Proceedings of the

Phenology 2025 Conference

PHENO

Towards a global phenology science | 2025

July 28th to August 1st

São Pedro, SP - Brazil

PHENO

Towards a global phenology science | 2025

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Hosted by

ISB INTERNATIONAL SOCIETY OF BIOMETEOROLOGY

unesp UNIVERSIDADE ESTADUAL PAULISTA "JÚLIO DE MESQUITA FILHO"

CBioClima Centro de Pesquisa em Biodiversidade e Mudanças do Clima

Phenology Lab

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Proceedings - PHENO2025: Towards a Global Phenology Science

São Pedro, SP, Brazil | 2025, July 28th to August 1st

Technical Edition

Patricia Morellato; Bruna de Costa Alberton; Pedro Joaquim Bergamo

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PRESENTATION

The Phenology 2025 Conference “PHENO2025 - Towards a Global Phenology Science" was the first Phenology Conference to be held in the Global South and in a tropical country, Brazil. The PHENO2025 served as a landmark event, bringing together scientists, researchers, students, technicians, and policymakers from all around the world, all committed to advancing the understanding of the impacts of climate change on ecosystems through the lens of phenology.

Phenology—the study of recurrent events in the life cycles of plants and animals (e.g., flowering, leaf fall and unfolding, animal migration) is an integrative science that combines ecology, evolutionary biology, climatology, and environmental sciences. Phenology also serves as a key indicator of environmental changes, uniting experts from multiple disciplines, stakeholders, and society at large.

The PHENO2025 Conference aimed to foster global collaboration and innovation in monitoring, modeling, and predicting phenological shifts. Specific areas of focus included phenology of species, communities and ecosystems and phenological networks, standards and protocols for data collection, phenology as a bioindicator of climate change, impacts of phenology on organism performance and ecosystem function, physiological and genetic determinants, remote sensing phenology, biodiversity conservation and ecological restoration, with attention to highly diverse ecosystems. Other relevant topics addressed included phenological decoupling and the temporality of ecological networks and interactions, climate change and urban phenology, citizen science, networks and botanical gardens, and the use of historical data as well as herbarium and museum collections to understand temporal responses to climate change. This comprehensive approach was considered vital for developing adaptive strategies to mitigate the adverse effects of climate change on biodiversity, food production, planetary health, and human well-being. PHENO2025 served as a platform to highlight the importance of standardized global phenological data collection and sharing. Enhanced international cooperation was emphasized as a means to build more comprehensive datasets, enabling better-informed decisions at local, regional, and global levels.

The conference also explored the integration of traditional ecological knowledge with modern scientific approaches, highlighting the role of Indigenous and local communities in phenological research. Ultimately, PHENO 2025 acted as a venue bridging the Global North and South, advancing the field of phenology and contributing to more resilient ecosystems and societies in the face of a rapidly changing climate.

The strong presence in the media also enhanced communication with both the scientific community and society. Check out our media channels: @pheno2025 and the Pheno2025 webpage.

CONFERENCE ORGANIZING

ORGANIZING COMMITTEE

PATRICIA MORELLATO (UNESP, Brazil) - **Conference Chair**

Patricia Morellato is a Professor at the São Paulo State University (UNESP) and the Director of the Center for Research on Biodiversity Dynamics and Climate Change (CBioClima) at Rio Claro, São Paulo/Brazil. She is a plant ecologist working mainly on phenology and the temporal ecology of tropical vegetation and plant-animal interactions. She investigates the effects of global climate change and other anthropogenic disturbances on the growth and reproductive cycles of megadiverse vegetation and the implications for the conservation and restoration of biodiversity. She coordinates the first phenology network in the tropics (e-phenology network), monitoring leaf phenology using repeated digital photographs to understand the temporal dynamics across tropical biomes and the responses to climate change.

BRUNA ALBERTON (UNESP, Brazil) - **Conference Co-Chair**

Bruna Alberton is a researcher at the São Paulo State University (UNESP) and Center for Research on Biodiversity Dynamics and Climate Change at Rio Claro, São Paulo/Brazil. Her works focus mainly on the remote phenology of tropical vegetation. She investigates leaf phenological patterns and interannual dynamics, focusing on their main drivers and their relationship with ecosystem processes. She is also an expert on imagery and time series analysis using phenocameras. Alberton is also co-coordinator of the e-phenology network, the first and largest phenocamera network in the tropics.

LOCAL ORGANIZING COMMITTEE

PATRICIA MORELLATO (UNESP, Brazil)

BRUNA DE COSTA ALBERTON (UNESP, Brazil)

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MARIA MARAIZA PEREIRA DOS SANTOS (UNESP, Brazil)

BEATRIZ LOPES MONTEIRO (UNESP, Brazil)

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RENAN RAMOS CHAVES (UNESP, Brazil)

EMERSON JOSÉ (UNESP, Brazil)

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ALFREDO HUETE (University of Technology Sydney, Australia)

ALISON DONNELLY (University of Wisconsin, United States of America)

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JENNIFER FITCHETT (University of the Witwatersrand, South Africa)

JIN WU (The University of Hong Kong, Pokfulam, China)

JUAN ARROYO (Universidad de Sevilla, Spain)

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VANESSA GRAZIELE STAGGEMEIER (Universidade Federal do Rio Grande do Norte, Brazil)

YONGSHUO FU (Beijing Normal University, China)

YULE ROBERTA NUNES (Universidade Estadual de Montes Claros, Brazil)

FULL PROGRAMME

2025, July 28

08:00 - 17:00	Registration and secretary services
09:00 - 09:30	**Opening Session**
09:30 - 10:15	**Keynote: Patricia Morellato (Unesp, Brazil) - Towards a Global Phenology Science**
10:10 – 10:15	**Tribute to Professor Patricia Morellato**
10:15 - 10:30	**Book Signing Session -** Phenology: An Integrative Environmental Science 3rd ed.
10:30 - 11:00	Special Coffee Break
11:00 - 12:30	**Oral Session 1: Thematic Axis "Phenological methods, standards, protocols and cutting-edge approaches"**
11:00 - 11:05	**Session Chairs:** Vanessa Staggemeier - UFRN/Brazil - Carmen Benítez Benítez - Universidad de Sevilla/Spain
11:05 - 11:20	**João Custódio Fernandes Cardoso, UFMG, Brazil (Voluntary Contribution):** Are We In The Right Direction With Phenological Analysis? Revisiting Circular Statistics
11:20 - 11:35	**Alessandro Mainardi, University of Freiburg, Germany (Voluntary Contribution):** A New Lens on Tropical Phenology: How Time-Lapse Canopy Cameras Are Changing The Game
11:35 - 11:50	**Carmen Benítez Benítez, University of Seville, Spain (Voluntary Contribution):** Flowering phenology in Mediterranean woodlands: combined effects of phylogeny, reproductive traits, habitat and elevation in Andalusian National Parks (Spain)
12:05 - 12:20	**Mark Schwartz, University of Wisconsin-Milwaukee, USA (Voluntary Contribution):** Changes in L48 USA Spring Onset Since 1900
12:20 - 12:30	Discussion (10 minutes)
12:30 - 13:45	Lunch Break

14:00 - 14:40	**Keynote: Geetha Ramaswami (Nature Conservation Foundation, India) - Tree seasonality and citizen science - making phenology mainstream**
14:40 - 15:40	**Oral Session 2: Thematic Axis "Phenology Networks from North and South: Towards a Global Phenology Science" - PART I**
14:40 - 14:45	**Session Chairs:** Desirée Marques Ramos - ITV/Brazil - Mário Marcos do Espírito Santo - UNIMONTES/Brazil
14:45 - 15:00	**Desirée Marques Ramos, ITV, Brazil** (Invited Speaker): PhenoChange: Towards a Dry Tropics Global Phenological Monitoring Network
15:00 - 15:15	**Italo Antonio Cotta Coutinho, UFC, Brazil (Invited Speaker):** Phenological Patterns of Woody And Ground cover caatinga Species
15:15 - 15:30	**Francisco Maiato Pedro Gonçalves, Universidade Mandume Ya Ndemufayo, Angola (Invited Speaker):** Leaf phenology across southern African woodlands, a perspective from Bicuar National Park, SW Angola
15:30 - 15:40	Discussion (10 minutes)
15:40 - 16:00	Coffee Break
16:00 - 17:10	**Oral Session 2: Thematic Axis "Phenology Networks from North and South: Towards a Global Phenology Science" - PART II**
16:00 – 16:05	**Session Chairs:** Desirée Marques Ramos - ITV/Brazil - Mário Marcos do Espírito Santo - UNIMONTES/Brazil
16:00 - 16:15	**Vera De Cauwer, Namibia University of Science and Technology, Namibia (Invited Speaker):** Phenological Patterns in Namibia's Woodlands: from Satellite Data to Ground-based Observations
16:15 - 16:30	**Mário Marcos do Espírito Santo, UNIMONTES, Brazil (Invited Speaker):** Long-term ecological research in Brazilian dry ecosystems: linking plant phenology and functional traits across scales
16:30 - 16:45	**Jonathan Ilunga Muledi, University of Lubumbashi, Congo (Invited Speaker):** PhenoCam project in Haut-Katanga: phenological monitoring of tree species for sustainable management of the Katanga's Miombo forest in the Democratic Republic of Congo

16:45 - 17:00	**Ola Langvall, Swedish University of Agricultural Sciences, Sweden (Voluntary Contribution):** Swedish phenology for short-term forecasts and long-term scenarios of climate change effects
17:00 - 17:10	Discussion (10 minutes)
17:10 - 18:30	**Ice Break cocktail + MPB concert**

2025, July 29

08:00 - 17:00	Secretary services
09:00 - 09:45	**Keynote: Jin Wu (University of Hong Kong, Hong Kong) - Bridging phenology from tree individuals to regional scales**
09:45 - 11:00	**Oral Session 3: Thematic Axis "Remote Phenology: from near-surface to orbital sensors and modeling integration" - PART I**
09:45 - 09:50	**Session Chairs:** Bruna de Costa Alberton - UNESP/Brazil - Alison Donnely - University of Wisconsin/USA
09:50 - 10:05	**Bruce Walker Nelson, INPA, Brazil (Voluntary Contribution):** Delayed brown-down response to severe drought in a Central Amazon Forest
10:05 - 10:20	**Maria Maraíza Pereira dos Santos, UNESP, Brazil (Voluntary Contribution):** Long-term phenological responses are driven by climatic variability and drought events in seasonal tropical forests
10:20 - 10:35	**Andeise Cerqueira Dutra, INPE, Brazil (Voluntary Contribution):** Vegetation Composition and Cover Drive Land Surface Phenology in Drylands: Insights from Near-Surface and Satellite Data in the Southern Hemisphere
10:35 - 10:50	**Mateus Geovane Lima da Silva, UNESP, Brazil (Voluntary Contribution):** Linking leaf canopy phenology and leaf traits to herbivory in a Central Amazonian forest using digital cameras
10:50 - 11:00	Discussion (10 minutes)
11:00 - 11:30	Coffee Break
11:30 - 12:40	**Oral Session 3: Thematic Axis "Remote Phenology: from near-surface to orbital sensors and modeling integration" - PART II**

11:30 – 11:35	**Session Chairs:** Bruna de Costa Alberton - UNESP/Brazil - Alison Donnely - University of Wisconsin/USA
11:30 - 11:45	**Marjane Myriam Sakina Kaddouri, University of Liège, Belgium (Voluntary Contribution):** Monitoring leaf phenology and stem growth dynamics in central African Tropical forests using Phenocams and electronic dendrometers
11:45 - 12:00	**Alison Donnelly, University of Wisconsin-Milwaukee, USA (Voluntary Contribution):** The last ones standing: how leaf senescence and chlorophyll degradation in native and non-native shrubs shape autumn phenology dynamics in a temperate deciduous woodland
12:00 - 12:15	**Yi Xiao, INRAE, France (Voluntary Contribution):** Phenology Monitoring of Deciduous Broadleaf and Evergreen Needleleaf Forests Using Sentinel-1 SAR and Deep Learning Methods
12:15 - 12:30	**Drew Terasaki Hart, CSIRO, Australia (Voluntary Contribution):** Global phenology maps reveal the diversity, convergence, and asynchrony of ecosystem function
12:30 - 12:40	Discussion (10 minutes)
12:45 - 14:00	Lunch Break
14:00 - 14:40	**Keynote – Silvana Marten-Rodriguez (Universidad Nacional Autónoma de Mexico, Mexico) - Climate change effects on the phenology and other organismal traits of plants and pollinators: a global review**
14:40 - 15:40	**Oral Session 4: Thematic Axis "Phenological Mismatching and Temporality of Mutualistic Networks" - PART I**
14:40 - 14:45	**Session Chairs:** Silvana Marten-Rodriguez - UNAM/Mexico - Pedro Joaquim Bergamo - UNESP/Brazil
14:45 - 15:00	**Paulo Eugênio Oliveira, UFU, Brazil (Voluntary Contribution):** Phenology across complex landscapes: the importance of habitat temporal complementarity in plant-animal interactions in the Brazilian Cerrados

15:00 - 15:15	**Irene Gélvez Zúñiga, UNESP, Brazil (Voluntary Contribution):** Ancient and diverse: reproductive phenology, floral traits and visitors of Vellozia species from campo rupestre
15:15 - 15:30	**Mauricio Quesada, Universidad Nacional Autonoma de Mexico, Mexico (Voluntary Contribution):** Global change drivers cause changes in flowering phenology, pollinator decline, and loss of floral resources that maintain plant-pollinator interactions
15:30 - 15:40	Discussion (10 minutes)
15:45 - 16:15	Coffee Break
16:15 - 17:55	**Oral Session 4: Thematic Axis "Phenological Mismatching and Temporality of Mutualistic Networks" - PART II**
16:15 – 16:20	**Session Chairs:** Silvana Marten-Rodriguez - UNAM/Mexico - Pedro Joaquim Bergamo - UNESP/Brazil
16:15 - 16:30	**Lucas Benício de Castro, Instituto de Biodiversidade, Brazil (Voluntary Contribution):** Phenological overlap and morphology drive high niche partitioning in a butterfly-flower interaction network
16:30 - 16:45	**Pedro Joaquim Bergamo, UNESP, Brazil (Voluntary Contribution):** Phenological regulation of indirect interactions in pollination networks
16:45 - 17:00	**Heloisa Ribeiro, UFPR, Brazil (Voluntary Contribution):** Trait Similarity in Co-flowering Modules in a Hummingbird Pollination System
17:00 - 17:15	**Daniel Pareja Bonilla, Universidad de Sevilla, Spain (Voluntary Contribution):** Functional traits predict changes in floral phenology under climate change in a highly diverse Mediterranean community
17:15 - 17:30	**Andrea Lizeth Silva Cala, FSU Jena and MPI for Biogeoquemistry, Germany (Voluntary Contribution):** Space-for-time substitution approach in flowering phenology under climate change
17:30 - 17:40	Discussion (10 minutes)
17:50 -17:40	**POSTER SESSION I**
18:00 - 19:00	**Ana Luisa Sotelo Caballero, Instituto de Biología** - UNAM, Colombia: Do Elevation Gradients Influence The Temporal

	Availability Of Floral Resources? A Case Study With Andean Ornithophilous Plant Communities
18:00 - 19:00	**Annessa Foss, Arizona State University, USA (Voluntary Contribution):** Flowering phenology in a dryland ecosystem as affected by climate
18:00 - 19:00	**Bruna Alberton, UNESP, Brazil:** A review of phenology monitoring using phenocamera across the tropics: main advances and research gaps
18:00 - 19:00	**Carolina Ovalle Romero, UPTC, Colombia:** From Classroom To Campus Community: Initial Strategies For Participatory Plant Phenology Monitoring At The UPTC
18:00 - 19:00	**Carolina Pontes Santos, UFMG, Brazil:** Reproductive phenological periods of Jacaranda spp. in urban areas of the city of Belo Horizonte, Brazil
18:00 - 19:00	**Ellen G Denny, USA National Phenology Network, USA:** Phenobase: An open-access, integrated database of global plant phenology
18:00 - 19:00	**Erika Rocio Reyes Gonzalez, National Autonomous University of Mexico, Mexico:** Use of Phenological Cameras for Vegetation Monitoring in Protected Areas of Central Mexico
18:00 - 19:00	**Izabela Fonseca Aleixo, INPA, Brazil:** Long-Term Phenological Dynamics of Amazonian Trees Reveal Species-Specific Responses to Climate Variability
18:00 - 19:00	**Leonardo César Rocha Ganz, IPA, Brazil:** Phenological monitoring of Blue Jacaranda in Brazilian urban green spaces: assessing social media engagement to boost citizen science programs
18:00 - 19:00	**Lucas Heleno Lopes, Museu Nacional/UFRJ, Brazil:** Reproductive Phenology of Erythroxylum ovalifolium Peyr. (Erythroxylaceae)
18:00 - 19:00	**Maria Laura Araujo Gonçalves, Museu Nacional/UFRJ, Brazil:** Reproductive phenology of a dioecious species of Sapindaceae
18:00 - 19:00	**Maria Luisa Passos Frigero:** Can Urban Surface Temperature Be Associated With Flowering Patterns Of A Brazilian Species Widely Used In Urban Afforestation?
18:00 - 19:00	**Maria Tereza Grombone Guaratini, IPA, Brazil:** Seasonal variation on leaf functional traits of cerrado: a comparison of lianas and trees

18:00 - 19:00	**Marly Antonielle de Ávila, UNIMONTES, Brazil:** How drought stress shapes litterfall dynamics in veredas of Northern Minas Gerais
18:00 - 19:00	**Nathan Felipe Alves, UNESP, Brazil:** Invasive woody species change the vegetation phenology and hydrological dynamics in Veredas
18:00 - 19:00	**Ezrah Natumanya, UNESP, Brazil:** A hydrological view of drylands and association to vegetation phenology: perspectives for future research in the Caatinga seasonally dry tropical forests in Brazil
18:00 - 19:00	**Ola Langvall, Swedish University of Agricultural Sciences, Sweden:** Swedish PhenoCam Network reveals improved quality, coverage and availability of phenology monitoring data in Sweden
18:00 - 19:00	**Pedro Amaral Anselmo, UFMG, Brazil:** Changes in flowering plant composition from rocky outcrops in the Brazilian Campo Rupestre over two decades.
18:00 - 19:00	**Shady Susana Ruiz Díaz Medina, University of Florida, USA:** Bioclimatic predictors of forest structure, composition, and phenology in the Paraguayan Dry Chaco
18:00 - 19:00	**Srinivasan Kasinathan, Nature Conservation Foundation, India:** Phenology of 50 tree species across 8 years in a South Asian tropical rainforest indicates complex influence of climate, traits, and phylogeny
18:00 - 19:00	**Thalita Surian, UNESP, Brazil:** Historical data collection on the phenology of blue jacaranda tree: A look at blue flowers through old newspapers
18:00 - 19:00	**Yule Roberta Ferreira Nunes, UNIMONTES, Brazil:** Phenological Patterns and Litter Accumulation in Veredas: Sustained Ecological Monitoring
	Meeting - Remote Phenology

2025, July 30

08:00 - 13:00	**Field Trips** (departure from the Hotel)
08:00 - 13:00	**Cruzeiro do Facão Hiking Trail**

