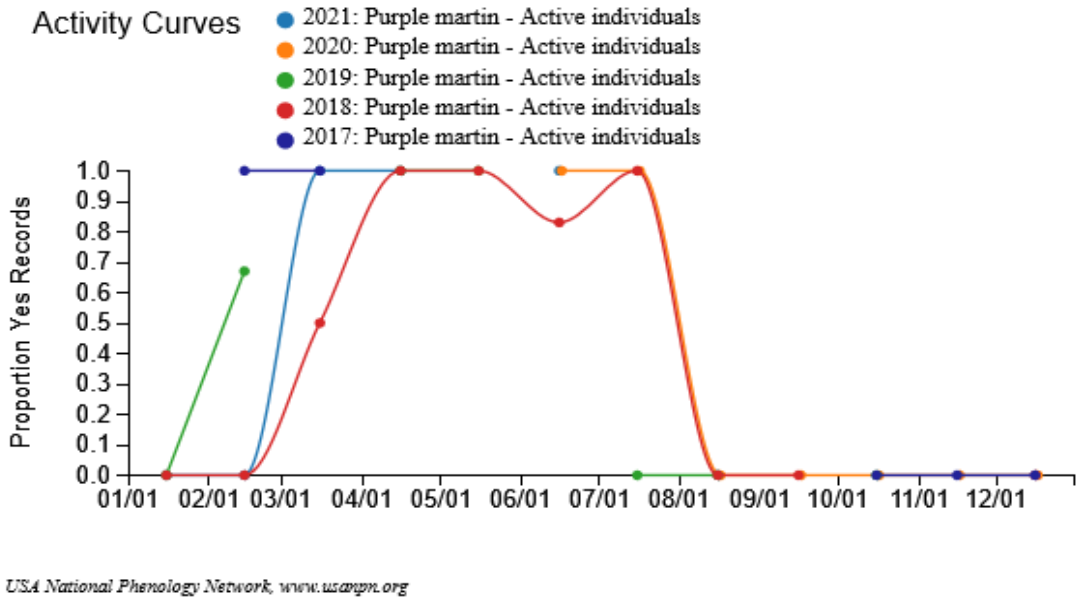


Figure 35. Activity curve for Purple Martin Active Individuals from 2017-2021.

In October 2020, Hurricane Zeta's winds knocked over the Grand Bay NERR's Purple Martin pole with 14 gourds that needed to be replaced in 2021 in time for the Purple Martin scouts to return. Sue Wilder, Jennifer Buchanan, and Gail Bishop paid for the cost of replacement gourds. These locally sourced gourds had precut holes and were covered with cement paint. New

appropriately drilled holes were later cut, and old holes capped. Staff and a volunteer did the work (Fig. 36).

Figure 36. Left – Damaged pole Middle-painting replacement gourds, Photos© Gbishop. Right – Purple Martins, Photo by Jeff Goff