08:00 - 13:00	**Serra do Itaqueri Viewpoints Tour**
08:00 - 13:00	**Tanquã Boat Tour** (Birdwatching)
08:00 - 17:00	Secretary services
14:00 - 15:30	**Meeting: The Blue wave - Jacaranda Project**
15:30 - 17:00	**Meeting: Phenological Botanical Gardens Network**
17:00 - 18:30	**Meeting: International Society for Biometeorology (ISB) - Phenology Commission Meeting**

2025, July 31

08:00 - 17:00	Secretary services
09:00 - 09:45	**Keynote – Jennifer Fitchett (University of the Witwatersrand, South Africa) - Tracking Phenology in the Global South: Phenological networks, creative data sources, and traditional knowledge**
09:45 - 10:45	**Oral Session 5: Thematic Axis "Phenology from Legacy and Herbarium Data to Botanical Gardens for Global Forecasting Climatic Change"**
09:45 - 09:50	**Session Chair:** Patricia Marollato – Unesp/Brazil
09:50 - 10:05	**Juan Arroyo Marin, University of Seville, Spain (Invited Speaker):** The value of natural history collections in retrospective and prospective analysis of phenological change in Mediterranean ecosystems of Andalusia (S Spain)
10:05 - 10:20	**Robert Rauschkolb, Friedrich-Schiller-University Jena, Germany (Voluntary Contribution):** The Intensity Of Flowering In Herbaceous Species Is Strongly Influenced By Their Competitive Ability And Phenological Niche
10:20 - 10:35	**Vanessa Graziele Staggemeier, UFRN, Brazil (Voluntary Contribution):** Flowering Niche and Range Dynamics Under Global Warming Scenarios: an Atlantic Rain Forest study case
10:35 - 10:45	Discussion (10 minutes)

10:45 - 11:15	Coffee Break
11:15 - 12:30	**Oral Session 6: Thematic Axis "Phenology, Traditional knowledge, and Citizen science"**
11:15 - 11:20	**Session Chair**: Jennifer Fitchett - University of the Witwatersrand/South Africa
11:20 - 11:35	**Per Bengtson, Swedish Centre for Nature Interpretation, Sweden (Voluntary Contribution):** Counting on Change - An exhibition activating Nature Centre Visitors in Phenology for increased Climate Change awareness
11:35 - 11:50	**Udo Busch, Deutscher Wetterdienst, Germany (Voluntary Contribution):** Reporting Phenological Observations by Citizens using the new DWD Warn-Wetter-App
11:50 - 12:05	**Jociene Oliveira Vitoria Nascimento, Secretaria de Educação da Bahia, Brazil (Voluntary Contribution):** Mandacaru "Fulorar" During The Drought, It Is Sign That Rain Is Coming To The "Sertão"? Phenology And Local Ecological Knowledge In Quilombola Communities Of The Caatinga
12:05 - 12:20	**Michelle Bastian, University of Edinburgh, UK (Voluntary Contribution):** Visualising Blue Jacaranda phenology data: connecting people with local climate change indicators
12:20 - 12:30	Discussion (10 minutes)
12:30 - 14:00	Lunch Break
14:00 - 14:40	**Keynote: Mauricio Quesada (Universidad Nacional Autónoma de Mexico, Mexico) - Decadal Flowering Phenology and Pollen Metabarcoding Reveal Climate-Linked Shifts in a Tropical Montane Forest**
14:40 - 15:40	**Oral Session 7: Thematic Axis "Tropical Phenology, Biodiversity Conservation and Restoration under global change" PART I**
14:40 - 14:45	**Session Chairs**: Beatriz Lopes Monteiro - UNESP/Brazil - Aparajita Datta - Nature Conservation Foundation/India
14:45 - 15:00	**Aparajita Datta, Nature Conservation Foundation, India (Invited Speaker):** Shifts in phenology patterns of trees and hornbills linked to climate variability in the Eastern Himalaya

15:00 - 15:15	**Arun Poornima Madhavan, Nature Conservation Foundation, India (Voluntary Contribution):** Tree phenology in relation to climate and dispersal mode in a tropical wet evergreen forest in South Asia
15:15 - 15:30	**Monize Altomare, UNESP, Brazil (Voluntary Contribution):** Trends and Gaps in Neotropical Flowering Phenology
15:30 - 15:40	Discussion (10 minutes)
15:40 - 16:10	Coffee Break
16:10 - 17:55	**Oral Session 7: Thematic Axis "Tropical Phenology, Biodiversity Conservation and Restoration under global change" PART II**
16:10 – 16:15	**Session Chairs**: Beatriz Lopes Monteiro - UNESP/Brazil - Aparajita Datta - Nature Conservation Foundation/India
16:10 - 16:30	**Soumya Banerjee, Nature Conservation Foundation, India (Voluntary Contribution):** Effects of the El Nino Southern Oscillation (ENSO) on Long-term Tree Reproductive Phenology in the Indian Eastern Himalaya
16:30 - 16:45	**Hannelise de Kassia Balduino UNESP, Brazil (Voluntary Contribution):** You Shall Not Starve: The Presence of Leaves Guarantees Nectar for Ants All Year Round
16:45 - 17:00	**Beatriz Lopes Monteiro, UNESP, Brazil (Voluntary Contribution):** Reproductive phenology after fire: a brief assessment of a plant community in a biodiversity hotspot
17:00 - 17:15	**Yang Dasheng, Meteorological Observation Center/China Meteorological Administration, China (Voluntary Contribution):** Automatic Observation Instruments for Phenology Deployed Nationwide in China
17:15 - 17:30	**Mauricio Talebi Gomes, UNIFESP, Brazil (Voluntary Contribution):** Phenological Cycles of Staple Food Dietary Items for the Southern Muriqui (Brachyteles arachnoides - PRIMATES, CR) in the southeastern Brazil's Atlantic Forest
17:30 - 17:45	**Priscila Tunes, UNESP, Brazil (Voluntary Contribution):** Drought Effects on the Flowering Phenology of a Global Crop: Potential Consequences for Pollination and Food Security
17:45 - 17:55	Discussion (10 minutes)

18:00 - 19:00	**POSTER SESSION II**
18:00 - 19:00	**Amanda Eburneo Martins, UNESP, Brazil:** Climate-induced shifts in long-term tropical tree reproductive phenology: insights from species dependent on and independent of biotic pollination
18:00 - 19:00	**Ângelo Antônio Corrêa da Silva:** Fruiting phenology of zoochoric species in a frugivore reintroduction area in Tijuca National Park, Rio de Janeiro
18:00 - 19:00	**Antonia Mirelle Lopes Marques, UFC, Brazil:** Leaf Phenology in Carrasco Vegetation, a Caatinga Physiognomy: New Perspectives from the Use of Phenocameras
18:00 - 19:00	**Arun Poornima Madhavan, Nature Conservation Foundation, India:** Assessment of a signal processing approach to study tree phenological patterns and estimate biologically-relevant parameters in a south Asian tropical rainforest
18:00 - 19:00	**Daiane Cristina Carreira, UNESP, Brazil:** Long-term fruiting patterns shape bird-plant interaction networks in the Brazilian Cerrado
18:00 - 19:00	**Daniel Pareja Bonilla, Universidad de Sevilla, Spain:** Keeping up the pace: Changes in the phenology of pollinators in a Mediterranean community over the past 35 years.
18:00 - 19:00	**Eliana Gressler, UNESP, Brazil:** Plant community phenology over three years in the Brazilian Atlantic Rainforest
18:00 - 19:00	**Ellen G Denny, USA National Phenology Network, USA:** The USA National Phenology Network's Recent Growth and Advancements
18:00 - 19:00	**Felipe Alvarez Silva Nunes, UNESP, Brazil:** Flames and Flowers: Fire Season Drives Reproductive Timing in the Cerrado
18:00 - 19:00	**João Custódio Fernandes Cardoso, UFMG, Brazil: Blooming Lies:** Unveiling the Timing Behind Batesian Floral Mimicry
18:00 - 19:00	**Larissa de Oliveira Leite, UNICAMP, Brazil:** Leaf phenology patterns in Brazilian campos de altitude assessed by phenocameras
18:00 - 19:00	**Magna Soelma Beserra de Moura, Embrapa, Brazil:** Characterizing Vegetation Phenology in a Seasonally Dry Tropical Forest Using Near Ground-Based Spectral Indices and Precipitation Dynamics

18:00 - 19:00	**Mário Marcos do Espírito Santo, UNIMONTES, Brazil:** Do tree functional traits affect leaf phenology? A proximal-sensing approach in a Brazilian tropical dry forest
18:00 - 19:00	**Marsal Danrlei de Amorim, UFMG, Brazil:** Floral trait similarity between neighbors increases reproductive success suggesting facilitation through pollinator sharing
18:00 - 19:00	**Nattália do Prado Neves, UNESP, Brazil:** Leaf Strategies in Seasonally Dry Tropical Forests: The Trade-off Between Investment and Longevity
18:00 - 19:00	**Paula Maria Montoya Pfeiffer, UNESP, Brazil:** Spatial-Temporal Centrality of Plant-Pollinator Interactions in a Campo Rupestre Ecosystem
18:00 - 19:00	**Robert Rauschkolb, Friedrich-Schiller-University Jena, Germany:** PhenObs 2.0 - Extending A Phenological Observation Network In Botanical Gardens To The Tropics
18:00 - 19:00	**Vanessa Graziele Staggemeier, UFRN, Brazil:** Spatial and Temporal Patterns of the Phenological Research on Caatinga
20:00 - 00:00	**Gala dinner** (with traditional Brazilian food and samba music)

2025, August 1st

08:00 - 12:30	Secretary services
09:00 - 09:45	**Keynote: Susanne Jochner-Oette (Catholic University of Eichstätt-Ingolstadt, Germany) - The International Phenological Gardens Network - Importance, Challenges, Recent Findings, and Future Prospects**
09:45 - 10:30	**Oral Session 8: Thematic Axis " Urban Phenology and Global Change"**
09:45 - 09:50	**Session Chair:** Pietro Kiyoshi Maruyama Mendonca - UFMG/Brazil
09:50 - 10:05	**Giuliano Maselli Locosselli, USP, Brazil (Invited Speaker):** Phenology in Urban Tree Management

10:05 - 10:20	**Kaio Murilo Leite, UNESP, Brazil (Voluntary Contribution):** Is Urbanization Intensity Associated With Mass Flowering Patterns In A Brazilian Native Plant Species?
10:20 - 10:30	Discussion (10 minutes)
10:30 - 11:00	Coffee Break
11:00 - 12:00	**Special Issues PHENO2025**
12:00 - 12:30	**Closing Ceremony**
12:30 - 13:45	Lunch

SUMMARY

Keynote

TOWARDS A GLOBAL PHENOLOGY SCIENCE

Patricia Morellato[1]

(1) Center for Research on Biodiversity Dynamics and Climate Change and Department of Biodiversity, Phenology Lab, Biosciences Institute, UNESP São Paulo State University, São Paulo, Brazil.

Phenology 2025 conference will mark the sixth conference in the series hosted by the Phenology Commission of the International Society of Biometeorology (ISB). The event will be distinguished as the second held in the Southern Hemisphere and the very first held in the Global South and Neotropics. These dynamic conferences have combined researchers of phenology from all around the world, from seasoned experts to early-career scientists to promote community building. Considering the themes, since the very first Conference, all have converged to the understanding of climate change adaptation and mitigation, sustainable solutions and societal awareness. Hosted in Brazil, the PHENO2025 Conference aim to bond Global North and South researchers around the Conference theme: "Towards a Global Phenology Science". The PHENO2025 aiming at bringing together scientists, researchers, students, technicians, and policymakers from around the world to explore the impacts of climate change on ecosystems through the lens of phenology. Considering the previous conferences, we expect to surpass number of subscriptions as well as abstracts, from previous meetings. Phenology2025 is organized with a strong commitment to inclusivity and equity, targeting to create a platform that reflects diverse perspectives and contributions. Special attention has been given to involving contributors from the Global South, and women and other less represented groups, reaching an unmatched participation compared to previous conferences. As Phenology science has a historical dominance from Global North, we suggest that alternating the North and South Conference may diversify and improve science for both sides. We propose that build up and strengthen Global South Networks and Phenology Citizen may improve the number of phenology scientists. We also suggest that Urban Phenology may be a way to construct networks combining citizen science and historical and cultural legacy data to frame a new paradigm for Global Phenology bonding not just the Global South but North and South in an equitable research collaboration. The PHENO2025 conference is anticipated to drive significant progress in scientific dialogue, technological innovations, and collaborative research, thereby enhancing the scope and impact of phenological studies globally.

Acknowledgement: Supported by: ISB, UNESP, IBRC, FAPESP (#2021/10639-5; #2022/07735-5; 2025/05992-9), CNPq (440849/2025-0), CAPES (88881.012125/2024-01)

Session 1

Phenological methods, standards, protocols and cutting-edge approaches

Oral Session

ARE WE IN THE RIGHT DIRECTION WITH PHENOLOGICAL ANALYSIS? REVISITING CIRCULAR STATISTICS

João Custódio Fernandes Cardoso(1); Graeme D. Ruxton(2); E. Pascal Malkemper(3); Lukas Landler(4)

(1) Universidade Federal de Minas Gerais. (2) School of Biology, University of St Andrews. (3) Research Group Neurobiology of Magnetoreception, Max Planck Institute for Neurobiology of Behavior - caesar. (4) Institute of Zoology, BOKU University.

Phenological data is circular since observations are on a cyclical rather than a linear scale, requiring circular statistics. Although this type of analysis developed historically, phenological studies usually do not incorporate many methodological possibilities, limiting data reliability and inference. Investigating uniformity is one of the most common procedures. Uniformity tests indicate whether data is uniformly distributed throughout the circle/year or non-uniformly distributed (significant result), indicating occurrence peaks and, therefore, seasonality. Common procedures include the Rayleigh test for von Mises distributed data and Rao's spacing and Hermans-Rasson tests for other distributions. Based on this state-of-the-art, we identify caveats and innovations that may benefit phenology through the methodological incorporation of well-established and open-source circular methods. The first consists of "considering the grouped nature of the data". In other knowledge areas, circular data are commonly grouped into bins from 1° to 10°, which are equally spaced arc sectors of the circle. This data grouping can cause analytical problems, such as inflating type I error rates (i.e. false positive results). The solution to address this problem is to use "tie-breaking" versions of uniformity tests that correct the p-value calculation and must be applied to Rao and Hermans-Rasson tests. However, in no other area, the arc sectors are so spaced as in the case of monthly phenological samplings. The 360° of the circle representing the year is divided by 12, resulting in large 30° sectors. To demonstrate the hazard of dividing the circumference into such widely scattered sectors, we simulated different distributions with different sample sizes (10,000 iterations each) grouped on month. We demonstrate the high type I error risk and corroborate that using tie-breaking versions of tests controls the type I error and yields robust results, allowing researchers to analyze monthly sampled data properly. The second methodological incorporation consists in "investigating the number of phenological peaks". After a significant result from a uniformity test, researchers usually assume non-uniformity and finalize analysis. However, a valuable follow-up procedure consists of testing if distributions are uni- or bimodal using a model selection approach. This reveals the number of phenological peaks and allows

more in-depth biological interpretations. The third methodological incorporation consists of "using a MANOVA approach" (based on sines and cosines) with covariates, allowing the simultaneous testing of uniformity and comparing different distributions. Altogether, using these circular methods in phenology allows the usage of uniformity tests accurately while moving beyond them, expanding the range of statistical inference. This will reduce errors, generate standardization, and increase statistical power and biological meaning.

A NEW LENS ON TROPICAL PHENOLOGY: HOW TIME-LAPSE CANOPY CAMERAS ARE CHANGING THE GAME

Alessandro Mainardi[1]; Claudia Viganò[1]; Urs Kalbitzer[2]; Juan Pablo Uchuari[3]; Diego Pablo Gonzalez(3); Carlos Ivan Espinosa[3]; Andrea Guerrero Jara[3]; Lars Opgenoorth[4]; Katrin Heer[1]

(1) University of Freiburg. (2) University of Konstanz & Max-Planck-Institute of Animal Behavior. (3) Universidad Técnica Particular de Loja. (4) Philipps-Universität Marburg.

Tropical forests are considered among the most biodiverse ecosystems on Earth, playing a crucial role in global carbon cycling. Given the logistical constraints in setting up long-term monitoring in these environments, our understanding of tropical tree phenology and the climatic drivers used as proximate cues to synchronize phenological transitions remains limited. In highly seasonal tropical forests, such as dry forests, phenological events occur in response to precipitation, whereas in rainforests, characterized by low seasonality, trees likely rely on other cues. Identifying these climatic drivers is crucial for understanding how climate change affects forest dynamics and trophic interactions in the tropics. To address this gap, we investigated leaf and flower phenology of four tree species in an Andean cloud forest and one in a coastal lowland dry forest in Southern Ecuador using high-frequency digital repeated photography. Over 30 months, time-lapse images of individual tree canopies were captured every 15 minutes from 6 AM to 6 PM using cameras installed in adjacent trees using tree-climbing techniques. Meteorological data were obtained from a weather station for the cloud forest and satellite sources for the dry forest. Leaf phenology was quantified using Green Chromatic Coordinates (GCCs), extracted from portions of images corresponding to the tree canopies. Flower phenology was assessed daily by visually recording the presence and absence of flowering events and their intensity on a 0-4 scale. We analyzed phenological patterns and identified their climatic drivers using Bayesian Hierarchical Generalized Additive Models (HGAMs). Seasonal trends and peak timing of leaf and flowering phenology were modeled using cyclic splines, and synchrony was assessed by considering the credible intervals of peak timing. HGAM univariate models, with leaf and flower intensity as responses and lagged climate variables as predictors, were employed to identify the climatic drivers of phenology, with the most informative selected through the Leave-One-Out Information Criterion (LOOIC). For the species that occurred in both habitat types, we found that leafing synchrony was higher in the dry forest compared to the cloud forest, suggesting that water constraints lead to shorter and more concentrated phenological activity. Contrarily, flowering synchrony was equally high in both environments, highlighting the selective pressure driving adaptations

that maximize pollination success. Our models suggest that cumulative solar irradiance is the main climatic driver of phenology in the cloud forest, whereas rainfall is most important in the dry forest. These findings enhance our understanding of phenological responses to the ongoing climate change, essential for predicting shifts in plant-animal interactions and planning conservation programs.

Acknowledgement: This research was funded by the Emmy Noether project "Phenology of tropical tree species - environmental cues, molecular mechanisms, and consequences for plant-animal interactions" (HE 7345/9-1) and PROY_INV_BA_2023_3733 of UTPL. In addition, KH, AM and CV were supported by the Eva Mayr-Stihl Foundation.

FLOWERING PHENOLOGY IN MEDITERRANEAN WOODLANDS: COMBINED EFFECTS OF PHYLOGENY, REPRODUCTIVE TRAITS, HABITAT AND ELEVATION IN ANDALUSIAN NATIONAL PARKS (SPAIN)

Carmen Benítez-Benítez[1]; Leonor Patricia Cerdeira Morellato[2]; Montserrat Arista[1]; Juan Arroyo[1]

(1) University of Seville, Department of Plant Biology and Ecology, Faculty of Biology. (2) Universidade Estadual Paulista, Center for Research on Biodiversity Dynamics and Climate Change (CBioClima), Phenology La.

Flowering phenology has been shown to be a critical trait for the functioning of ecosystems, given its importance for persistence of primary producers and its shaping by natural selection. In addition, the strong dependence of flowering on climatic conditions makes it an excellent candidate for monitoring the effects of past, present, and future climate change. Mediterranean-type regions are particularly prone to strong impacts of natural climate changes due to their intermediate position between temperate and tropical regions. Additionally, these transition areas are now also experiencing the effects of human-induced climate change. These environments are characterized by hot, dry summers, while montane regions also display cold winters as another limiting factor. This is the case of Andalusia (southern Spain), where Mediterranean forests and scrublands range from sea level to 3,479 meters. In this study, we examine the varying phenology of woody plants across the three National Parks of Andalusia: (1) Doñana, located in coast and lowlands with sandy soils and marshes, (2) Sierra de las Nieves, in mid elevation mountains, and (3) Sierra Nevada, in high- elevation mountains. Our aim is to determine to what extent flowering phenology is constrained by phylogenetic relationships and how it correlates with other plant traits functionally related to flowering, such as life-form, flower, fruit and seed traits related to pollination and dispersal. We resolved a phylogenomic tree of angiosperm woody taxa of these three local floras, using the angiosperm-353 universal probe set. Our tree includes 535 taxa, which represents 70% of the total woody local flora and 49% of the woody regional flora of Andalusia, being the sample progressively increased. We estimated the phylogenetic signal of several functional traits, focusing particularly on sexual reproduction, and especially on flowering phenology, which is low to moderate in different National Parks. The results from the three parks show that the effect of phenology is strongest in Sierra Nevada, which features the widest elevation range and encompasses a high percentage of the regional flora. In Sierra Nevada, this effect is further reinforced when using local phenological data. This study may serve as a valuable reference for other floras across the Mediterranean Basin and could also be used for comparison with climatically similar regions worldwide.

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CHANGES IN L48 USA SPRING ONSET SINCE 1900

Mark D Schwartz[(1)]; Joshua J. Hatzis[(1)]

(1) University of Wisconsin-Milwaukee.

The seasonal timing, or phenology, of many North American plant species is in flux with accelerating environmental change. The influence of temperature and precipitation on plant growth (as weather patterns change from spring to summer) vary from place-to-place, month-to-month, and for different plants species. By combining gridded daily weather data across the conterminous USA (lower 48 states, L48) with rich ground-based phenological data from the USA National Phenology Network (USA-NPN) we have recently constructed new Spring Development Indices (SDI) to extend our ability to represent spring plant development across a wider range of times during the season. Across the entire L48, species × phenophase models had an average error (MAE) of 8.55 days. These leaf and bloom model outputs for individual species across the spring season were temporally aggregated into four leaf and bloom groups to produce the suite of SDIs. The SDIs ranged from 7.39 to 10.02 days of error, demonstrating that the new indices, in general, perform nearly as well as the individual species models at reflecting the timing of activity in their component species. Unlike the earlier Spring Indices models (SI-x), which were developed using observations of cloned plants, the new models were constructed using observations of wild and planted individuals of natural (not cloned) plants, which inherently exhibit greater genetic diversity than cloned plants. To accommodate this genetic variation, these models were allowed to be spatially dependent, meaning their responses to environmental drivers could vary across space. This paper presents an initial application of these SDIs: exploring changes across the L48 since 1900. As noted by earlier SI-x analyses, southeastern USA trends are the most different from the rest of the L48. Looking at specific time periods, 1901-1930 trends are toward earlier spring onset, especially in the eastern/southeastern USA, and stronger at the beginning of the season. Next, 1931-1980 trends are toward later spring onset, again especially in the eastern/southeastern USA, and stronger at the beginning of the season. Lastly, 1981-2020 trends are toward earlier spring onset, especially in the southern USA, and stronger at the beginning of the season.

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Poster session

FLOWERING PHENOLOGY IN A DRYLAND ECOSYSTEM AS AFFECTED BY CLIMATE

Annessa Foss[1]; Osvaldo Sala[1,2,3]

(1) School of Life Sciences, Arizona State University. (2) Global Drylands Center, Arizona State University. (3) School of Sustainability, Arizona State University.

Plant species worldwide are experiencing temporal shifts in phenology. Dryland ecosystems are uniquely influenced by precipitation rather than temperature as the primary driver of phenology, yet they remain underrepresented in our phenological understanding. At the Jornada Basin LTER site, New Mexico, USA, interannual variability in precipitation is ~47%, highlighting the extreme fluctuations that could potentially drive plant phenological shifts. To determine this, we propose using three complementary approaches: (i) Field experiments with phenocams; (ii) long-term monthly observations; and (iii) short-term snapshot observations. Combining these three approaches creates a robust dataset to study flowering phenology in a novel way. Field experiments, which manipulate precipitation by ±80%, capture a broad range of climate conditions with fine-scale, daily captured images of two dominant species, Bouteloua eriopoda and Prosopis glandulosa. Long-term observational data (since 1992) provides a large number of species (n=53) but is limited by monthly measurements. Short-term snapshot observations offer direct information on 4 species but explore a shorter range of climatic conditions. Our analysis on a monthly scale showed weak relationships between precipitation and flowering day of year (DOY) across both grass and shrub species (e.g., Eragrostis lehmanniana slope= 0.38, R^2= 0.03; Larrea tridentata slope= -0.10, R^2= 0.014). Because surveys occur on fixed calendar dates, the data captures flowering seasonality rather than shifts in timing. This data yielded temporal clusters, with the grasses flowering in the late year (September-November) and shrubs typically flowering earlier (April-June). Analysis of phenocam data revealed that the generalized response, regardless of treatment, of the flowering DOY of P. glandulosa to precipitation is highly significant (p=0.00083). For every additional ~10mm of precipitation, the flowering dates of all the plots advance earlier by ~0.15 days. Regardless of interannual variability in precipitation, however, plots with increased precipitation (+80%) delay their flowering DOY by 2.6 days when compared to the control plots (p=0.29). Plots with drought treatment (-80%) advance their flowering DOY by 1.6 days (p=0.42). We predict similar results for B. eriopoda. Our results indicate that precipitation drives flowering in drylands, differing from temperature-driven phenology in temperate ecosystems. These findings could be extrapolated to fit other ecosystems with high interannual variability in precipitation, such as tropical seasonal forests. Temporal shifts in flowering may have far-reaching ecological impacts, including changes to plant-

pollinator synchrony and vegetative composition. These findings highlight the need for a multifaceted approach, combining snapshot observations, long-term datasets, and fine-scale measurements to enhance our understanding and prediction of phenological responses to climate change.

Acknowledgement: JRN-LTER Graduate Research Fellowship Program (GRFP)

ASSESSMENT OF A SIGNAL PROCESSING APPROACH TO STUDY TREE PHENOLOGICAL PATTERNS AND ESTIMATE BIOLOGICALLY-RELEVANT PARAMETERS IN A SOUTH ASIAN TROPICAL RAINFOREST

Arun Poornima Madhavan(1); Srinivasan Kasinathan(1); Divya Mudappa(1); T. R. Shankar Raman(1)

(1) Nature Conservation Foundation.

Biologists have used different methods to study intra- and inter-annual phenological patterns and estimate relevant parameters such as peak timing and amplitude, and duration of phenophases. Here, we apply and assess a novel analytical approach to phenological data based on signal processing of time series data of phenophase expression (proportion of individuals) and abundance (sum of scores). Phenological observations were made monthly over 8 y in a tropical rainforest in the Anamalai Hills, Western Ghats, India. We focused on a set of 8 tree species (8 families) showing diverse phenological patterns to test the signal processing approach: Vateria indica, Palaquium ellipticum, Macaranga indica, Mesua ferrea, Oreocnide integrifolia, Phyllanthus anamalayanus, Cullenia exarillata, and Gomphandra coriacea. Forty individuals of each species (n = 22 for Critically Endangered P. anamalayanus) were monitored monthly and scored (0-4) for leafing, flowering, unripe and ripe fruits in order to quantify frequency, duration, amplitude, timing of peak, and interval between peaks of different phenophases. We tuned a signal processing algorithm using the function 'findpeaks' from the R package 'pracma' incorporating static and dynamic parameters into the function to detect peaks. Static parameters specified number of time-steps up (1) and down (2) around putative peaks, minimum distance between two peaks (4 months), and handling of plateaus. Dynamic parameters that varied by species and each corresponding time-series included minimum peak height (computed as the minimum of the yearly maxima), and a threshold parameter (proportional difference between a given value from its neighbouring values measured as (max-mean)/(max-min)). The signal processing algorithm successfully detected peaks and helped identify complex phenological signals with high accuracy, including frequency (annual, supra-annual, and sub-annual), timing, and duration for both proportion and score type data. For ripe fruiting patterns across species, the estimated frequency (peaks/year) ranged between 0.3 (once in 3 years) to 1.7 (twice a year), duration ranged between 1.4 (± 1.8 SE) to 11.4 (± 1 SE) months, and peak amplitude (proportion) ranged from 0.3 (± 0.1) to 0.57 (± 0.2). Fruiting peaks occurred between May and July for four species, October-November for three species, and February for one species. Time interval between flower opening and fruit initiation ranged from 1-2 months for four species, 3-5 months for two species,

and 7-9 months for two species. We detected potential limitations and inaccuracies in the signal processing approach for two species with continuous or irregular patterns. The signal processing approach is a promising addition to the toolbox of biologists studying phenology to parse time series data to identify significant events from residual activity. As a highly scalable method, it offers a new lens to examine and analyse phenology data.

Acknowledgement: We thank the Tamil Nadu Forest Department for cooperation and permits. We are grateful to Shri AMM Murugappa Chettiar Research Centre, Rohini Nilekani Philanthropies, Cholamandalam Investment and Finance Co. Ltd, Fondation Franklinia, and Rainmatter Foundation for funding and support through the years.

Poster Session

PHENOBASE: AN OPEN-ACCESS, INTEGRATED DATABASE OF GLOBAL PLANT PHENOLOGY

Ellen G Denny[1,2]; And The Phenobase Team[2,3,4,5,6,7]

(1) USA National Phenology Network. (2) University of Arizona. (3) University of Florida. (4) Florida International University. (5) iNaturalist. (6) Berkeley National History Museum. (7) Chicago Botanic Garden.

Plant phenology stands at the forefront of our understanding of how accelerating environmental changes--including climate and land-use transformations--are reshaping the biosphere. In response to this critical need, recent expansions in in situ monitoring networks, community-driven biodiversity imaging platforms, and historical specimen digitization projects have generated unprecedented volumes of phenologically-relevant data. Despite this wealth of information, pressing scientific questions about phenology remain difficult to address due to significant challengesin extracting phenology data from different resources and integrating data across them. Building upon our foundational work with the Plant Phenology Ontology (PPO), we have developed Phenobase, an open-access, integrated knowledge base of global plant phenological data, including insights generated from community science and herbarium images. In this poster, we present the progress and upcoming plans of the Phenobase project.

PHENOBS 2.0 - EXTENDING A PHENOLOGICAL OBSERVATION NETWORK IN BOTANICAL GARDENS TO THE TROPICS

Robert Rauschkolb[1,2,3]; Christine Römermann[1,2,3]

(1) Institute of Ecology and Evolution with Herbarium Haussknecht and Botanical Garden, Friedrich-Schiller-University, Jena, Germany. (2) German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Leipzig, Germany. (3) Senckenberg Institute for Plant Form and Function Jena, Jena, Germany.

Climate-driven shifts in phenology are affecting biodiversity and ecosystem services in fundamental ways. However, there are still substantial gaps in our understanding, particularly for predicting how herbaceous plants, which represent much of plant biodiversity, will respond to abiotic and biotic factors and acquiring a synthetic understanding of the consequences of phenological changes for biotic interactions and ecosystem functions. PhenObs, a network of Botanical Gardens (www.idiv.de/en/phenobs.html) established in 2017, is filling these knowledge gaps by distributed observations of phenology, plant traits and environmental conditions on a large set of herbaceous wildflower species. For this purpose, we developed and implemented a monitoring protocol for year-round phenological observations of perennial herbaceous species in botanical gardens. Today, PhenObs is an active international network from 20 Botanical Gardens and 13 countries that contribute in diverse ways to phenological research. Even though tropical regions cover the largest part of biodiversity, most of the work on phenology has been done in temperate regions (temperate phenological paradigm). Therefore, in the coming years, we want to facilitate the extension of this network to non-temperate regions of the Northern Hemisphere. Since we assume that the PhenObs monitoring protocol cannot be easily applied to the phenology of tropical herbaceous species, we want to test and further develop the applicability of the protocol together with local scientists. We aim to facilitate this process through online symposiums and a set of workshops at iDiv (Germany) with a dedicated group of scientists from living collections (e.g. botanical gardens) located in tropical climates. One research focus of PhenObs is to explain phenological patterns in perennial herbaceous species functionally with the traits. With this approach, we are convinced that the extension of the project presented here will enable global analyses.

Acknowledgement: We would like to thank all members and partners of the PhenObs network. We acknowledge funding from the German Science Foundation (DFG) via the German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig.

Keynote

TREE SEASONALITY AND CITIZEN SCIENCE - MAKING PHENOLOGY MAINSTREAM

Geetha Ramaswami[(1)]

(1) Nature Conservation Foundation.

The knowledge of plant phenology is intimately linked to food availability for humans - it is not surprising therefore that the study of plant life-cycles has always been a part of human life. Some of the oldest and longest written records of phenology in the world are on culturally important trees, long before systematic observation of seasonality became an entire branch of inquiry in ecological sciences. In today's world, this kind of record-keeping would be termed 'citizen science' - the practice of scientific research by non-professionals. As climate change rears its very visible head across the world, large-scale and long-term phenology data can be especially valuable in adapting to these environmental changes; and citizen science places this opportunity in the hands of anyone who wants to be part of the knowledge-generating process. Citizen science data from temperate regions has already provided extremely valuable insights on changing climate through advancing or altered phenology. In tropical regions, diverse phenological strategies often make it difficult to understand climate impacts on trees. Here too, citizen science has helped create a robust picture of contemporary phenological changes. In this talk, I will present an overview of how citizen science has been used to understand tree phenology across the world, and how one project in India - SeasonWatch - leverages valuable cultural knowledge on tree phenology to quantify contemporary changes in relation to the environment.

Session 2

Phenology Networks from North and South: Towards a Global Phenology Science

Oral Session

PHENOCHANGE: TOWARDS A DRY TROPICS GLOBAL PHENOLOGICAL MONITORING NETWORK

Desirée Marques Ramos[1,2]; Kyle Dexter[3]; Patrícia Morellato[1]; Phenochange Team[1]

(1) Center for Research on Biodiversity Dynamics and Climate Change (CBioClima), IB, Department of Biodiversity and Phenology Lab, São Paulo State University (UNESP), Rio Claro, Brazil. (2) Instituto Tecnológico Vale, Belém, Pará, Brazil. (3) Department of Life Sciences and Systems Biology, Università Di Torino.

PhenoChange launched the first trans-continental network to monitor plant phenology of the dry tropics. Currently, controls on the timing of leaf display and the associated fluxes of energy and matter are a major uncertainty in earth system modelling, particularly for the dry tropics, limiting projections of vegetation responses to climate change. Tropical dry biomes, which cover 18% of the global landmass, are critical to climate-vegetation feedbacks but are still understudied. Approximately 80% of the dry tropics are located in South America and Africa, where these biomes occur in similar climatic spaces across both continents. However, despite the climatic and physiognomic similarities, the vegetation in these biomes has distinct evolutionary origins on each continent. Dry tropical ecosystems are structurally characterized by a combination of a canopy layer dominated by trees and a ground layer consisting mainly of grasses (in savannas and woodlands) or shrubs (in dry forests, shrublands, and thickets). The timing and intensity of leaf flushing, and how these patterns vary across different ecosystem components (e.g. trees versus grasses) determine fluxes of mass and energy, in particular controlling the acquisition phase of the carbon cycle. The IPCC Report 6 - WGII highlights the relevance of phenology and the persistent lack of information from tropical regions. Likewise, the UNEP Frontiers 2022 report describes phenology mismatches as a frontline research topic. A critical barrier to progress has been the lack of coordinated and geographically representative phenology data. PhenoChange addresses this gap by leveraging near-surface remote sensing-specifically, time-series imagery from digital cameras (phenocameras)-to deliver standardized, cross-continental observations of phenological patterns in tropical dry vegetation. The network includes savanna and dry forest sites in Brazil (across four states) and in four African countries, covering a gradient of rainfall seasonality and pairing similar climates across continents. Our aim is to test whether vegetation in similar climatic spaces on different continents exhibits convergent or divergent phenological patterns. We hypothesize that water availability is a stronger driver of phenological responses than the taxonomically distinct tree communities. Here, we present findings on leaf phenology in both ground and canopy layers of savannas and dry forests, observed over two growing seasons across both continents.

Acknowledgement: São Paulo Research Foundation-FAPESP (grant #2022/02323-0) and Natural Environment Research Council-NERC (grants NE/T01279X/1 and NE/X002993/1).

PHENOLOGICAL PATTERNS OF WOODY AND GROUND COVER CAATINGA SPECIES

Italo Antonio Cotta Coutinho(1); Antonia Mirelle Lopes Marques(1); Desireé Marques Ramos(2); Leonor Patricia Cerdeira Morellato(2)

(1) Universidade Federal do Ceará. (2) Universidade Estadual Paulista (UNESP) - "Júlio Mesquita Filho".

The Caatinga is a seasonally dry ecosystem, composed of woody trees and a shrub-herbaceous stratum (e.g., groundcovers) that faces severe water stress during dry season. These species present adaptive strategies as a quick leaf shedding, which can be regulated by several factors, such as water availability and photoperiod. However, studies related to these phenological patterns are poorly understood, especially for the groundcovers. This study aimed to understand the leaf shedding dynamics and the environmental triggers in a caatinga phytophysiognomy, the Carrasco, at Serra das Almas Natural Reserve by using six phenocameras which allowed the monitoring of the green chromatic index (Gcc) over time. Three of phenocams captured images of the woody canopy while the other three targeted the groundcover vegetation. Our results indicates that the seasonally dry tropical forest Brazil use to synchronize leaf flushing of woody species a few days after the first rainfall events as leaf flushing occurred in January 2024, shortly after the first rains, on day 10/2024. On the other hand, groundcovers began their growth approximately 90 days later, on day 100/2024. The Gcc values for groundcovers showed greater variability, reflecting a close association with annual precipitation patterns. Woody species demonstrate rapid regrowth and maintain greater leaf stability during the rainy season, while herbaceous plants depend on more constant rainfall to sustain their development. These phenological patterns, strongly influenced by water availability, evidence specific adaptations of each stratum to water stress. In the face of climate change and changes in rainfall patterns, understanding these dynamics is essential to support conservation, management and mitigation strategies for environmental impacts in the Caatinga.

Acknowledgement: FAPESP 2021/10639-5, PhenoChange Project, SECO Project, PPGSis, CAPES/CNPq

LEAF PHENOLOGY ACROSS SOUTHERN AFRICAN WOODLANDS, A PERSPECTIVE FROM BICUAR NATIONAL PARK, SW ANGOLA

Francisco Maiato[(1)]; Desiree Ramos[(2)]; John Godlee[(3)]; Manuel Cachissapa[(4)]; Patricia Morellato[(5)]; Kyle Dexter[(6)]

(1) Francisco Maiato. (2) Desiree Ramos. (3) John Godlee. (4) Manuel Cachissapa. (5) Patricia Morellato. (6) Kyle Dexter.