Weather Data Summary

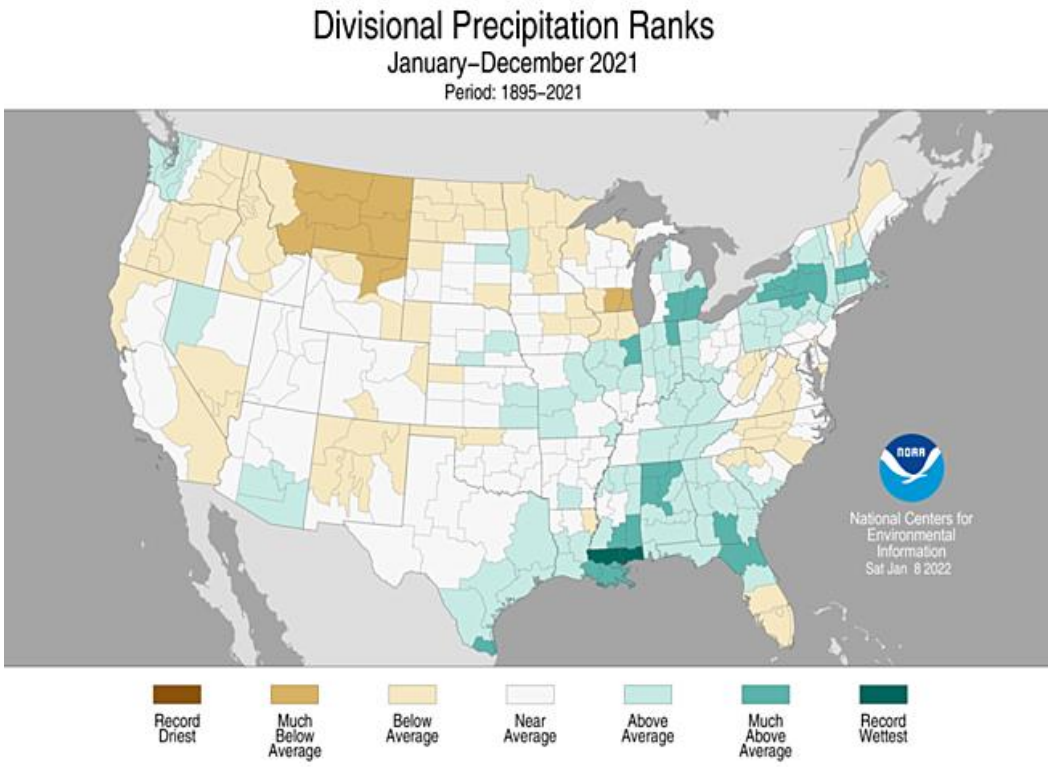


Figure 37. Divisional Precipitation Ranks, courtesy of NOAA

Regional Weather and Climate Norms

In 2021, higher than normal rainfalls were recorded across the observation sites with either "much above normal", "record wettest", or "above average" (Fig. 37). In April, spring rains produced the highest monthly record at New Orleans Louis Armstrong Airport at 12.85 inches or almost 7 inches above normal. Gulfport/Biloxi, Trent Lott, and Mobile Downtown Airports received heavier than normal rainfall in June, 2021. Overall, all airport weather stations received higher than normal rainfall amount for2021. New monthly climate normals were published for the period 1991-2020 so for this report both normal 30-year climate periods are presented. More information about Monthly Climate Normals is available here: https://catalog.data.gov/ar/dataset/u-s-climate-normals-2020-u-s-monthly-climate-normals-1991-2020.

New Orleans, Louisiana

In 2021, six months were warmer in New Orleans than the 30-year normal (1991-2021). Across months, the average temperature was 3.3 degrees higher. Warmer air and Gulf temperatures caused the formation of *Claudette* into a tropical storm after it crossed the shoreline in Louisiana early on June 19. According to the weather.com , "Claudette produced peak storm surge of just over 3.21 feet in Shell Beach, Louisiana. Hurricane Ida made landfall in Port Fourchon on August 29, 2021, as a Category 4 with maximum winds of 150 mph." The storm surge also devastated the Jean Lafitte area according to nola.com. A second weather event was the Artic outbreak of February 2021 with a low of 25 degrees in New Orleans. Later, heavy rains were recorded in April and May.

Based on the 30-year new normal, seven of the months were wetter than normal, and five months were dryer. Overall, the 2021 the rainfall for New Orleans was 13.99 inches wetter than the 30-year normal rainfall average (Table 3 and 4).

Table 3. Temperature summary table for New Orleans Airport Weather Station in 2021 Departure from 30-year normal is based on years 1981-2010 and 1991-2021 (NOAA 2021).

Month 2021	Mean Temperature (F) (red indicates warmer than 30Yr Normal)	30-Year Normal Based on 1981-2010	30-Year Norma Based on 1991-2021
January	55.4	53.4	54.3
February	54.6	56.7	58.0
March	66.6	62.6	63.8
April	69.7	69.1	70.1
May	77.1	76.1	77.1
June	82.9	81.5	82.4
July	84.9	83.3	83.9
August	85.3	83.3	84.0
September	79.4	79.7	80.8
October	75.4	71.3	72.5
November	61.3	62.7	62.4
December	65.6	55.6	56.6
Annual Mean	73.3	69.7	70.5

Table 4. Precipitation summary table for New Orleans, Lou. Airport Weather Station in 2021. Departure from 30-year normal is based on years 1981-2010 and 1991-2021 (NOAA 2021).