Woodlands, characterized by a sparse tree canopy over a grassy understory, span a vast region across the African continent, exhibiting distinct tree species compositions. Patterns in phenology, i.e., the flushing and senescence of leaves, can vary across climatic gradients, between trees and grasses and among different tree species, with important consequences for ecosystem functions like forage provision. Bicuar National Park in Angola represents a dry Miombo woodland (864 mm mean annual precipitation), with the vegetation displaying a pronounced seasonal leafing pattern. In this study we examined the differences in leaf flushing and fall between grasses and trees, and whether ecosystem-level leafing patterns are influenced by tree species composition. Five 1-ha vegetation survey plots were selected, each with distinct floristic compositions dominated by: 1) Combretum spp. (Plot 2); 2) Julbernardia paniculata and Brachystegia (Plot 5); 3) Baikiaea plurijuga and Baphia massaiensis (Plot 9); and 4) Burkea africana; J. paniculata (Plot 10) and 5) Brachystegia spiciformis and Baikieae plurijuga (Plot 12). Cameras were used to monitor leaf phenology, capturing one leaf fall and one leaf flushing event, from 2022 to 2023, and one entire growing season from 2023 to 2024. Time series of vegetation greenness (quantified by the green chromatic coordinate (Gcc) index) was used to calculate phenological metrics, the start and end of the growing season (SOS and EOS). The SOS for grasses and trees was similar and did not vary across plots. However, trees retained their leaves for a more extended period (i.e., later EOS), particularly in plots dominated by B. plurijuga and B. africana, in comparison to those dominated by Combretum and Brachystegia spp. These differences likely stem from the distinct characteristics of B. africana and B. plurijuga, both tall trees that likely have deep roots which can access groundwater.

PHENOLOGICAL PATTERNS IN NAMIBIA'S WOODLANDS: FROM SATELLITE DATA TO GROUND-BASED OBSERVATIONS

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The southern margin of the forest biome in southern Africa transitions into arid and semi-arid open woodlands, dominated by legume tree species. In these systems, rainfall is highly variable across space and time, complicating the assessment of climate change impacts on phenology. This study addresses two key objectives: (1) to assess long-term relationships between precipitation and growing season dynamics across Namibia's woodland biome using satellite data, and (2) to investigate fine-scale phenological responses using in-situ observations in Namibia's mopane woodlands.For the regional-scale analysis, we used four decades of daily CHIRPS precipitation data and 26 years of daily NDVI data from the AVHRR satellite archive. Results indicate a brief rainy season averaging 66 days, but no correlation between the timing of the rainy season and the start and end of the growing season. The growing season extends for approximately 338 days, typically beginning between October and January and ending between October and December of the following year. While the satellite data suggested a potential lengthening of the rainy season, no consistent trends for the start and end of the growing season were detected. To complement the coarse-resolution satellite data, we installed a network of phenocameras in 2023 across four vegetation plots in a mopane woodland savanna within a private game reserve in northern Namibia. Preliminary results from the first season reveal substantial variation in canopy phenology among plots. Notably, a lowland plot with deeper soils dominated by Colophospermum mopane exhibited a distinct pre-rain green-up compared to the other sites. Continued phenocam monitoring, coupled with potential network expansion, will enhance our understanding of how rainfall timing and magnitude influence species-specific phenological responses in dry woodland ecosystems.

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LONG-TERM ECOLOGICAL RESEARCH IN BRAZILIAN DRY ECOSYSTEMS: LINKING PLANT PHENOLOGY AND FUNCTIONAL TRAITS ACROSS SCALES

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The dry tropics are an important and highly variable component of carbon sequestration, but the lack of information in these regions limits the development of robust global models, which require data on functional traits such as leaf carbon content and wood density, as well as their seasonal variations (phenology). We aim to explore the importance of phenological and plant functional trait studies (and their integration) for monitoring the functioning of terrestrial ecosystems across different temporal scales (seasonal patterns, natural regeneration, and climate change) and spatial scales (in the Cerrado and Caatinga biomes and in dry ecosystems globally). For this purpose, two interconnected initiatives focused on the global South are underway: SECO and PhenoChange. In the first, a global network of 646 permanent plots in 88 areas of the dry tropics is determining vegetation structure and dynamics, species composition, soil characteristics, carbon stocks and plant functional traits (e.g., leaf specific area, leaf nutrient content, wood density). In 26 of these plots (16 in Brazil and 10 in Africa), 94 digital trap cameras are taking photos of the canopy and understory in a time-lapse mode (phenocameras) using a standardized protocol. These photos are continuously processed to extract the color indices from the regions of interest (ROIs) to calculate different phenological metrics, such as SOS (Start of the Season), EOS (End of the Season), and LOS (Length of the Season) at the community level and for the most representative tree species in the plots (i.e., summing at least 80% of the plot's basal area). This large dataset is currently being used to address several questions, from local scales (e.g., the relationship between functional traits and phenological variables) to global scales (comparisons between dry ecosystems in Brazil and Africa), and also to improve global carbon cycle models through international collaborative research networks.

Acknowledgement: FAPEMIG, FAPESP, CNPq, NERC-UK

PHENOCAM PROJECT IN HAUT-KATANGA: PHENOLOGICAL MONITORING OF TREE SPECIES FOR SUSTAINABLE MANAGEMENT OF THE KATANGA'S MIOMBO FOREST IN THE DEMOCRATIC REPUBLIC OF CONGO

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For several decades now, the Katanga region has been experiencing remarkable climatic disturbances: low rainfall compared with the annual average on the one hand, and rising temperatures on the other. The INERA station recorded barely 540 mm of rainfall for the rainy season last year. Suddenly, everything seems to be returning to normal this year. This phenomenon affects both agrarian and forest ecosystems at the same time. At a functional level, pollinating insects may either disappear or undergo a profound change in their biological cycles. This can cause a shift in the mobilization of resources at a particular time of year to ensure the pollination of plants in the forest. Studies have also shown that climate change, as experienced in our region, can delay or shorten the flowering/fruiting and leafing periods of miombo plants. Species unsuitability can be revealed by: (i) phenological disruption (foliage, flowering); (ii) reduced diaspore production; (ii) increased mortality rate of the unfit species, etc. The Phenocam project (a research project) studies the leaf phenology of the miombo forest to predict the future behavior of tree species in the face of climate change. More specifically, we would like to focus on three species, namely Brachystegia spiciformis, Julbernardia paniculata and Marquesia macroura. The study also aims to quantify the phenological behavior of these three flagship species in the face of the effects of CC. For many years, phenological monitoring has been based on direct observations. However, this approach has many shortcomings and is unable to capture the essential information required. This is why the PhenoCam project has become an asset for improving the approach to phenological monitoring of Miombo tree species. The study site is in the Mikembo reserve, at 35 km in the northeast of Lubumbashi town (Haut-Katanga province, Democratic Republic of the Congo, Africa). The Phenocams were installed in the Mikembo reserve.Some masks were created, after choosing the good region of interest showing the Miombo community in the Mikembo reserve. Below are some images showing masks of the six (6) cameras. After getting "the masks", we generated extractions indices (meanR; meanG; meanB; relR; relG; relB; excG; mean H) in CSV files for the six cameras, two in the canopy direction and two in the ground direction.Processing the data collected with the PhenoCam cameras will therefore enable us to understand the behavior of species based on their potential for combating the effects of CC and thus predict what will happen in the future. In this work, we will present the first analysis structure of the dataset already collected from the miombo forest of Haut-Katanga.

SWEDISH PHENOLOGY FOR SHORT-TERM FORECASTS AND LONG-TERM SCENARIOS OF CLIMATE CHANGE EFFECTS

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Detailed forest phenology data from the Swedish National Phenology Network has been used to produce forecast models of a) budburst of the most common tree species, b) the development of the most important wild berries and c) for the development of Eurasian spruce bark beetle (Ips typographus Linnaeus, 1758). Forecast models for the onset, maximum appearance and ending of budburst and leaf/shoot elongation of the most common tree species in Sweden; Silver birch (Betula pendula Roth), Downy birch (B. pubescens Ehrh.), Norway spruce (Picea abies [L.] H. Karst.) and Scots pine (Pinus sylvestris L.), are available to the public. Furthermore, models for the onset, maximum appearance and ending of flowering and ripening of the most common wild berries in Sweden; Cowberry (Vaccinium vitis-idaea L.) and Bilberry (V. myrtillus L.), and a model for the timing of the swarming of the spruce bark beetle for the mother generation and, more interestingly, for the coming generations during the same season, are also available.The forecasts are based on weekly assessments of bud and shoot lengths on trees, of flower and berry counting on berry shrubs, and of spruce bark beetle catchments at four Experimental Forests in Sweden, from 2006 and forward. Daily air temperature data from the same sites are used to produce critical accumulated temperatures for when target phenological phases appear. Based on the current year's weather data and long-term averages, they are used to produce forecasts predicting the timing of e.g. budburst, berry ripening and swarming of first generation offspring that may establish a second generation of beetles. The forecasts are specific for the current season and updated daily. As an example, the berry forecast model correctly predicted a 14 day earlier ripening of bilberries during 2024 than usual, as the spring and early summer weather was unusually warm. The forecast model for spruce bark beetle also revealed that the beetle may have produced two generations in one season during the extremely hot 2018, when it normally only produces one generation per season on those latitudes (55-69°N).The beetle forecast is used by the Swedish Forest Agency and forest companies, to plan for activities reducing the effects of insect outbreaks. The budbust forecast are used e.g. for planning aerial photo and laser scanning sessions, where the outcome and interpretation will be different, depending on if leafs are out or not. The berry forecasts are used by the public, to plan their berry picking. The models have also been applied on scenario data, to reveal the long-term effect of climate change in the Swedish forests. The scenarios predict that

broadleaf trees will have on average a 14-28 days earlier start of the season in the period 2076-2100, compared to the reference period 1971-2000. Northern Sweden and local continental areas are expected to experience the least change, compared to southern Sweden and, especially, the maritime west coast area.

Acknowledgement: The Swedish National Phenology Network is hosted by the Swedish University of Agricultural Sciences, which has funded this through its program for Environmental Monitoring and Assessment. The monitoring program of spruce bark beetle is hosted by the Department of Ecology's Forest entomology unit. The field assessments are performed at the University's Experimental Forests. We like to thank professor Martin Schroeder, who analysed and developed the models for critical accumulated temperatures for swarming of spruce bark beetles, and Mats Jonsell, who is coordinating the monitoring program for the beetles. We are also grateful for the long-term commitment in the field that all the staff at the Experimental Forests have put into the phenology assessments for the past 20 years.

Poster Session

LEAF PHENOLOGY IN CARRASCO VEGETATION, A CAATINGA PHYSIOGNOMY: NEW PERSPECTIVES FROM THE USE OF PHENOCAMERAS

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The Caatinga biome, the largest Seasonally Dry Tropical Forest (SDTF) in the Americas, is characterized by strong climatic seasonality, with long dry periods and irregular rainfall. Present in this biome, the Carrasco physiognomy stands out for its dense shrub-tree vegetation and predominance of deciduous species adapted to prolonged water scarcity. Despite its ecological importance, the leaf phenology of Carrasco tree species remains poorly understood, especially under continuous monitoring. This study aims to investigate the leaf phenology of tree species typical of the Carrasco and their response to climate variation. The research was conducted at the Serra das Almas Natural Reserve (RNSA), in the state of Ceará, Brazil. A digital camera (phenocamera) was installed at the top of a tower to monitor the canopy between 2023 and 2024. Using near-surface remote sensing techniques, we extracted the green chromatic coordinate (Gcc) index from daily images to track changes in leaf cover. These data allowed us to determine key phenological events: Start of Season (SOS), End of Season (EOS), and Length of Season (LOS). Daily precipitation data were also collected and analyzed alongside phenological signals. The results from the 2023-2024 cycle show that leaf flushing began shortly after the onset of the rainy season, with a sharp increase in Gcc values following the first significant rainfall events. The green peak, indicated by the increase in Gcc, occurred around the beginning of 2024 (DOY ~ 30), suggesting synchronized flushing among dominant species. After the decline in rainfall, a gradual decrease in Gcc values was observed, indicating leaf senescence and shedding. The average leaf season lasted approximately 150-160 days, suggesting strong seasonal control over leaf dynamics. These results indicate that Carrasco species clearly respond to rainfall start and end, which acts as the primary trigger for leaf flushing and fall, respectively. The use of phenocameras, combined with meteorological data, proves to be a robust and high-temporal resolution data for monitoring phenology in dry tropical forests. The data contributes to a better understanding of the ecological strategies of Carrasco vegetation in the face of

climatic variability and provides insights for evaluating potential impacts of climate change on leaf dynamics and ecosystems functioning in semi-arid regions.

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THE USA NATIONAL PHENOLOGY NETWORK'S RECENT GROWTH AND ADVANCEMENTS

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Since its establishment in 2007, the USA National Phenology Network (USA-NPN) has become a premiere source of plant and animal phenology data and information in the U.S. The USA-NPN offers robust capacity to collect, store, and share in situ phenology observations and support decision making in a growing array of applications. In addition, the network fosters an increased understanding of plant and animal response to rapidly changing climate conditions among students of all ages and the public. In recent years, the USA-NPN team has made notable changes and improvements to the infrastructure and resources available to support data contributors and users. Enhancements include an entirely retooled website, with expanded capacity for both data contributors and data users; new resources to assist observers in making accurate observations; and the addition of a suite of short-term forecasts of models indicating the progression of springtime plant activity. New efforts include a major overhaul of our mobile app to lower barriers to entry for new and continuing observers, and a collaboration with AI researchers to better understand the phenology data contributed to date to Nature's Notebook and how we might direct future data collection for maximum insight and impact.

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Keynote

BRIDGING PHENOLOGY FROM TREE INDIVIDUALS TO REGIONAL SCALES

Jin Wu[1]; Guangqin Song[1]; Yingyi Zhao[1]; Jing Wang[2]; Yating Gu[3]; Xiang Zeng[1]

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Plant phenology serves as a vital fingerprint of climate change and a key regulator of ecosystem functions-from photosynthetic carbon uptake to ecosystem resilience to climate change. Yet, a critical gap persists in scaling phenological observations from individual tree individuals to ecosystems and beyond, hindering our ability to predict ecological responses to global change. Remote sensing offers a transformative solution, but its potential has been limited by conventional spatial and temporal resolution trade-offs. Recent advances in high-resolution satellite constellations (e.g., PlanetScope), coupled with innovative data integration techniques, now enable unprecedented cross-scale phenology monitoring.Here we present how cutting-edge remote sensing bridges scale-dependent phenological insights through two pioneering case studies. In temperate forests, we integrate multi-scale satellite data (3-m PlanetScope to 500-m MODIS) with near-surface phenocams to reveal how fine-scale phenological variability-driven by functional traits and microclimate-shapes ecosystem stability. By incorporating solar radiation as a key constraint, we enhance spring phenology (i.e., start of growing season) predictions by 22%, advancing mechanistic models and their linkages to regional carbon cycling. In tropical rainforests, spectral unmixing of PlanetScope data reveals cryptic deciduousness at individual tree-crown scales, challenging the long-held "static evergreen" paradigm. This hidden seasonality, mediated by hydroclimate and nutrient availability, resolves 20% of uncertainties in Amazon carbon flux simulations. Collectively, this research pioneers a framework for scalable, observation-driven phenology by linking fine-scale diversity to global processes. It underscores the urgency of merging multi-scale remote sensing with ecological theory to refine predictions of climate change impacts-a vital step toward safeguarding biodiversity and planetary health.

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Session 3

Remote Phenology: from near-surface to orbital sensors and modeling integration

Oral Session

DELAYED BROWN-DOWN RESPONSE TO SEVERE DROUGHT IN A CENTRAL AMAZON FOREST

Bruce Walker Nelson(1); Adriana Simonetti(1); Aline Lopes(2); Leonardo Ziccardi(3); Natalia Restrepo-coupe(4,5); Ricardo Dalagnol da Silva(6); Shuli Chen(4); Scott Saleska(4); Nathan Borges Gonçalves(3)

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At the Central Amazon Tall Tower site (ATTO; -59.00 lon, -2.14 lat), a severe drought in 2015-16 led to delayed upland forest brown-down, seen as progressive post-drought decreases in the Landsat 8 near-infrared (NIR) reflectance and the Enhanced Vegetation Index (EVI). Changes reported here use difference images (delta-NIR, delta-EVI), as "treatment minus control". The three treatment images had different post-peak-drought ages in 2016: zero, five and seven months. Zero corresponds to peak-drought, i.e., lowest Cumulative Water Deficit (CWD) of 2015-16. Drought ended in March of 2016 when CWD zeroed out. The three control images were chosen from normal-climate years, with < 5 d separation in Day of Year (DOY) from their paired treatment image. Matching DOY across years when preparing difference images minimizes artifacts in pixel brightness caused by topography or by view and illumination geometry. Sampled region avoided unmasked cloud shadows, cloud adjacency effects and had small N-S and E-W ranges. At peak drought (post-drought age zero) the forest had slightly higher NIR and EVI relative to the normal climate image (mean delta-NIR = 0.0027, CI95: 0.0023-0.0030, n= 4950 non-contiguous pixels; mean delta-EVI = 0.0068, CI95: 0.0063-0.0073). By June of 2016 (post-peak drought age of five months), well-drained oxisol plateau forests showed brown-down, while slope forests retained normal greenness. By August of 2016 (post-drought age of seven months), plateau and slope forests were both in the brown-down state relative to control image. Plateau forest pixels in August 2016 showed mean decrease in NIR reflectance of -0.028 and EVI mean drop of -0.04 units. The NIR anomaly was about 10% of normal plateau forest NIR reflectance, suggesting moderate leaf loss and bare branch exposure at seven months post-peak drought. We speculate that partial embolism of upper canopy branches during the drought led to a reduced crop of new leaves during the following June to September, when leaf turnover is most intense. By 20 months after peak drought (Aug 2017), NIR and EVI had returned to normal at ATTO. For the peak drought image (Jan 2016) and its respective control it was necessary to relax aerosol masking to obtain data. There was more haze in the

control image, so we examined haze effect on our January delta-NIR and delta-EVI images, using the delta-ultra-blue surface reflectance as a proxy for difference in remnant haze. Delta-ultra-blue had no influence on delta-NIR ($p = 0.7$), but did contribute to the uncorrected delta-EVI of 0.0068 ($p < 0.001$). Removal of the remnant haze effect gave a mean delta-EVI of 0.0041. This left a small green-up signal at peak drought, consistent with delayed (not simply prolonged) post-drought brown-down in the ATTO region. These results differ from a report using MODIS-MAIAC for upland forest at Santarém region, where EVI brown-down was initially synchronized to drought and followed by longer recovery (~3 y).

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LONG-TERM PHENOLOGICAL RESPONSES ARE DRIVEN BY CLIMATIC VARIABILITY AND DROUGHT EVENTS IN SEASONAL TROPICAL FORESTS

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Climate change has intensified the frequency of extreme weather events, particularly droughts, inducing shifts in ecosystem dynamics by constraining water availability. In tropical ecosystems, where seasonal drought is an inherent climatic feature, leaf phenology can be highly responsive to increased dryness. However, the extent to which interannual climate variability influences these vegetation responses remains unclear, especially in seasonally dry tropical forests (SDTFs). In this study, we assessed the occurrence of El Niño and La Niña events and drought severity using the Standardized Precipitation Evapotranspiration Index (SPEI) across sites in the Caatinga (CAAT) and Cerrado (CORE and PEG). We also analyzed long-term phenological time series from satellite (2000-2023) and phenocameras (> 10 years) to investigate shifts in leaf phenology in response to interannual climate variability and drought events. Our results reveal that all sites experienced moderate to exceptional droughts, with extreme events coinciding with significant vegetation anomalies detected by Enhanced Vegetation Index (EVI) and Green Chromatic Coordinate (GCC). In addition, a decreasing rainfall trend has been observed in the Cerrado, along with rising air temperatures over the years in both biomes. Severe drought years, often linked to El Niño, were associated with declines in EVI, indicating an impact on vegetation which resulting in an abrupt senescence. Additionally, we found that the start of the growing season (SOS) was significantly influenced by interannual climate drivers, with rainfall and humidity promoting earlier leaf flushing in the Caatinga. At the same time, higher temperatures seem to interact with the delayed trend in SOS, particularly in the Cerrado. These findings highlight the contrasting climatic controls on phenology in these ecosystems and reinforce the role of climate variability and weather extremes in shaping leafing patterns.

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VEGETATION COMPOSITION AND COVER DRIVE LAND SURFACE PHENOLOGY IN DRYLANDS: INSIGHTS FROM NEAR-SURFACE AND SATELLITE DATA IN THE SOUTHERN HEMISPHERE

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Understanding leaf phenology is essential to climate research and sustainable land management, as it links vegetation dynamics to carbon and water fluxes, biodiversity, and resilience. However, accurately detecting land surface phenology (LSP) in drylands using remote sensing remains a significant challenge due to their spatial and temporal heterogeneity, sparse vegetation cover, and complex spectral signals. These difficulties are particularly pronounced in the Southern Hemisphere, where LSP dynamics across local and regional scales remain poorly understood. Integrating diverse remote sensing data, including orbital and near-surface sensors, is crucial to overcome these limitations and enhance LSP monitoring. This study combined phenocam observations with satellite data from Sentinel-2/MSI, Landsat-8/OLI, Terra&Aqua/MODIS, and Himawari-9/AHI to analyze LSP in three representative dryland ecosystems in Brazil and Australia. Our objectives were to (1) evaluate the influence of spatial and temporal resolution on LSP detection; (2) examine the role of vegetation composition and fractional cover in shaping LSP signals; (3) disentangle phenological responses of grasses and trees in heterogeneous vegetation landscapes and identify the key drivers shaping landscape-level LSP dynamics. (1) Our findings demonstrated that spatial and temporal resolution significantly influenced LSP detection. As sensor temporal resolution increases, even with coarser spatial resolution, the strength of the relationship between satellite and phenocam data generally improves. For instance, coefficients of determination (r2) values rose from 0.65 for Sentinel-2/MSI to 0.75 for Himawari-9/AHI. This trend suggests that coarser-spatial resolution sensors could be more effective at capturing landscape-level phenological trends, likely due to a more stable and generalizable signal. However, this comes at the expense of losing sensitivity to detect fine-scale variations, which higher-spatial resolution sensors like MSI are capable of capturing. (2) We also found marked variability in LSP detectability across vegetation types: dry forests dominated-landscape yielded the strongest correlations (r^2=0.65-0.75), followed by savannas (r^2=0.41-0.64), and shrublands (r^2=0.14-0.29). LSP relationships were strongest in satellite pixels with higher vegetation cover, highlighting the critical influence of

vegetation composition and cover on LSP signal strength. (3) Finally, grasses and trees exhibited distinct contributions to landscape-level LSP signals. Despite occupying less than 30% of the satellite pixel footprint, grass phenology showed stronger correlations with satellite data (r^2=0.81) than trees (r^2=0.63), indicating that herbaceous layers played a dominant role in shaping landscape-scale phenological signals in drylands. Altogether, these findings improve our understanding of LSP variability in heterogeneous drylands and underscore the importance of integrating sensors across scales.

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LINKING LEAF CANOPY PHENOLOGY AND LEAF TRAITS TO HERBIVORY IN A CENTRAL AMAZONIAN FOREST USING DIGITAL CAMERAS

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Tropical tree species face high herbivory pressure, especially during the wet season when herbivores' abundance is higher compared to dry season. As a result, species may exhibit distinct leaf phenology strategies and leaf anti-herbivory traits due to varying risk and vulnerability. Here, we aimed to investigate the interplay between the timing of canopy leaf flushing and leaf-antiherbivory traits in an evergreen Central upland Amazon. We used tower-mounted RGB digital cameras (phenocams) to monitor leaf flushing from 60 individual crowns. We used daily images to calculate the Green chromatic coordinate (Gcc) of individual tree crowns, and the onset of leaf flushing was estimated using derivatives from the Generalized Additive Mixed Model (GAMM) to detect whether species initiate leaf flushing during the dry or wet season. Furthermore, we applied ANOVA to assess whether the onset of leaf flushing was associated with morphological leaf traits, including specific leaf area (SLA), leaf toughness, and leaf thickness. Preliminary results reveal a seasonal leaf flushing, with most species starting leaf flushing during the dry season compared to the wet season ($x^2 = 7.81$, df=1, p= <0.05), despite low interspecific synchrony. Contrary to our expectations, trees that flushed in the dry season tended to exhibit high SLA, as well as tougher and thicker leaves, although differences in leaf traits were not statistically significant. This pattern suggests that variation in leaf phenology and leaf traits may not be solely related to herbivory, but may also reflect adaptive strategies to cope with drought conditions. Further analyses will include additional leaf traits to better evaluate this variation. These preliminary results highlight the complexity of leaf phenology and leaf traits relationship in tropical forest and suggest the potential influence of multiple selective factors influencing plant's strategies.

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MONITORING LEAF PHENOLOGY AND STEM GROWTH DYNAMICS IN CENTRAL AFRICAN TROPICAL FORESTS USING PHENOCAMS AND ELECTRONIC DENDROMETERS

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The functioning of Central African tropical forests is significantly influenced by seasonal drought, yet canopy deciduousness remains poorly documented. Leaf phenology is especially under-studied, as most surveys focus on fruit availability for megafauna or timber species maturity, with infrequent field observations that are not suited to detect brief leaf processes (flush, loss, color changes). Documenting leaf phenology is crucial for understanding forest dynamics, tree responses to seasonal drought, and future climate change impacts. This study examines leaf phenological diversity at the individual tree crown level, focusing on three species with distinct patterns, using Phenocams in Lopé National Park, Gabon. A total of 4,221 images from two Phenocams (2019-2023) were processed. The daily phenology of 6 Ceiba pentandra, 38 Lophira alata, and 9 Aucoumea klaineana were analyzed. Tree crowns were manually segmented on a reference image for each phenocam and field of view. All images were aligned to reference images using the AKAZE-ECC method, which combines keypoint detection with an image correlation algorithm to match each image to a reference. In the field, each tree was identified to species, tagged and geolocated. We annotated the percentage of leaves for each crown of the three species in every image using custom software, which integrates raster data, tree identity, and species information to allow precise, crown-level annotation, with leaf cover categorized into five classes (0, 25, 50, 75, 100) reflecting field observation scales (Tutin et al., 1991). Three metrics GCC, RCC, and Hellinger distance were computed per pixel and averaged at the crown level. Leaf loss events were identified using peak and minima detection, with species-specific parameters optimized through thresholding and percentage-based criteria. Predictions were validated using manual annotations, and the optimal parameter configurations were selected based on the F1-score. A total of 27, 76 and 13 leaf loss events were recorded with the tagged data, respectively for Ceiba pentandra, Lophira alata and Aukoumea klaineana defined as fully deciduous, partially deciduous and evergreen. A strong annual trend was observed for the cyclicity index for both Ceiba pentandra and Lophira alata (≥ 290 days), with a high individual variation within species. The duration of leaf loss events was also found to be highly variable between a few days and a few months. This study aims to characterize the diversity of phenological patterns in the tropical canopy and evaluate phenocams potential for long-term phenology monitoring. By

integrating high-frequency image analysis and phenological metrics, this approach offers new insights into the seasonal dynamics of tropical tree species. Additionally, seasonal tree growth variations will be examined through a two-year monitoring of stem growth in Lopé National Park, providing a complementary view of forest functioning.

THE LAST ONES STANDING: HOW LEAF SENESCENCE AND CHLOROPHYLL DEGRADATION IN NATIVE AND NON-NATIVE SHRUBS SHAPE AUTUMN PHENOLOGY DYNAMICS IN A TEMPERATE DECIDUOUS WOODLAND

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Shrubs, both native and non-native, play a pivotal role in temperate deciduous forest dynamics by providing food and habitat for a range of organisms, contributing to nutrient and carbon cycling and extending the growing season. Phenological patterns in shrubs differs from trees, including earlier leaf-out and delayed leaf senescence, which prolongs the photosynthetic active period and enhances carbon uptake. Despite their ecological significance shrubs remain understudied. The objective of this research was to quantify variations in autumn leaf senescence rates between native and non-native shrubs using a range of methods, including in situ observations, chlorophyll meter (SPAD) readings and PhenoCam derived greenness decline. Phenological observations and SPAD values were recorded twice weekly throughout the autumn season (2018-2024) on 5 native shrub species and 4 non-native shrub species in a small (4.5 ha) woodland fragment on the University of Wisconsin-Milwaukee campus. Additionally, daily Green Chromatic Coordinate (GCC) data from a PhenoCam installed at the site were analyzed to determine autumn transition dates. Preliminary findings indicate that non-native shrubs retain green leaves roughly 3-weeks longer than native species. Chlorophyll meter readings support this trend, showing prolonged chlorophyll retention and a more abrupt drop in leaf chlorophyll content in non-native shrubs. GCC transition dates for the end of autumn showed close agreement with the end of senescence as determined by the other methods. These findings will improve our understanding of how senescence rates differ between native and non-native shrubs and how each contributes to an extension of the growing season and, potentially impacts understory light availability and nutrient recycling. Understanding these processes can aid in predicting forest resilience to climate change and the long-term ecological impacts of non-native shrubs on temperate deciduous forest dynamics.

PHENOLOGY MONITORING OF DECIDUOUS BROADLEAF AND EVERGREEN NEEDLELEAF FORESTS USING SENTINEL-1 SAR AND DEEP LEARNING METHODS

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Vegetation index (VI) time series derived from optical remote sensing is confirmed to be efficient in tracking large-scale forest phenology. However, data discontinuities and critical phenological stages observation gaps caused by cloud cover substantially hinder accurate optical VI reconstruction and phenology extraction. Synthetic Aperture Radar (SAR) can penetrate the cloud and obtain the information related to tree condition, offering a unique perspective for phenology monitoring in cloudy areas. Nevertheless, because SAR signals cannot directly capture vegetation greenness, its ability to reliably derive forest phenology remains poorly understood. In this study, we propose a novel deep learning framework for monitoring the spring and autumn phenology of deciduous broadleaf and evergreen needleleaf forests. Specifically, the framework employs a deep neural network to extract fine-scale details from high resolution Sentinel-1 signals, while a shallow neural network captures global patterns from low spatial resolution meteorological data, facilitating accurate phenological predictions using C-band Sentinel-1 SAR. Within this framework, several deep learning methods including CNN, U-Net, Transformer and TCN are evaluated. The start and end of season (SOS and EOS) are derived from the Green Chromatic Coordinate (GCC) based on the phenocam network, as target variables, with input features including VH, VV, VV/VH ratios, the radar vegetation index (RVI), and various meteorological factors. The results indicate that the proposed deep learning framework enables accurate predictions of SOS and EOS for both deciduous broadleaf and evergreen needleleaf forests, and demonstrates that Sentinel-1-derived information can effectively forecast optical phenological metrics. This study reveals the significant potential of Sentinel-1 for monitoring forest phenology, providing a novel approach to overcome the limitations of optical remote sensing in cloudy regions.

GLOBAL PHENOLOGY MAPS REVEAL THE DIVERSITY, CONVERGENCE, AND ASYNCHRONY OF ECOSYSTEM FUNCTION

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Globally consistent mapping of land surface phenology (LSP) can improve our understanding of ecosystem dynamics, plant ecophysiology, and evolutionary biogeography. Using multivariate analysis of remote sensing imagery, we provide unprecedented insight into global LSP diversity, documenting intercontinental convergence between similar climate regions as well as regional heterogeneity associated with topoclimate, ecohydrology, and vegetation structure. We map the global pattern of spatial phenological asynchrony, explore the modes of seasonal asynchrony that control it, identify hotspots of phenological asynchrony in tropical montane and subtropical Mediterranean climate regions, and report evidence for the hypothesis that climatically similar sites exhibit greater phenological divergence within the tropics. Finally, we find that our LSP map predicts complex geographic discontinuities in flowering phenology, genetic divergence, and even harvest seasonality across a range of taxa, establishing remote sensing as a crucial tool for understanding the ecological and evolutionary consequences of "allochrony by allopatry". Our approach and findings point toward a unified understanding of the ecological and evolutionary implications of landscape phenological patterns and offer novel perspectives for a wide range of fields.

Poster Session

A REVIEW OF PHENOLOGY MONITORING USING PHENOCAMERA ACROSS THE TROPICS: MAIN ADVANCES AND RESEARCH GAPS

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Near-surface phenology uses ground-based imaging and radiometric sensors to monitor leaf changes. Digital cameras, known as phenocameras, are among the most effective sensors for tracking these transitions. Their integration with other vegetation monitoring techniques has greatly enhanced global leaf dynamics monitoring over the past two decades. However, the disparity in the coverage of phenology phenocamera monitoring worldwide, mostly in temperate regions, prejudices our current understanding of phenological responses, climate change effects, and the performance of dynamic vegetation models. We review advancements and challenges of phenocameras in assessing plant phenology, particularly in tropical regions where they hold potential but face barriers. We evaluated their global use of phenocameras worldwide, focusing on applications in the tropics and outlining primary methods. Our goals include identifying the main tropical vegetations monitored, assessing research objectives, determining the availability of monitoring networks, combining technologies (e.g., drones), and exploring research gaps and innovative applications. We conducted a systematic literature review on Web of Science, assessing studies that used digital cameras for phenological monitoring in natural vegetation. A list of metadata was retrieved from the selected articles. A total of 196 articles were included in the survey. Phenocamera applications mainly tracked phenological patterns and developed methods. Camera-derived time series validated orbital sensors, investigated leaf phenological drivers, and related to terrestrial productivity proxies. Long-term studies on interannual phenological variation and climate change effects were limited in temperate and tropical regions. The distribution of global sites confirmed a concentration of study sites in the northern hemisphere. Most sites monitored by phenocameras are in the USA and Western Europe, indicating a significant clustering within temperate biomes like Boreal forests, Temperate Seasonal Forests, Temperate Woodland and Shrubland, and Temperate grasslands/deserts. Tropical studies covered mostly seasonally dry tropical ecosystems such as seasonally dry tropical forests and scrublands (Caatinga) and savanna woodlands and grasslands, but also included wet forests such as the

Amazon Forest, the Atlantic Rainforest, and tropical mountain grasslands. By addressing these challenges and biases, our review demonstrates an increasing monitoring coverage in the tropics, which can promote a more equitable distribution of phenological studies and enhance our comprehension of the effects of climate change on biodiversity and ecosystem dynamics globally. Our analytical framework insights can guide future research, advancing inclusive phenological monitoring methods while addressing the growing interest in phenology's role in conservation and climate resilience.

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USE OF PHENOLOGICAL CAMERAS FOR VEGETATION MONITORING IN PROTECTED AREAS OF CENTRAL MEXICO

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In the past 20 years, the study of phenology has gained significant relevance in the fields of biology, ecology, and the effects of climate change on species. According to the IPCC, phenology is one of the simplest processes for tracking ecological changes in species in response to climate change. Therefore, understanding the mechanisms and factors that influence vegetation phenology is essential for assessing current impacts and predicting future ones. Long-term vegetation monitoring is crucial for understanding the biological processes of ecosystems. Traditionally, phenological data has been collected through human observation; however, phenological cameras are a cost-effective monitoring tool that can provide phenological observations of species across a broad range of temporal and spatial scales and in different climatic contexts.The main objectives of this research were: a) to characterize the phenological response of crops through the use of phenological cameras; and b) to identify the stages of the growing season for the vegetation of interest. To capture images, a Bushnell brand camera trap equipped with the Timelapse function was used. This feature allows the user to program image capture at two user-defined time intervals. In this case, images were taken every 15 minutes during two daily periods: from 07:00 to 10:00 h and from 15:00 to 17:00 h. The data collected covered the period from June 2023 to March 2025. The images were analyzed using the R-Studio package "Phenopix". Two Areas of Interest (AOIs) were defined in maize crop zones (Zea mays). The study site was established in the municipality of Áporo, Michoacán, near the boundary of the Monarch Butterfly Biosphere Reserve. For each AOI, the Green Chromatic Coordinate (GCC) vegetation index was extracted, and the stages of the growing season were determined. A survey was designed to determine the planting dates and the moments when farmers identify the beginning of plant development, peak growth, the onset of senescence, and harvest. The results obtained from the surveys were compared with the dates of the different stages of the maize growing season in this region of Mexico.The results showed a strong correlation with information gathered in the field from local residents, who reported that the beginning of the growing season typically occurs in July, depending on the planting date, while peak values were observed in September. Finally, the end of the growing season was recorded in November, which coincides with the harvest period in the region. Phenocams were identified as a potentially valuable tool for monitoring crops and, potentially, temperate forest species such as those from the Pinus genus. It is expected that the use of phenological cameras can serve as a practical tool for vegetation monitoring in Mexico, especially given the lack of ground observers, and that it will help in the future to identify the effects of climate variability and change on vegetation.

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LEAF PHENOLOGY PATTERNS IN BRAZILIAN CAMPOS DE ALTITUDE ASSESSED BY PHENOCAMERAS

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The effects of climate on plant phenology help us to understand the functioning of ecosystem processes. The campos de altitude, highland grasslands ecosystems in mountaintops of the Brazilian Atlantic forest, have a marked seasonality with a wet and warm season and a dry and cold season. Furthermore, these highland ecosystems are particularly susceptible to climate change due to their disjunct occurrence in mountaintops. However, leaf phenology patterns are still unclear in these environments. It is therefore urgent to assess plant phenology in these areas to understand vegetation dynamics with consequences for predicting their response to climate change of these ecosystems. The images captured by phenocameras have been making it possible to calculate vegetation indexes, allowing the detection of phenological transitions in an area. We investigated leaf phenology patterns in campos de altitude using digital camera images. We hypothesize that there will be more gains in green coloration extracted from the images in the wet season than in the dry season. The study was conducted in campos de altitude at Itatiaia National Park (22°22'01.0"S / 44°41'53.4"W). We implemented a digital camera (Bushnell Core S-4K) to capture daily images of the vegetation between September 13, 2023 to September 15, 2024, programmed from 6 a.m. to 6 p.m. Rainfall and temperature data were obtained from the CHIRPS and ERA5-Land datasets, respectively, by means of Google Earth Engine, for the period January 2023 to December 2024. We calculated the Gcc index for each hourly image taken each day and the daily time series was taken as the 90th percentile of the daytime data for a three-day window. The mean Gcc was 0.36 (± 0.01); the mean temperature was 16.92 °C (± 2.60) and the mean rainfall was 4.99 mm (± 11.09). A positive correlation was observed between temperature and Gcc (ρ = 0.38; $p < 0.001$), while precipitation and Gcc presented were not correlated (ρ = 0.06; p = 0.35) (Spearman's test). We observed an increase in Gcc values from September 2023 to February 2024, corresponding to the wet season. This suggests that the vegetation growing season follows trends in temperature, while water availability may not have a direct influence. This can be reflected in ecosystem and community dynamics (e.g., primary productivity, plant-herbivore interactions) in campos de altitude. Gcc reduces in the dry season, reflecting senescence strategies related to the severe climatic and edaphic conditions in campos de altitude. Determining leaf changes through images allows us to understand phenological

patterns and responses to climatic factors in campos de altitude, which will be especially important in the face of climate change.