Month 2021	Total Precipitation (in.) (Red indicates higher than 30Yr Normal)	30yr Monthly Normal Total Precipitation (in.). 1981-2010	30yr Monthly Normal Precipitation (in.) 1991-2021
January	2.04	5.15	5.18
February	4.83	5.30	4.13
March	9.78	4.55	4.36
April	12.85	4.61	5.22
May	12.80	4.63	5.64
June	8.15	8.01	7.62
July	10.61	5.93	6.79
August	9.61	5.98	6.91
September	9.39	4.97	5.11
October	2.44	3.54	3.70
November	.52	4.49	3.87
December	3.07	5.24	4.82
Annual Total	76.44	62.45	63.35

Gulfport, Mississippi

In 2021, seven months out of twelve were warmer in Gulfport than the 30-year normal (1991-2020). The average temperature in 2021 was 0.43 degrees warmer in the period from 1981-2010 and 0.73 degrees warmer in the new normal period from 1991-2020. (Table 5.) It was a

rainier year in 2021 compared to the time from 1981-2010 with 34.56 inches more inches of rain and also compared to the time period from 1991-2020 with 36.42 more inches of rain. More rain fell from February – September 2021 than normal. April received 2.5-3 times more than normal (Table 6). Tropical weather occurred with wind gusts of 40 to 60 mph associated with Hurricane Ida were reported along the Gulf Coast from Mississippi to Florida.

Table 5. Mean Temperature summary table for Biloxi/ Gulfport, Miss. Weather Station in 2021. Departure from 30-year normal is based on years 1981-2010 and 1991-2020 (NOAA 2021).

Months 2021	Average Temperature (F) (red indicates warmer than 30Yr Normal)	30yr Normal Temperature (F) 1981-2010	30yr Mean Temperature F 1991-2020
January	51.7	50.8	51.8
February	51.5	53.8	55.5
March	64.4	50.1	61.1
April	65.8	57.4	67.5
May	74.1	74.3	75.0
June	81.0	80.3	80.9
July	81.9	82.4	82.7
August	83.1	82.4	82.6
September	78.1	78.2	79.2
October	73.1	69.2	70.0
November	64.8	60.3	59.6
December	58.8	53.1	54.0
Annual Mean	69.03	67.6	68.3

Table 6. Precipitation summary table for Biloxi/Gulfport Airport, Miss. Weather Station in 2021. Departure from 30-year normal is based on years 1981-2010 and 1991-2021 (NOAA 2021).

Month	Total Precipitation (in.). Red indicates higher than Normal	30yr Total Precipitation (in.) 1981-2010	30yr Mean Precipitation (in.) 1991-2020
January	01.35	5.19	4.87
February	04.87	5.23	4.44
March	07.01	5.99	5.22
April	15.43	4.56	5.51
May	07.95	5.11	4.74
June	17.03	6.39	6.89
July	11.85	7.21	7.21
August	18.62	6.28	6.53
September	07.26	5.63	5.18
October	04.51	3.55	3.71
November	00.89	4.64	4.03
December	02.41	4.90	4.03
Annual Total	99.18	64.68	62.82

This year, we also include precipitation and average temperatures from the weather station at Trent Lott Airport in Pascagoula because of its general proximity to Grand Bay NEER in Moss Point, Mississippi.

Table 7 Temperature Summary Table for Trent Lott Airport, Miss. Weather Station in 2021. Departure from 30-year normal is based on years 1991-2021 (NOAA 2021), 30 year mean temperature for 1981-2010 is not available for this location.

Month 2021	2021 Mean Temperatures	30yr Mean Temperature 1991-2020
January	51.8	51.7
February	52.5	55.5
March	64.4	61.2
April	65.3	66.6
May	73.3	73.6
June	80.9	80.3
July	82.9	82.1
August	82.8	81.9
September	78.1	78.5
October	72.4	69.2
November	57.6	59.1
December	63.1	54.0
Annual Mean	68.75	67.8

Table 8 Precipitation summary table for Trent Lott Airport Miss. Weather Station in 2021. Departure from 30-year normal is based on years 1981-2010 and 1991-2021 (NOAA 2021).

Month 2021	Total Precipitation (in.). Red indicates higher than Normal	30yr Total 1981-2020 (in.).	Mean Totals 1991-2020 (in.)
January	01.33	5.19	4.97
February	05.23	5.23	4.01
March	05.68	5.99	4.73
April	12.46	4.56	4.40
May	06.97	5.11	4.95
June	16.24	6.39	6.91
July	07.99	7.21	6.65
August	16.71	6.28	7.89
September	08.67	5.63	4.84
October	09.29	3.55	3.69
November	01.28	4.64	3.79
December	01.28	4.90	4.90
Annual Total	99.24	64.68	61.73

Mobile Downtown Airport, Alabama

Overall, the average temperature in 2021 was 0.05 degrees warmer compared to the time period 1981-2010 but cooler by 1.45 degrees when compared to the time period 1991-2020 (Table 7 and 8). According to the online data summary at December 2021 Climate Summaries Mobile/Pensacola (weather.gov). "Mobile saw 14 total days of record temperatures. Of the records, the only record highs for the year surprisingly occurred the last four days of December. The remainder of the records comprised of two record lows both occurring in February, six record high low temperatures and two record low high temperatures." Six months of record rainfall amounts were recorded more than the mean average rainfall than 1981-2010 and 1991-2020.

Table 9. Mean Temperature summary table for Mobile, Alabama Downtown Airport Weather Station in 2021. https://www.weather.gov/lix/newnormals. Departure from normal is based on NOWeather Online Data (https://www.weather.gov/wrh/Climate?wfo=mob)

Month 2021	Average Temperature (F) (red indicates warmer than 30Yr 1991-2020 Normal)	Mean Average Temperature Normal (F) 1981-2010	Mean Temperature Average 1991-2020
January	51.8	51.1	52.3
February	50.3	55.0	55.9
March	62.9	60.9	61.8
April	64.6	66.9	68.3
May	71.4	74.4	75.7
June	77.9	80.1	81.5
July	78.9	81.9	83.5
August	79.7	81.6	83.6
September	75.0	78.1	80.3
October	69.8	69.0	71.1
November	55.9	58.9	60.8
December	61.0	53.3	54.6
Annual Mean	67.65	67.6	69.1

Table 10. Precipitation summary table for Mobile Downtown Airport, Ala. Weather Station in 2021. Departure from normal is based on NOWeather Online Data (https://www.weather.gov/wrh/Climate?wfo=mob)

Month 2021	Total Precipitation (in.) (Red indicates higher than 30Yr Normal) Mobile Downtown Airport	Total Preceipitation Normal (In.) 1981-2010 (Mobile Weather Station)	Total Precipitation Normal (In) 1991-2021 Mobile Downtown Airport
January	1.77	5.65	5.66
February	5.50	5.12	4.47
March	5.70	6.14	5.44
April	9.54	4.79	5.71
May	5.43	5.14	5.39
June	10.28	6.11	6.55
July	5.93	7,25	7.69
August	7.64	6.96	6.87
September	5.39	5.11	5.30
October	3.27	3.69	3.95
November	0.57	5.13	4.60
December	2.61	5.06	5.45
Annual Total	63.63	66.15	67.08

Education and Outreach

Trail Coordinator Gail Bishop and Science Advisor Sue Wilder worked with Hilairie Schacki, New Orleans Master Naturalist Coordinator, in October 2021 to offer an outdoor *Nature's Notebook* training for New Orleans Master Naturalist participants at the Couturie Trail located at the New Orleans City Park.

Sue Wilder, Jennifer Buchannan and Gail Bishop communicated and met with Theresa Downs, an Advanced Master Gardener student. She chose for her project to design signage and to produce a brochure to introduce visitors to Crosby Arboretum's Phenology Journey Trail.

We continued communications with staff at the Grand Bay NERR, Pascagoula River Audubon Center, Mississippi Gulf Coast Community College, USM-Long Beach, USM Marine Education Center. Crosby Arboretum, Barataria Preserve, SELA National Refuges Complex, and New Orleans City Park.

The ongoing pandemic impacted recruiting and training volunteers, however retention of long-term volunteers helped maintain observations (Fig. 38). We created multiple training opportunities in different locations to sustain our network of volunteers. We develop online zoom trainings for local volunteers when we could not meet for in person training.

Figure 38. Number of *Nature's Notebook* observers contributing to all Gulf Coast Phenology Trail partner locations combined, by month, in 2021.

When we asked volunteers their reason for continuing to make observations, most indicated it is their connection with "their plants," individual curiosity and desire for education, and the desire to contribute to Trail objectives. According to several partners, educational opportunities for students and the public are of high value to them.

Summary and Next Steps

We continue to work toward the long-term goals for the Gulf Coast Phenology Trail:

- Promote the increased use of *Nature's Notebook* for collecting local phenology data along the Gulf Coast
- Create a sustained network of citizen scientists for 7-10 years (launched in 2017)
- Provide insights through the knowledge gained from the phenology data collected
- Develop local partnerships across the Gulf Coast to establish sites that address local climate change and conservation issues while strengthening the overall mission of the Gulf Coast Phenology Trail.

After five years of data collection, we have started to see patterns for some species. While some species are consistent in their phenology, others have a wider variability from year to year. For example, red maple seems to produce flowers about the same time every year. We have observed that some locations, especially in Louisiana, produce flowers earlier than eastern Mississippi. Other species, such as Chinese tallow, show more variation in timing for phenophases such as initial growth and fruiting.