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DO TREE FUNCTIONAL TRAITS AFFECT LEAF PHENOLOGY? A PROXIMAL-SENSING APPROACH IN A BRAZILIAN TROPICAL DRY FOREST

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Phenology is an integrative science of great prominence in climate change research because it allows for monitoring, understanding, and predicting biological events related to climate. Through functional traits - characteristics of plants that determine their development and resource usage - it is possible to categorize and group different tree species that compose a community, since these species respond similarly to changes in environmental conditions. The use of digital cameras in "proximal-sensing" phenological monitoring has proven efficient in temperate ecosystems, although it is still underexplored in tropical regions. This study uses digital cameras positioned close to the ground level, aiming to: (i) describe the phenological patterns and functional traits of the dominant species in a tropical dry forest area located in the Cavernas do Peruaçu National Park, southeastern Brazil; (ii) determine the relationship between phenology and functional traits, grouping species based on carbon acquisition and water use strategies (acquisitive vs. conservative); and (iii) identify whether these groups differ in their vegetative phenological patterns. For this purpose, we extracted the color indices from the regions of interest (ROIs) in the continuous images obtained by digital cameras to calculate different phenological metrics, such as SOS (Start of the Season), EOS (End of the Season), and LOS (Length of the Season) from 17 dominant species inside a 1-ha plot, from which we also determined the specific leaf area (SLA), wood density, diameter at breast height (DBH) and height. The results showed that the studied species exhibited large variations in their functional traits, and marginally significant positive correlations were observed between the length of the season (LOS) and SLA. The species formed three distinct groups based on the representativeness of the traits for each group. Among the functional traits, wood density (WD) and DBH stood out, while for phenological attributes, LOS, EOS, and EOS_lag were the most representative variables. The groups displayed different phenological patterns, with the growing season duration (LOS) ranging from 152 to 182 days (iii). For all groups, the species were highly influenced by seasonality, exhibiting production and leaf drop patterns that were well synchronized with the onset and end of rainfall.

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INVASIVE WOODY SPECIES CHANGE THE VEGETATION PHENOLOGY AND HYDROLOGICAL DYNAMICS IN VEREDAS

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Veredas are key ecosystems in the Cerrado, supplying water that feeds most of the Brazilian river basins. They are essential for biodiversity maintenance, harboring endemic species and functioning as ecological corridors for fauna and flora. They occur in enclosed valleys where the groundwater emerges, forming hydromorphic soils with vegetation adapted to these conditions. However, anthropogenic pressures are harming these ecosystems, stemming from the historical misuse of hydrological resources for irrigation, agribusiness and changes in the precipitation regime caused by climate change. These threats jeopardize the future of water availability in the country. In response, Veredas have reduced their water capacity, drying and oxygenating the soil, which consequently is subjected to the invasion of woody species. The monodominance of these can harm the unique native biodiversity of Vereda ecosystems through taxonomic and functional losses. In addition, this can intensify the drying process because woody species need more water and have higher evapotranspiration and metabolic rates, leading to different leaf phenological patterns when compared to the typical hydromorphic vegetation. Here, we hypothesize that the species causing woody encroachment have an evergreen phenological pattern throughout the year, modifying the leaf phenology of Veredas and potentially increasing evapotranspiration in these environments. To test this, a DJI Phantom 4 drone was flown for twelve consecutive months between September/2022 and August/2023 in a Vereda located in Uberlândia-MG. Using the QGIZ 3.40.6 software, we aligned the twelve orthomosaics and created 20 ROI's (Region of interest) comprising areas with and without woody encroachment (10 grids each). Following the time series of the orthomosaics, the areas were subjected to the extraction of the GCC index, whose values indicate the relative brightness of the green, in reference to changes in leaf color. To do so, we used the Python programming language, along with the GeoPandas, Rasterio, Pillow (PIL), NumPy and Matplotlib libraries. The results obtained indicated different patterns between the native (0.3460 ± 0.0079) and woody-invasive vegetation (0.3713 ± 0.0095), in which the latter, despite oscillating between a higher GCC in the rainy season and a lower one in the dry season, is always green. On the contrary, native vegetation has a more seasonally marked

GCC, with a low amount of green during the dry season. These results indicate that woody encroachment changes the leaf phenological patterns of Veredas, increasing overall primary production. In addition, the evergreen pattern of woody-invasive plants indicates higher water demands for metabolic maintenance, even in the dry season when the water table is lower. Our results suggest that woody plants invading Veredas intensify evapotranspiration, which can potentially aggravate the soil desiccation and affect their essential water supply services.

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SWEDISH PHENOCAM NETWORK REVEALS IMPROVED QUALITY, COVERAGE AND AVAILABILITY OF PHENOLOGY MONITORING DATA IN SWEDEN

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Three Swedish research infrastructures, the Swedish National Phenology Network, the Integrated Carbon Observation System (ICOS) in Sweden and the Swedish Infrastructure for Ecosystem Science (SITES) thematic program SITES Spectral, which are using phenological web cameras for continuous and objective observations of phenological phase shifts on plants in Sweden, form the new Swedish PhenoCam Network. Other infrastructures with potential to increase the coverage of PhenoCams are Nature Visitor Centres and LTER research sites which will also be invited to be included in the network.The network will develop a common portal that can receive images from all cameras, with a common platform for evaluation and implementation of scientifically based image analysis methods, and to publish images and analysis results, to make them available to the scientific community, as well as to governmental agencies.The Swedish PhenoCam Network will deliver analysis data with a much better coverage of Sweden, which can reveal how the growing season of plants is adapted to our northern climate and, thus, can reveal the amplitude of the impact from a changed climate on them. PhenoCam images can, in contrast to ground observations and satellite images, give continuous daily observations and provides detailed complementary information. The network effort gives the opportunity to analyze all data from the different infrastructures with consistent methods and publish the results in a common portal in a harmonized structure across the partners. This will greatly simplify further analyses and will be an important tool for, e.g. the evaluation of the Swedish environmental objective Reduced Climate Change Impact, and for many phenology-related research projects in Sweden.Furthermore, the network can increase the public knowledge on the effects of climate change by outreach activities. At Nature Visitor Centers that are included in the network, PhenoCam analysis results can be used in their pedagogic activities concerning climate change and about nature's adaptions to seasonal changes in general. Here, the visitors can also be engaged in the monitoring of climate change effects in a citizen science concept, by introducing defined photo points in the surroundings of the visitor centers, where the visitor's photos can be uploaded to the network and analyzed similarly to the method for the webcam images.

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BIOCLIMATIC PREDICTORS OF FOREST STRUCTURE, COMPOSITION, AND PHENOLOGY IN THE PARAGUAYAN DRY CHACO

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The Gran Chaco biome is among the largest remaining tropical dry forests globally, with Paraguay hosting a quarter of its area. The flora in this region is diverse in structure, function, composition, and phenology. Despite its ecological importance, the Chaco faces high deforestation rates due to agricultural expansion, highlighting the urgent need for understanding its ecological dynamics. This study assesses how bioclimatic variables influence the forest structure, composition, and phenological patterns in the Paraguayan Dry Chaco by integrating data from permanent forest inventory plots, high-resolution monthly NDVI satellite imagery from PlanetScope satellites, and historical climate records from WorldClim. Our results show interactions between bioclimatic factors and forest structural and compositional variables. Precipitation seasonality showed interactions with stem density and compositional evenness (Pielou evenness index), indicating that water availability significantly influences forest composition and density. Temperature-related variables influenced basal area, indicating a moderating role of temperature in forest growth and structure. In terms of phenological responses, precipitation lagged by one month was identified as the driver for leaf flush and leaf senescence, with temperature lagging by two months as a secondary regulator. Phenology during the period with highest water stress was associated with forest structural and compositional variables. Forests dominated by taller trees maintained higher NDVI values during the dry season, presumably due to deeper root systems accessing subsoil water. Conversely, forests with greater basal area and higher diversity showed lower NDVI during the dry season, indicating dominance of highly deciduous species that shed leaves rapidly under seasonal water stress. This study emphasizes the key role of precipitation in shaping phenological patterns in Dry Chaco forests, complemented by regulatory effects of temperature. Understanding these dynamics is essential for predicting forest responses to climatic variability and extremes. The relations identified between phenological behavior and forest structural-compositional variables offer valuable insights for managing these ecosystems under changing climatic conditions. Continuous research combining

fine-scale phenological observations and long-term climatic analyses is essential to enhance predictive capabilities and develop effective strategies for conservation and adaptive management of these vulnerable tropical dry forests.

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CHARACTERIZING VEGETATION PHENOLOGY IN A SEASONALLY DRY TROPICAL FOREST USING NEAR GROUND-BASED SPECTRAL INDICES AND PRECIPITATION DYNAMICS

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Vegetation phenology in seasonally dry tropical forests (SDTFs), such as Brazil's Caatinga, is tightly linked to rainfall and influences ecosystem productivity and carbon fluxes. Here, we investigated phenological dynamics in a preserved Caatinga site (2024-2025) using near-surface spectral sensors (NDVI-SRS-Tower), MODIS-NDVI, and canopy-level phenocam imagery (Gcc). Time series were smoothed and correlated with daily and accumulated precipitation. We found strong agreement between NDVI-SRS-Tower and both MODIS-NDVI ($r = 0.83$) and Gcc ($r = 0.73$), with the highest correlation between MODIS-NDVI and Gcc ($r = 0.86$), indicating consistent detection of vegetation changes. Daily correlations with rainfall were weak (e.g., MODIS-NDVI: $r = 0.21$), likely due to lagged vegetation responses typical of SDTFs. Lagged correlations provided deeper insight. NDVI-SRS-Tower showed peak correlation at a 10-day lag ($r = 0.670$, $R^2 = 0.448$, $p < 0.001$), with 6.3 mm of accumulated rainfall. MODIS-NDVI peaked at an 11-day lag ($r = 0.577$, $R^2 = 0.333$, $p < 0.001$), with 7.6 mm. Gcc showed maximum correlation at a 15-day lag ($r = 0.576$, $R^2 = 0.332$, $p < 0.001$), linked to 10.4 mm of accumulated rain. These results suggest that vegetation greening initiates after ~6-10 mm of rainfall, with NDVI capturing structural responses and Gcc indicating earlier physiological activity. While Gcc had slightly lower correlation values than NDVI, its response started earlier (significant from lag 5, $p < 0.01$), reinforcing its role in detecting early leaf development and chlorophyll activation. Despite scale differences, ground-based and satellite-derived NDVI showed strong temporal coherence ($r = 0.83$), supporting the reliability of NDVI across spatial scales in SDTF monitoring. This study highlights the utility of combining NDVI and Gcc to track phenology in dry ecosystems and underscores the importance of accounting for rainfall lags. Although we did not compute metrics like start or end of season, future work will explore these phenophases under varying moisture regimes. Despite the short

observation period, the findings reveal key rainfall-driven vegetation signals and emphasize the value of continued multiscale monitoring in water-limited environments.

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Keynote

CLIMATE CHANGE EFFECTS ON THE PHENOLOGY AND OTHER ORGANISMAL TRAITS OF PLANTS AND POLLINATORS: A GLOBAL REVIEW

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Phenology -the timing, duration, and synchrony of recurring biological events- is one of the most sensitive indicators of climate change. Along with plant flowering phenologies, floral attraction and reward traits, pollinator visitation, and fruit set are also affected by climate change. Through a global literature review, this study aimed to assess how warming and altered precipitation patterns affect plant reproduction, pollination interactions, and pollinator traits across different Earth´s ecoregions. We conducted a systematic review of the scientific literature in Web of Science to evaluate variation in flowering time and duration, floral attraction and reward traits, pollinator visitation patterns, plant reproductive success (fruit and seed set), and various pollinator traits under warming, decreased water availability, and earlier snowmelt across arctic, alpine, Mediterranean, temperate, and tropical biomes. After screening abstracts and retaining only studies that assessed climate change effects through historical analyses, experiments, or climate modeling, we kept 340 articles reporting population or community-level data. Evidence supports previous findings that species worldwide are shifting their flowering phenology in response to climate change, predominantly flowering earlier. However, late-flowering species and southern hemisphere communities exhibit delayed or unchanged flowering times. How climate change will alter the reproductive phenologies of plants across tropical ecosystems is still unclear, but community-level studies have reported changes in flowering intensity, synchrony, and timing. Some studies have demonstrated the effects of phenological change on plant-pollinator interactions and plant reproductive output. Floral rewards and

pollinator responses to warming are generally negative in temperate and Mediterranean biomes, while flower and fruit production showed diverse responses across Earth ecosystems. Pollinators, studied primarily in temperate biomes, are experiencing negative effects under warming conditions. Climate-driven mismatches between plants and pollinators have been documented mainly in temperate regions; however, pollination mismatches are expected to become more frequent with the ongoing shifts in species distributions, phenologies, and physiological traits. Conclusions: Phenological shifts are the most consistent plant reproductive response to climate change, but their direction and fitness consequences may vary with latitude, biome, and taxonomic group. Current evidence is still limited for most study traits across tropical latitudes, but effects are expected to vary among the different tropical biomes. Expanding joint phenological and climate monitoring in tropical and southern-hemisphere biomes is essential for forecasting climate-driven disruptions to plant-pollinator interactions and plant fitness.

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Session 4

Phenological Mismatching and Temporality of Mutualistic Networks

Oral Session

PHENOLOGY ACROSS COMPLEX LANDSCAPES: THE IMPORTANCE OF HABITAT TEMPORAL COMPLEMENTARITY IN PLANT-ANIMAL INTERACTIONS IN THE BRAZILIAN CERRADOS

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The Bazilian Cerrados is an ecosystem characterized by a mosaic of habitats, spanning from grasslands to denser riparian forest formations, although it is defined by open savanna habitats comprising mostly grassy and woody elements. Each of these distinct habitats shows different plant phenological patterns, so that many mutualistic animals need to track available resources in space across the seasons in this complex landscape. Such intricate landscape dynamics may be an essential element promoting biodiversity in the Cerrados, but we still lack a synthesis of the many examples previously documented. Here, we offer such a synthesis and illustrative examples showing the occurrence of landscape complementarity, with pollinators and frugivores/seed dispersers moving across the different habitats throughout the year, actively tracking floral and fruit resources. We also provide flower and fruit resources availability data across habitats, both at community and regional scale. For instance, peak flowering in open savanna areas tends to be in the transition from dry to the rainy season, while both swamp (vereda) and forest areas have most of their flowering peaks later along the middle rainy and dry seasons, respectively. While open savanna areas show fruiting peaking during the rainy season, fruit production in forested areas is more constant. Importantly, palm swamps may function as an oasis for frugivores during the resource-poor dry season since these open vegetation areas harbor abundant plants bearing fruits when adjacent savanna areas do not. Such community-level differences may be downscaled to closely related species, such as the flowering phenological displacement between vicariant bat pollinated Cerrado tree Hymenaea stigonocarpa and its forest counterpart H. courbaril. Or even upscaled to explain hawkmoth migratory patterns tracking long-tubed flowers blooming at a regional scale. These distinct phenological patterns imply that pollinators and seed dispersers move between neighboring areas throughout the year. Moreover, because a given plant formation seldom offers enough resources for residing pollinators or dispersers along the annual cycle, such movements are vital for ecosystem functioning in the Cerrado landscape, possibly both at local and near continental scales. These trends mean that conservation

action targeting only specific habitats, such as forests or palm swamps, and not the complex landscape in its entirety, will likely fail to maintain the plant and animal diversity in this World's most biodiverse savanna region.

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ANCIENT AND DIVERSE: REPRODUCTIVE PHENOLOGY, FLORAL TRAITS AND VISITORS OF VELLOZIA SPECIES FROM CAMPO RUPESTRE

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In diverse communities, phylogenetically related species may present similar floral signaling patterns to enhance their attraction to flower visitors. Also, species with similar floral traits may exhibit distinct flowering phenologies as a mechanism to reduce interspecific competition, favor cross-pollination and maintain floral constancy. Encompassing about 250 species with up to 75% of endemism, the Velloziaceae family is a characteristic component of campo rupestre, a megadiverse fire-prone mountain ecosystem formed by quartzite and ferruginous rock outcrops surrounded by sandy, stony and humid fields. This study aimed to evaluate whether the convergence in flower traits of Vellozia species leads to distinct flowering times, avoiding potential competition, or if the flower convergence may facilitate pollination and avoid excessive florivory. We expected a lower overlap in flowering of species with similar floral traits and legitimate pollinators, as a strategy to avoid interspecific competition and favor cross-pollination. To do so, we monitored the reproductive phenology from January 2023 to March 2025, totalizing 27 months and encompassing 16 species, measured floral morphological traits and described the functionality of floral visitors of Vellozia species from campo rupestre in the southern portion of the Espinhaço mountain range, Brazil. Flowering events occurred massively in Vellozia, in patches of individuals of the same species and last between 7-12 days, with patches blooming in alternate years. Overall, open flowers are functional for 3-6 days, depending on the species, but all species extended the anthesis for 24h when bagged to avoid visitation. The stigmas remain receptive throughout anthesis, while the pollen is released a few hours later. The group includes species with nectar and pollen as a reward, the corollas are mostly actinomorphic but there are some species with zygomorphic and asymmetrical flowers. Flowers are produced primarily from October to February, which represents the warm rainy season in the region, with a larger number of co-flowering species in November and February. Vellozia caruncularis, V. epidendroides, V. variabilis and V. patens extended their flowering events during the transition between dry and rainy seasons. Interestingly, fire events stimulate massive flower production in V. alata and V. caruncularis, which supply nectar, pollen and tissues for bees, ants, beetles, hummingbirds and rodents during the dry to wet season transition. Self-compatibility is a reproductive

strategy present in all the studied species; however, they all rely on a biotic vector to allow fertilization, to later set fruits and seeds. Our results provide new insights into the flowering phenological patterns and morpho-functional traits of a diverse and emblematic genus of campo rupestre flowers, reinforcing the necessity to deepen the understanding of the species coexistence under the ongoing biodiversity crisis.

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GLOBAL CHANGE DRIVERS CAUSE CHANGES IN FLOWERING PHENOLOGY, POLLINATOR DECLINE, AND LOSS OF FLORAL RESOURCES THAT MAINTAIN PLANT-POLLINATOR INTERACTIONS

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Anthropogenic global land-use change is the most important driver of biodiversity loss. Land use change includes the loss of natural habitat, a reduction in connectivity among remaining patches, and increased habitat homogeneity and degradation. These changes reduce population sizes and increase isolation among the remaining populations. Climate change is also affecting plants and animals on a global scale. Several studies have shown that these anthropogenic changes alter biotic interactions, but few long-term studies have analyzed the global drivers at a regional scale. Anthropogenic global change is probably one of the main causes of pollinator decline, negatively affecting pollination and plant reproduction, but more studies need to directly demonstrate how plant-pollinator interactions are disrupted, particularly in the tropics. Here, I present results of several regional-scale studies on the drivers that are possibly causing changes in flowering phenology, pollinator decline, and loss of floral resources that maintain plant-pollinator interactions. Our studies on tropical trees have shown that the flowering period of trees in disturbed habitats is initiated between 15 to 20 days before the flowering period of trees in undisturbed habitats for 3 years. Flowering of trees in undisturbed habitats peaked at the end of the flowering period of the trees in the disturbed habitat. The proportion of trees that flowered was greater in undisturbed habitats. Another study at the community level showed higher diversity of blooming plant species and a higher richness of pollinators and floral visitors in mature, undisturbed forests. Peak abundance of pollinators and floral visitors overlapped with flowering peaks in mature forests, but this was not consistently the case in disturbed habitats. A long-term study of these plant-floral visitor communities indicates a significant reduction in links and size of interaction networks, possibly caused by direct and indirect climate change drivers. Finally, a study of naturalized honeybees in Mexico showed a significant decline in the number of colonies over 40 years. Using DNA metabarcoding techniques, we found that bee colony density was greater in more diverse floral resource landscapes than in poorly diverse industrialized, agricultural, and urban

landscapes. Habitat loss, as a consequence of agricultural intensification and urbanization, emerges as a significant driver of pollinator decline. Agricultural intensification negatively impacts plant communities, consequently diminishing the availability of essential floral resources for honeybees and the abundance of pollinator species. Pollen and nectar supply the energy and nutrients essential for honeybee colonies; hence, access to a diverse range of floral plant sources is crucial for the long-term survival of colonies. Monocultures offer floral resources for only brief periods, leading to nutritional stress among honeybees.

PHENOLOGICAL OVERLAP AND MORPHOLOGY DRIVE HIGH NICHE PARTITIONING IN A BUTTERFLY-FLOWER INTERACTION NETWORK

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Plant-pollinator interactions represent a crucial ecosystem function for maintaining terrestrial biodiversity. Many of the world's plants depend on animal vectors for pollen transfer to produce fruits and seeds, while pollinating animals rely on floral resources for survival. This close relationship is shaped by niche-based or neutral mechanisms, which structure the communities. Lepidoptera represents a species-rich group and evolved closely with plants; the adult form (moths and butterflies) are potential pollinators when feeding on nectar plants. Butterfly-flower interactions are diverse, ranging from generalists to specialists, and remain understudied at the community level. Here, we investigated the ecological process that shapes the organisation of butterfly-flower interactions in a highly biodiverse community. This study was conducted within a 50-hectare natural area of campos rupestres located in the Universidade Federal dos Vales do Jequitinhonha e Mucuri, in Diamantina, Minas Gerais, Brazil. The climate is seasonal, with the rainy season from October to March and the dry season from April to September. To sample butterfly-flower interactions, we defined five transects measuring 100 x 20 meters, spaced approximately 500 meters apart. These transects were sampled biweekly over one year, from March/2023 to February/2024, between 9:00 a.m. and 4:00 p.m. Two observers sampled the interactions, which involved slowly walking each of the five transects for 30 minutes, totalling 2 hours and 30 minutes per day

(60 total hours). All flowering plant species were observed during the walk, and interactions between butterflies and flowers were recorded. Complementary, the proboscis length of the butterflies and the plant corolla length were measured. The plants were categorised by their extinction threat level. Using network-level metrics, we characterised the butterfly-flower interaction network structure and constructed probability matrices based on species abundances, phenology, and morphology to identify the processes that shape butterfly-flower network interaction frequencies. The butterfly-flower network comprised 43 butterflies and 24 plant species and exhibited a modular structure with a specialised interaction pattern. Niche-based ecological processes, such as morphology and phenological overlap, better explain the intensity of interactions. Additionally, seasonality greatly influenced the turnover of interactions between the rainy and dry seasons. Threatened plant species were the most visited in the community, serving as preferred resources for a subset of butterfly species. In a scenario of extinction involving these threatened plants, we interpret the modular organisation of butterfly-flower interactions as ensuring community robustness. Our study shows that ecological exploitation barriers constrain butterfly-flower interactions, showing a high niche partitioning in a clade that generally is subsampled in plant-pollinator interactions.

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PHENOLOGICAL REGULATION OF INDIRECT INTERACTIONS IN POLLINATION NETWORKS

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Indirect interactions (i.e. when a species interaction is modified by a third species) influences the structure and dynamics of ecological communities. Similarly, phenology determines the availability of interacting species and consequently, community structure and dynamics. However, the temporal variation and how phenology regulates patterns of indirect interactions and its consequences for the temporal variation of ecological communities are still unclear. This knowledge gap hampers our ability to predict how indirect interactions structures ecological communities. Pollination networks are a nice model to investigate phenological regulation of indirect interactions and community structure because plant phenology determines the availability of resources in these systems. In plant-pollinator interactions, a plant species can modify visitation patterns of a shared pollinator to another plant species. Shared pollinators may also transfer pollen between plant species, which can lead to reproductive failure of these plants. Finally, pollinators often compete for shared floral resources (i.e. for the same plant species). I will present an overview of temporal variation and phenological regulation of indirect interactions in distinct pollination networks, with a focus on biodiverse mountaineous systems. Overall, periods of abundant floral resources are associated with positive indirect interactions (plants facilitating pollinator visitation of each other) in tropical grasslands of Brazilian Atlantic forest and Chinese Himalayas. On the other hand, periods of floral resource scarcity led to more intense negative indirect interactions in Brazilian campo rupestre (pollen transfer between species) and Chinese Himalayas (bumblebees competing for floral resources). Plant and pollinator species with extended phenology (flowering and foraging for longer periods) governed indirect interactions across these distinct systems. Overall, these results show that phenology can be related to the direction (facilitation vs. competition) of indirect interactions in ecological communities. Moreover, species phenological traits determine their importance in indirect interaction chains. Thus, it is imperative to consider phenological variation to understand how indirect interactions may structure ecological communities.

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TRAIT SIMILARITY IN CO-FLOWERING MODULES IN A HUMMINGBIRD POLLINATION SYSTEM

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Floral trait patterns among co-flowering plants can help reveal the role of plant-plant interactions mediated by pollinators (i.e., competition or facilitation) in plant community assembly. Although floral traits and flowering phenologies can lead to pollination niche partitioning, we do not fully understand how these mechanisms interact at the community level. In highly diverse communities, a network approach can reveal distinct subsets of plants exhibiting greater flowering overlap among themselves (i.e., co-flowering modules), enabling an integrated view of phenology and floral trait patterns. We investigated patterns of floral trait similarity, phenological modularity, and pollinator overlap in plant communities pollinated by hummingbirds to determine whether these patterns were consistent with competition or facilitation processes. We also analysed how these patterns change along altitudinal gradients and biogeographical regions. We collected plant phenological data in 30 sites along an altitudinal gradient, over an average of 26 months, in Brazil, Costa Rica, and Ecuador. We measured the corolla tube length, width, and curvature as proxies of floral functional traits, and recorded pollinators´ visits to flowers. Using the phenological data, we constructed unipartite plant-plant networks and identified phenological modularity with the Louvain algorithm. We tested if modularity departed from a random expectation using null models. We calculated functional divergence across plant species within modules and tested it against null models. We fitted generalized linear mixed models to evaluate the effect of floral trait similarity, within or between module levels, and altitude on pollinator overlap degree between plants. We found a modular phenological structure in 23 sites across the three countries. Floral functional divergence within modules showed predominantly random patterns. Pollinator overlap was mainly explained by floral trait similarity in all countries, where higher similarity led to higher pollinator overlap. In Ecuador, pollinator overlap was higher among plants within the same module, consistent with facilitative interactions. In Costa Rica, altitude explained pollinator overlap in a non-linear relationship. Our results suggest that facilitation is the dominant process shaping plant communities in Ecuador, while we did not detect evidence of competition or facilitation in the other two countries. Flowers with higher floral trait similarity also exhibited higher pollinator overlap, which aligns with trait-matching in plant-hummingbird interactions. Although ecological specialization is evident, how similar plants explored hummingbird resources over time remained uncertain, as floral traits were randomly distributed within modules. We

provide evidence of facilitation shaping a highly diverse plant community, and highlight that co-flowering modularity is a consistent pattern in tropical plant communities pollinated by hummingbirds.

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FUNCTIONAL TRAITS PREDICT CHANGES IN FLORAL PHENOLOGY UNDER CLIMATE CHANGE IN A HIGHLY DIVERSE MEDITERRANEAN COMMUNITY

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Plants are altering their flowering phenology in response to climate change, with trends varying across species and communities. Functional traits are instrumental in explaining these phenological shifts, making them valuable for predicting which species will be most impacted. We investigated the influence of functional traits on the flowering phenology of 269 species from a Mediterranean community over the past 35 years. Using circular statistics, we evaluated whether the community means for the onset of flowering, intense flowering, and end of flowering had advanced. Generalised linear mixed models were employed to determine the impact of vegetative and reproductive traits on shifts in flowering phases and durations. Additionally, we examined the implications of these changes for flowering order and co-flowering patterns. Most species exhibited an advancement in their entire flowering phenology and an increase in flowering duration. These unprecedented changes in magnitude highlight the severe effects of climate change on Mediterranean ecosystems, though these effects varied among species. The first flowering date advanced in 88.4% of species, the first peak flowering date in 85%, the last peak flowering date in 75.1%, and the last flowering date in 72%. Early flowering led to a reorganization of the community's flowering order and the formation of new co-flowering assemblages, with a slight trend towards increased overlapping flowering times. The novel scenario may lead to new competition or facilitation interactions and to the loss or gain of pollinators. Both vegetative and reproductive traits influenced significant advancements in the flowering phenology of the community. Woody species, shorter plants, species with wider leaves, high specific leaf area (SLA) values, larger flowers, early flowering, or shorter flowering periods showed greater advancements in the start of flowering. Conversely, taller plants, species with high SLA values, or early flowering advanced more in the end of flowering. Taller species with wider leaves and early flowering species with shorter flowering durations increased their flowering duration more significantly. These phenological shifts, conditioned by functional traits, differ from those reported at higher latitudes, indicating context-dependent responses. In our Mediterranean community, reproductive traits were crucial for predicting flowering shifts, suggesting that plant reproduction during the hottest and driest periods-the Mediterranean resting season-may be compromised, along with the survival of dependent animals.

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SPACE-FOR-TIME SUBSTITUTION APPROACH IN FLOWERING PHENOLOGY UNDER CLIMATE CHANGE

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The increase in temperature is changing the plant phenology, causing, for example, an advance of the flowering event. Understanding changes in phenology under global warming is important because phenology influences very specific dynamics, like species interaction, but also drives essential ecosystem functions, like carbon uptake. One method that could help to easily evaluate and analyze phenological changes is the space-for-time substitution (SFTS). This method relies on the observed response of phenology to an increase in temperature along a spatial gradient to predict how the phenology will be under future temperature conditions. However, this method is only suitable when the assumption of space-time equivalence is met. In this study, we assessed the space-time equivalence assumption and if climate change is affecting it. We compared the variation in phenological responses to an increase in temperature on a temporal and spatial gradient. We use mean annual temperature data from the Era5-Land product as well as long-term flowering phenology data from 23 herbaceous and dwarf shrub species from the PEP725 database. The data covers mainly Central Europe and has sites in Northern and Western Europe. The sites are observational sites used for years to monitor phenology. To assess the influence of climate change, we divided our data into the periods 1950 to 1985 (early decades) and 1986 to 2022 (recent decades) and selected the species with observations in all years. We evaluate linear mixed effect models of the spatial-temporal relationship between the day of the year of flowering and the temperature. We extracted the slopes of each model as an indicator of flowering phenology response to increasing temperature and compared them on the spatial and temporal gradients using a t-test and Jensen-Shannon distance.We found that flowering responses to temperature are significantly different between the spatial and temporal gradients ($t = 6.7$; $p = 0.001$), however, the response shares 65% similarity, showing mostly a negative relationship. Response patterns are species-specific, with some species showing high similarity between both gradients, while others showing divergent patterns or with different magnitudes. The phenological response to an increase in temperature appears to be more consistent in the recent decades (72% similarity) than in the early ones (65%), especially becoming more homogeneous across the temporal gradient and showing steeper negative slopes. Accordingly, we conclude that, in the context of climate change, flowering phenology is responding strongly

to temperature, masking the influence of other factors like habitat conditions or plant traits in determining the flowering time. The implementation of SFTS in phenology leads to a correct response direction to the increase in temperature, but it would most probably be underestimated. For this reason, we recommend being cautious when drawing general conclusions when using SFTS.

Poster Session

DO ELEVATION GRADIENTS INFLUENCE THE TEMPORAL AVAILABILITY OF FLORAL RESOURCES? A CASE STUDY WITH ANDEAN ORNITHOPHILOUS PLANT COMMUNITIES

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High-elevation environments are associated with reduced pollinator availability, which consequently limits sexual plant reproduction. The increased pollination probability hypothesis states that plants respond to elevation by increasing their floral display and longevity, improving the chances of cross-pollination. Here, we test this hypothesis with respect to flowering phenology, expecting that plant communities at high elevations exhibit lower flowering concentration (i.e., less pronounced peaks) and longer flowering duration. We studied hummingbird-pollinated plants since these are primary pollinators in high-elevation environments in the tropical Americas. For the first time, we conducted a community-wide monthly monitoring of flowering phenology in ornithophilous species during one year across eight high-Andean plant communities in Colombia, distributed between 2,631 and 3,111 m.a.s.l. Using circular statistics, we classified flowering distribution strategies into uniform, unimodal, and bimodal. Flowering concentration was quantified as the community average of the mean vector length (r), a measure representing the degree of clustering of flowering events throughout the year, ranging from 0 (perfectly uniform) to 1 (perfectly concentrated). Flowering duration was defined as the community average angular extent of flowering activity, estimated in months. Both metrics were calculated only for unimodal species. No species exhibited a uniform flowering pattern, while 56% showed a unimodal pattern and 44% a bimodal pattern. The proportions of flowering patterns did not differ among communities. Using robust linear regressions, we found that elevation had a negative effect on flowering concentration and a positive effect on flowering duration across communities, explaining 71% and 19% of data variance, respectively. These findings corroborate

our hypothesis, indicating that community flowering patterns show less prominent peaks and last longer as elevation increases. This is probably related to the increased period of flower exposure, increasing the chances of pollinator visits and ensuring the reproduction of plants that are obligately dependent on pollinators. Our findings support the importance of phenological strategies as complementary traits to flower display and longevity, suggesting that the flowering patterns of ornithophilous plant communities along elevational gradients have been shaped as reproductive strategies in response to pollinator availability. Furthermore, we emphasize the importance of phenological studies for a better understanding of community functioning, especially under future climate change scenarios.

KEEPING UP THE PACE: CHANGES IN THE PHENOLOGY OF POLLINATORS IN A MEDITERRANEAN COMMUNITY OVER THE PAST 35 YEARS

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Climate change is altering the life cycles of plants and animals and there is a growing concern that the different rates at which species are changing will produce mismatches between their life cycles. Species that are interdependent, such as flowering plant and pollinator animals, are particularly vulnerable. However, information on the very occurrence of these mismatches is scarce. The Mediterranean region is a climate change hotspot and plants in this area are advancing their flowering phenology at high rates. Our goals in this study were (1) to assess the shifts in the phenology of pollinator insects in a Mediterranean community and (2) to test the occurrence of mismatches with flowering plants. To do so, we performed pollinator censuses weekly in a Mediterranean community in the south of the Iberian Peninsula during the year 1986 and again during the years 2020-2022. We analysed separately the records for the four most important orders: Hymenoptera, Diptera, Lepidoptera and Coleoptera; honeybees (Apis mellifera) were also analysed separately, as they are the only managed species on the area. We compared the dates in which the activity peak happened each year, as well as the dates in which the number of recorded individuals went over 50% (First high abundance date) and under 50% (Last high abundance date). We also analysed the changes in the shape of the abundance curve along the year for each group. Finally, we calculated the overlap of the pollinator abundance curves with the curve of plant species flowering for each year, generating a measure of changes in mismatch. Overall, all of the phenologically relevant dates occurred earlier in the 2020s than in 1986, but the pollinator groups showed differences in the magnitude of their response. The changes in the shape of abundance along the year also point to a generalised shift onwards of pollinator activity. The overlap between pollinators and plants increased for Hymenoptera, Diptera and Lepidoptera, but decreased for Coleoptera and A. mellifera. Our results reveal that the phenology of pollinator activity has shifted in the last 35 years, occurring now earlier than in the 80s decade. As plants are known to be showing the same trends in their flowering phenology in response to climate change, we hypothesize that the changes in the phenology of insects are also a response to climate change, either directly (to temperature) or indirectly (to the changes of plants). Plant reproduction may be affected by the changes in the phenology of the different pollinator groups depending on the specificity of their interactions. We have also demonstrated that

mismatches between plants and pollinators do arise, and that their direction and magnitude vary across groups.

BLOOMING LIES: UNVEILING THE TIMING BEHIND BATESIAN FLORAL MIMICRY

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Batesian mimicry consists of an eco-evolutionary system in which mimics obtain advantages by imitating the appearance of models, thus deceiving third-party organisms. In the case of Batesian floral mimicry, a mimic plant without resources imitates a model plant with resources, attracting pollinators and making reproductive success possible. There are several theoretical predictions for floral mimicry to function, including the phenology of the mimic being restricted within the phenology of the model. This indicates that the mimic's flowering pattern must be dependent on the presence of models in the environment, allowing pollinators that are already used to the model's appearance to be deceived. In this study, we evaluated this theoretical prediction for a neotropical system where the orchid Galeandra montana (Orchidaceae) imitates the pink tubular flowers of Jacaranda rufa (Bignoniaceae), fooling large female bees that are looking for nectar (Bombus and Xylocopa). Specifically, we hypothesize that the phenology of the mimic is restricted within the phenology of the model and is, therefore, less aggregated. To get temporal data on flowering phenologies, we based our analysis on herbarium records for the Minas Gerais state to reduce geographical bias, taking the day of the year (DOY) that the collection was made as a proxy of flowering. Using circular statistics, we compared the circular mean (μcirc) directions and overall circular distributions using the Rao polar test and a MANOVA approach based on the sines and cosines of the angles, respectively. To test our specific hypothesis, we used the Wallraff test of angular dispersion around the μcircs. The phenology of G. montana had a μcirc of 56.86° (± 38.69°sd), which corresponds to 27 February. Jacaranda rufa had a μcirc of 345.27° (± 86.40°sd), corresponding to 15 December. These mean directions were not significantly different from each other ($H = 0.44$, $df = 1$, $p = 0.51$). In addition, the overall distributions were not different ($Pillai = 0.03$, $F_{2,108} = 1.42$, $p = 0.25$). These results show that the phenology of the mimic is no different from that of the model in terms of flowering peak and distribution pattern, respectively, highlighting the similarity of natural history aspects. However, we found differences according to the concentration of the phenologies ($\chi^2 = 19.48$, $p < 0.001$), with the phenology of G. montana being more aggregated while J. rufa had a more widespread distribution (length of the mean vector $r = 0.80$ vs. 0.32, respectively). This

corroborates our hypothesis, indicating that the flowering of the mimic occurs more rapidly within the flowering of the model, possibly deceiving pollinators that are already used to the model's traditional appearance. These results show how herborized material combined with robust circular statistical techniques makes it possible to test well-developed biological hypotheses.