We continued to see anomalous weather across the Trail. April 2021 rainfall totals in Gulfport were the highest recorded of the five years. The 2021 hurricane season was active again as it was in 2020. In August, "Hurricane Ida" adversely impacted the Barataria Basin in southeast Louisiana including the phenology trails at the Barataria Unit of Jean Lafite National Historical Park and Preserve before moving across New Orleans and into Mississippi. NOAA predicts above-average activity for the 2022 hurricane season as well (https://www.noaa.gov/news-release/noaa-predicts-above-normal-2022-atlantic-hurricane-season).

We have deepened our focus on pollinators, especially butterflies such as monarch butterflies, as well as nectar or host plants they need to continue their life cycles or migration. Learning

what plants can provide nutrition such as eastern baccharis is important. Our observations will also allow better understanding of any mismatch between plants with early maturation that impacts the pollinators. A new phenology project led by the USA-NPN and funded by the South Central Climate Adaptation Science Center, *Time to Restore: Connecting People, Plants, and Pollinators*, focuses on supporting those working on pollinator restoration in Louisiana, Texas, Oklahoma, and New Mexico. As part of this new effort, additional species such as buttonbush have been added to some Louisiana sites.

The ongoing pandemic made it difficult to maintain data collection at some locations at the same frequency as in previous years. Despite the hiatus, some of the citizen scientists continued to make observations to ensure the data collected would continue to provide future insight into plant responses to climate change.

We will continue to strive to meet our long-term goals and make needed adjustments when necessary. Training for new volunteers in Jackson County, Mississippi will be offered at the Marine Education Center in late summer. Workshops and/or field trips should begin again in August 2022 for current volunteer observers. These activities provide opportunities to network and maintain engagement in the program.

Location of Project Components

All data is entered online via *Nature's Notebook* and is stored in the USA-NPN National Phenology Database, available for download at www.usanpn.org/results/data. Project documentation and resources for plant and animal identification are available at https://fws.usanpn.org/GulfCoastPhenologyTrail. Additionally, Trail fliers for public distribution, NPN Botany Primers, Trail supplies, and displays are housed locally at the coordinator's office.

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Image of map showing Divisional Precipitation Ranks for January-December 2021 courtesy National Centers for Environmental Information, January 8, 2022 NOAA.gov.

Image of map showing migration of purple martin to the North courtesy of Bing.com/images

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Appendix A. Partner and Observation Sites 2021

Partner	Site_ID	Site_Name	State	Latitude	Longitude	# Records	# Observers
Grand Bay NWR/NERR	28745	Boardwalk 1	MS	30.42939	-88.4286	4830	2
Grand Bay NWR/NERR	25174	Front Lawn	MS	30.42909	-88.4306	786	2
Mississippi Sandhill Crane NWR	26079	Visitor Center	MS	30.45158	-88.6555	6541	2
Mississippi Sandhill Crane NWR	28590	Fontainbleau Unit Nature Trail	MS	30.39778	-88.7572	8686	3
Pascagoula River Audubon Center (PRAC)	28353	PRAC-Boat Launch Trail	MS	30.41477	-88.5425	746	2
Pascagoula River Audubon Center	28354	PRAC-Trail 2	MS	30.41479	-88.5426	357	2
Pascagoula River Audubon Center	28357	PRAC Front Lawn	MS	30.41472	-88.5418	440	2
Mississippi Gulf Coast Community College -Gautier	29265	Pine Restoration Trail	MS	30.40065	-88.6451	5855	4
Big Branch Marsh NWR	25151	Main Parking Lot	LA	30.32165	-89.9369	2225	2
Big Branch Marsh NWR	25168	Entrance Road	LA	30.32005	-89.936	701	2
Big Branch Marsh NWR	30648	Blue Trail	LA	30.32059	-89.9382	2084	2
Bayou Sauvage NWR	25901	Boardwalk	LA	30.05377	-89.8805	13794	6
Jean LaFitte NHP&P Barataria Preserve	27474	Visitor Center Trail	LA	29.78447	-90.1148	1399	5
Jean LaFitte NHP&P Barataria Preserve	27475	Palmetto Trail	LA	29.78381	-90.1176	1209	3
Jean LaFitte NHP&P Barataria Preserve	27476	Ring Levee Trail	LA	29.78527	-90.1102	1971	4
Jean LaFitte NHP&P Barataria Preserve	27477	Bayou Coquille Trail	LA	29.79382	-90.1225	3663	6
Crosby Arboretum	28830	Phenology Journey	MS	30.50215	-89.6668	4538	4
USM Marine Education Center	30971	Osprey Point Nature Trail	MS	30.39134	-88.776	4689	2
USM-Long Beach	33862	Bayou Bear Path	MS	30.35395	-89.1362	981	2
New Orleans City Park	33401	Couturie Forest Phenology Trail	LA	30.00475	-90.0942	667	9
Bayou Lafourche Phenology Trail	28969	Wetlands Acadian Cultural Center	LA	29.79622	-90.8250	2886	3

Appendix B. 2021 Plant Monitoring Number of Species

BARP -Barataria Preserve (Jean LaFitte NPP)
BL – Bayou Lafourche Phenology Trail
BS-Bayou Sauvage NWR
BBM-Big Branch NWR
CR-The Crosby Arboretum
GB-Grand Bay NWR/NERR
MSC-Mississippi Sandhill Crane NWR
MGCCC - Mississippi Gulf Coast Community College
NOLA-CP- New Orleans City Park
PRAC – Pascagoula River Audubon Center
USM-LB-Long Beach Campus
USM-MEC-Marine Ed. Ctr

Species	BARP	BL	BS	BBM	CR	GB	MSC	MGCCC	NOLA-CP	PRAC	USM-LB	USM-MEC	TOTAL
American beautyberry	1	1		3			2		1			2	10
American Elm			2										2
American sycamore		1							2			1	3
American Witchhazel												1	1
Bald cypress	5	2	3						2				12
Black cherry				1									1
Black willow		1	2						1				4
Boxelder	3												3
Chinese tallow	1	1	2			3	1	2					10
Common buttonbush	2												2
Common hackberry			3						1				4
Common persimon			2										2
Eastern baccharis	3		3			1	3	2		1			13
Eastern poison ivy	5												5
Elliott's blueberry				2	3								5
Flowering dogwood							1						1
Honeylocust	1								1				2
Live oak	4	2	2						1		1		10
Longleaf pine					1		3				7		11
Mountain azalea					3		3						6
Pitcher Plant					2			1					3
Possumhaw	5												5
Red buckeye										3			3
Red maple	5	2	7	9	2	6	7	4	1	2	1	5	51
Redbay				2	4	4	6	5		2		4	28
Sassafras		1											1
Southern magnolia				3					1				4
Sugarberry		1											1
Sweetbay							2				3		5
Sweetgum	5		2						1				8
Trumpet creeper	4												4
Water tupelo	2												2
Wax myrtle	4				4	3	6	3		4		4	29
White crownbeard	2												2
Yaupon holly		1			4	4	7	3		4		4	29
Yellow trumpets					2		2						4
TOTAL	52	13	28	22	24	21	43	20	12	16	12	20	283

Appendix C. 2021 Animal Monitoring

BARP -Barataria Preserve (Jean LaFitte NPP)
BS-Bayou Sauvage
BBM-Big Branch
CR-Crosby Arboretum
GB-Grand Bay NWR/NERR
MSC-Mississippi Sandhill Crane NWR
PRAC – Pascagoula River Audubon Center

Species	BARP	BS	BBM	CR	GB	MSC	PRAC	TOTAL Sites
Birds (records)								
American Robin		x			x	x		3
Bald Eagle	x				x			2
Barred Owl	x							1
Blue Jay							x	1
Carolina Wren	x							1
Chimney Swift							x	1
Eastern Bluebird					x	x		2
Henslow Sparrow					x			1
Hooded Warbler	x							1
Northern Cardinal					x			1
Northern Mockingbird						x		1
Northern Parula	x							1
Osprey					x	x		2
Painted Bunting	x							1
Prothonotary Warbler	x							1
Purple Martin					x		x	2
Red-bellied Woodpecker	x							1
Ruby-crowned Kinglet							x	1
Ruby-throated Hummingbird							x	1
Sandhill Crane						x		1
Tufted Titmouse						x		1
Yellow Rumped Warbler		x					x	2
Insects (Records)								
Gulf fritillary		x			x			2
Bumblee					x			1
Honeybee					x			1
Monarch		x	x	x	x			4
Mammals (Records)								
Fox Squirrel					x			1
Reptiles (Records)								
American Alligator	x							1
Eastern Box Turtle					x			1
TOTAL Species	9	4	1	1	13	6	6	

Appendix D. Number of monthly site visits by Partner in 2021.