FLORAL TRAIT SIMILARITY BETWEEN NEIGHBORS INCREASES REPRODUCTIVE SUCCESS SUGGESTING FACILITATION THROUGH POLLINATOR SHARING

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The ability of plants to attract pollinators is context-dependent, influenced by floral traits, abundance, and resources from neighboring plants. Indirect interactions through shared pollinators, from competition to facilitation, may lead to varied reproductive outputs in plants, and the mechanisms behind these interactions remain to be fully elucidated in complex ecological communities. We aimed to disentangle the mechanisms by which the floral neighborhood may impact pollinator sharing and plant reproductive success in the highly biodiverse campos rupestres from Brazil. Fieldwork was conducted during the rainy season (October 2022-April 2023) in 32 plots (2.5 m^2 each) selected for environmental heterogeneity. In each plot, we recorded flower abundance, observed floral visitors, collected stigmas to quantify pollen deposition, and marked flowers to estimate seed set. These data were collected across nine sampling, each consisting of 15 days of fieldwork followed by a one-week break.To estimate floral similarity among species, we measured corolla length, corolla opening diameter, and stigma and anther height. Using a piecewise structural equation model (SEM) approach, we investigated the relationships among species traits, pollinator sharing, pollen deposition, and reproductive success (seed set) in variable community contexts. During the sampling, we found 404 interactions between 31 plant species and 35 pollinator morphospecies. The SEM results show that plant species with similar flowers in relation to their neighbors showed higher seed set, indicating facilitation. In contrast, species with high flower abundance showed decreased visitation rates per flower and conspecific pollen deposition, suggesting intraspecific competition. Our study reveals that, while there is an interplay between facilitation and competition, the former had a stronger influence on the reproductive output of plants sharing pollinators in a highly diverse tropical community. These results show that traits and abundance mediate complex indirect interactions in plant-pollinator communities.

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SPATIAL-TEMPORAL CENTRALITY OF PLANT-POLLINATOR INTERACTIONS IN A CAMPO RUPESTRE ECOSYSTEM

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The functionality and service provision of ecosystems depend on interactions between species that maintain ecological cohesion and influence internal processes and dynamics. Among these, plant-pollinator interactions are particularly vital to both natural and agricultural systems, as they are essential for the reproductive success of approximately 88% of all flowering plants. The traits of interacting plants and pollinators influence not only the likelihood of interactions occurring but also their centrality-that is, their importance in maintaining the stability and connectivity of plant and pollinator communities across spatial and temporal scales.In this study, we identified the most crucial plant-pollinator interactions at both spatial and temporal scales within a campo rupestre ecosystem in Serra do Cipó, located in the southern region of the Espinhaço Range. We constructed spatial and temporal meta-networks, calculated interaction degrees (frequency) as measures of centrality, and analyzed the effects of various traits of the interacting species, including the plant's pollination system, plant and flower abundance, pollinator taxonomic group, and pollinator abundance. For bee pollinators specifically, we also assessed the influence of body size and sociality.Our results showed that interactions were generally more stable over time than across space at the scales studied. Spatially consistent interactions were also temporally consistent, whereas many temporally consistent interactions appeared spatially restricted. Plants tended to interact more consistently with pollinators, while pollinators exhibited more spatial and temporal variability in their interactions with plants.Among plants, flower characteristics had a stronger influence on spatial interaction centrality than on temporal centrality. Plants with more specialized pollination systems formed more spatially consistent interactions compared to those with generalist systems. Moreover, spatial and temporal consistency increased in plants with higher flower abundance and overall population abundance.Among pollinators, species with greater flight capacity formed more central interactions than less mobile groups, such as ants and beetles. Pollinator abundance had a weak negative effect on both the spatial and temporal degrees of interaction. In the case of bee pollinators, interaction centrality did not significantly differ among body size groups. However, solitary bee species displayed higher spatial and temporal interaction centrality than social species, indicating a strong influence of solitary behavior on interaction patterns.

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Keynote

TRACKING PHENOLOGY IN THE GLOBAL SOUTH: PHENOLOGICAL NETWORKS, CREATIVE DATA SOURCES, AND TRADITIONAL KNOWLEDGE

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Phenological research outputs from the Global South represent a small proportion of the total body of international research. Most countries do not have formally established phenology networks, phenology gardens, or the funding for extensive phenology data sourcing programmes. However, there is a wealth of information held within traditional ecological knowledge, in documentary records, and in local adaptation to climate change. Indeed, emerging phenological research in the region is contributing to improved knowledge and understanding of climate change, and a heightened awareness of the changes in the natural environment. This in turn strengthens existing phenological networks, citizen science data collection campaigns, and acknowledgement of the value of indigenous knowledge.

Session 5

Phenology from Legacy and Herbarium Data to Botanical Gardens for Global Forecasting Climatic Change

Oral Session

THE VALUE OF NATURAL HISTORY COLLECTIONS IN RETROSPECTIVE AND PROSPECTIVE ANALYSIS OF PHENOLOGICAL CHANGE IN MEDITERRANEAN ECOSYSTEMS OF ANDALUSIA (SPAIN)

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Natural history collections have been growing fast since 16th century. In the case of plants, they are botanic gardens and herbaria. For practical reasons, most of botanic gardens are in urban areas, where growing conditions are largely artificial. As the amount of herbarium specimens have increased in number and geographic and time coverage, herbaria have undergone a recent flourishment witnessed by numerous studies which aim to identify temporal variation in traits recorded in specimens across decades and even centuries correlated with variables linked to climate change. Similarly, plant community studies performed several decades ago with enough detailed phenological information of species offer an extra opportunity to test for phenological changes without skewness of herbarium data. However, we also need to prospectively monitor the effects of ongoing climate change on natural systems. Whereas there is a long tradition of using phenological record of species with agronomical or ornamental interest, there has been very limited data on wild species. In this respect, initiatives such as long-term ecological research in natural sites may be very helpful for establishing phenological networks at world scales, as sentinels of climate change effects on ecosystem functioning. Mediterranean type ecosystems have been shown to be particularly sensitive to global and regional climate change. Here, we focus on a region, Andalusia (S Spain, W Mediterranean), with wide environmental variation and complex history which makes it a biodiversity hotspot. We present an ongoing research program to determine the effect of climate change in several tens of species particularly well represented (> 200 specimens each) in the two major herbaria in Andalusia (Universities of Seville -SEV- and of Granada -GDA-). Preliminary results in several species pairs within families and genera showed idiosyncratic responses involving advances and delays, and non-response in onset, peak and final flowering times during the last decades. In addition, on a broader scale, we present results from repeated phenological sampling with about 40-year lapse of a wide array of plant communities, where we also found idiosyncratic phenological responses at community level but with a trend to flowering advance.

Differences in responses lead to a re-organization of the flowering order of the community and generate new co-flowering assemblages of species. Finally, we present a design for a phenological network to track phenological records in living plants and their interacting organisms across 11 botanical gardens within Andalusian Natural Parks. This dataset may represent a cohesive phenological program that produces sound retrospective and prospective data at a regional level. Additionally, this design is based on experiences from other sites, allowing for integration into broader, global networks.

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THE INTENSITY OF FLOWERING IN HERBACEOUS SPECIES IS STRONGLY INFLUENCED BY THEIR COMPETITIVE ABILITY AND PHENOLOGICAL NICHE

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The timing of flowering in many plant species is shifting due to climate change, which may lead to phenological mismatches in biotic interactions. As flowering is typically a process covering a certain timespan, rather than a singular event, phenology-dependent interactions should be studied with respect to the course of the complete flowering curves. Information on flowering curves in time is, however, hardly available. Instead, cardinal points such as day of first flowering or peak flowering dominate reports in the literature.Here, we used data on the weekly observed proportion of open flowers in relation to buds, wilted flowers, and fruits (i.e. flowering intensity) of 263 perennial herbaceous species collected in 14 botanical gardens by the PhenObs network. We modelled flowering curves and derived four key characteristics per species: number of flowering peaks, maximum flowering intensity, flowering duration and skewness (indicating resource investment strategies to reach flowering peaks). We aimed to explore variations in flowering intensity curves across species, and determine whether patterns may be predicted based on species' functional properties (competitiveness, stress tolerance, and phenological niche).The characteristics of the flowering curves varied among species. Most flowering curves of herbaceous species were normally distributed or right-skewed, indicating a fast-initial investment of resources into flowering. Competitive species as well as early-flowering and late-flowering species invested resources in single but intensive flowering events, with shorter flowering durations and more left-skewed curves (i.e. "all-in-one" strategy). In contrast, stress-tolerating species distributed resources over several flowering peaks (i.e. "bet-hedging" strategy).Based on the results, we recommend taking the various characteristics of flowering curves into account when evaluating the effects of flowering shifts due to climate change, rather than just first flowering or peak flowering. For example, the inflexible high-intensity single peak of early flowering species may increase the risk of future phenological mismatches. If information on the course of flowering curves is not available, our study showed that functional properties of the species (i.e. competitiveness or phenological niche) can be used as approximations.

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FLOWERING NICHE AND RANGE DYNAMICS UNDER GLOBAL WARMING SCENARIOS: AN ATLANTIC RAIN FOREST STUDY CASE

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Plants exhibit phenological responses to environmental cues such as temperature, precipitation, and daylength. While earlier flowering in the Northern Hemisphere is a well-documented consequence of global warming-related rising temperatures, long-term data to assess tropical plant responses to climate change remain scarce. To address this gap, we employed ecological niche modelling to predict future phenological shifts in neotropical plants, using Atlantic Forest (AF) Myrtaceae as a model group. The flowering niche of 14 species was modelled using precipitation and temperature data matching with their flowering peaks, obtained from herbarium voucher records. Under two future climate change scenarios, we projected three potential phenological responses: earlier, later, or conservative flowering. Our findings indicate that an earlier flowering shift generally results in lower range loss across species. However, some widespread species displayed heterogeneous responses; for instance, northern AF populations might benefit from delayed flowering, while southern populations could be favoured by earlier flowering. Overall, southern AF species demonstrated greater resilience to global warming compared to northern AF species. Furthermore, species that currently flower during warmer seasons are predicted to be the most negatively impacted by future warming because highest temperatures are expected occur during the time that these species are flowering.

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Poster Session

SEASONS IN THE SHEETS: INVESTIGATING PHENOLOGICAL TRENDS OF ELAEOCARPUS SPECIES USING HISTORICAL HERBARIUM DATA

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Herbarium specimens serve as critical resources for detecting long-term plant phenological trends across spatial and temporal gradients, offering valuable insights into species' responses to environmental change. This study examines the reproductive phenology of three tropical tree species of the Elaeocarpaceae family - Elaeocarpus serratus, E. tuberculatus, and E. munroi - native to the Western Ghats, India. A total of 670 specimen records, collected between 1811 and 2022 from 15 herbaria, were analyzed. Specimens were included only if they exhibited identifiable reproductive structures (mature buds, open flowers, or fruits) and contained complete collection metadata, including date and location description. Collection dates were converted to Julian day (DOY), and locality data were georeferenced using Google Earth. Linear regression models were employed to examine temporal shifts in phenology, with DOY of each phenophase (bud, flower & fruit) as the response variable and year of collection as the predictor. Results revealed distinct variation in phenological patterns, with E. serratus and E. tuberculatus exhibiting a weak negative flowering trend. These findings suggest that reproductive phenology in these species has changed over the last two centuries, potentially in response to long-term climatic or environmental drivers. The study demonstrates the utility of herbarium collections for quantifying phenological change in tropical systems and emphasizes the need for integrating phenological data with historical climate records to assess the sensitivity and resilience of tropical tree species to ongoing climate change.

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Session 6

Phenology, Traditional knowledge, and Citizen science

Oral Session

COUNTING ON CHANGE - AN EXHIBITION ACTIVATING NATURE CENTRE VISITORS IN PHENOLOGY FOR INCREASED CLIMATE CHANGE AWARENESS

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(1) Swedish Centre for Nature Interpretation. (2) Swedish National Phenology Network.

The "naturum" visitor centres are popular gateways to nature in Sweden, usually located in national parks or other protected areas, with extensive educational activities and exhibitions. The nature interpreters working there have expressed the need for exhibitions and activities addressing climate change linked to biodiversity and related to what can be seen and experienced on site. They wanted the communication to be evidence-based, activating and hopeful.Researchers, in collaboration with the naturum centres, developed an exhibition project that focused on phenology and citizen science, and was based on local conditions. The outdoor exhibition "Counting on change" visualise phenological observations and comparisons with historical data. It shows different changes over time and invite participants to be involved. They can report their own photographs from photo points, which create time series from defined sites. At these photo points, the seasonal changes of different tree species and other vegetation can be studied by analysing the green and red colours of defined regions of interest in the images.The exhibition uses outdoor signs to explain changes in the landscape that can be experienced at that location, described in different ways. Large sized numbers give examples of changes, e.g. the number "49" at the Tåkern bird lake tells us that cranes (Grus grus L.) arrive on average 49 days earlier in spring today, compared to 100 years ago, and large-scale domino tiles describe a chain of events affecting the arrival and food availability of spotted flycatchers (Muscicapa striata Pallas, 1764). Visitors provide different types of feedback to the exhibition activities. Firstly, they send in photos from the seasonal photo points, which at the same time engages the visitor in the long-term monitoring of phenology at the site and empowers participants, leading to discussions and an interest to find out more about phenology and climate change. This spring, 47 photos have been reported from the birch (Betula pendula Roth) tree photo point in Tåkern. The series of images reveals the timing of the budburst and leaf development with high precision, in the same way as a phenology camera, thanks to the many visitors.The participants in the exhibitions are also encouraged to leave comments and share their own experiences on a wall where notes can be attached. Many share their thoughts and tips, both on their observations of changes, such as the amount of snow that has fallen or the number of flowers that bloom in midsummer. They also give suggestions for actions for the environment. The results from this interactive wall will be categorised, analysed and presented. Involving participants in simple reporting opens the door to more extensive citizen science reporting within the Swedish National Phenology Network and to increase the awareness and understanding of the consequences of climate change in nature.

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REPORTING PHENOLOGICAL OBSERVATIONS BY CITIZENS USING THE NEW DWD WARN-WETTER-APP

Udo Busch[1]

(1) Deutscher Wetterdienst.

The DWD has operated a phenological observation network since 1951. It currently consists of around 1,000 volunteer observers who report plant development throughout the year from fixed stations according to uniform guidelines. Until now, there was no other way for volunteers to make phenological observations for the DWD.Since March 2023, it has been possible to submit plant reports using the full version of the new DWD Warn-Wetter-app. These can be sent from any location. The DWD plans to use this additional information from the app to supplement the data of the existing phenological observation network and also to recruit new stationary plant observers.The consolidation of phenological data contributes to a better understanding of current plant development in Germany and to draw conclusions about climate change. Furthermore, they provide a valuable basis for the development of (agricultural meteorological) models and the improvement of pollen forecasts.The entry and display of plant observations are similar to the weather reports in the DWD Warn-Wetter-app. The observation can be reported under the "Enter Plant Reports" product and is separated into "Wild Plants and Fruit" and "Agricultural Crops." This is followed by the selection of a plant stage (e.g., beginning of flowering) and a plant species such as forsythia. The date and location are also required for the report. A photo of the observed plant is required to verify the report.Furthermore, there is the option to report additional plant observations using "Other Stage" and "Other Plant Species."The reported plant observations are then displayed on a map of Germany with symbols for the respective stages. The background color of the symbol indicates whether the report was observed earlier or later than the long-term average.The first comparisons between the data collected via the new app and the data observed by traditional observers have already been conducted, with very promising results. A detailed description of this functionality of the new DWD-Warn-Wetter-App can be found at www.dwd.de/pflanzenmeldungen.

MANDACARU "FULORAR" DURING THE DROUGHT, IT IS SIGN THAT RAIN IS COMING TO THE "SERTÃO"? PHENOLOGY AND LOCAL ECOLOGICAL KNOWLEDGE IN QUILOMBOLA COMMUNITIES OF THE CAATINGA

Jociene Oliveira Vitoria Nascimento[1,2]); Alexsandro Bezerra da Silva[2,3]; Adelly Cardoso de Araujo Fagundes[2,3]; Isiara Silva Menezes[1]; Sãmia Paula Santos Neves5[2,3]; Sinzinando Albuquerque de Lima[2,4]; Eraldo Medeiros Costa Neto[2,3]; Ligia Silveira Funch[2,3]; Roberth A. Voeks[5]

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Studies that consider both local ecological knowledge (LEK) and academic ecological knowledge (AEK) regarding the phenological rhythms of plants are scarce but essential for understanding ecosystem dynamics. Focusing on cacti of ethnobotanical importance in Brazil's semi-arid region, we investigated the influence of climatic factors on the reproductive phenology of Xiquexique gounellei (F.A.C.Weber ex K.Schum.) Lavor & Calvente, Melocactus zehntneri (Britton & Rose) Luetzelb., and Cereus jamacaru DC. In this study, we assessed whether the LEK of Quilombola communities in the Northeast about the phenophases of these species aligns with patterns observed through phenological monitoring in a Caatinga area of the same region. AEK was determined through monthly qualitative observations between December 2020 and November 2023, recording the presence or absence of each phenophase. LEK was investigated using phenological calendars developed with three focus groups, totaling twenty participants. Climatic data were obtained from regional meteorological stations. We used generalized linear models (GLMs) and circular analysis to analyze the data. Regarding phenological patterns, the cacti showed flowering and fruiting throughout the year, without marked seasonality, and were influenced by temperature and precipitation. There was a relative agreement between the phenological monitoring data and the phenological calendars: flowering events reported by participants were consistent with field observations. This corresponds to the cultural perception of the studied communities, where the most significant season is winter - important for rainfed agriculture - and thunderstorms, which help fill local reservoirs. Monitoring environmental factors can help reduce crop losses. Such practices are deeply embedded in Northeastern Brazilian culture, to the point of being immortalized in poems, novels, and songs such as Xote das Meninas by the King of Baião. Thus, we emphasize the importance of strengthening community/academic partnerships in order to redefine the monitoring of climatic variables - such as precipitation and temperature - by the

communities themselves, alongside the phenology of the plants in their surroundings.

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VISUALISING BLUE JACARANDA PHENOLOGY DATA: CONNECTING PEOPLE WITH LOCAL CLIMATE CHANGE INDICATORS

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Engaging the wider public with phenology has often been seen by those in the field as a promising way to cut through many of the dilemmas faced by traditional climate change communication. While climate change has previously been seen as remote, abstract and disconnected from many people's everyday lives, phenology has promised a way of showing the effects of climactic changes on people's doorsteps long before the impacts experienced in recent years were felt. Richard Primack's restudy of Thoreau's records in Massachusetts, USA, has offered a prominent example for the Northern Hemisphere, and more recently a team of researchers from Brazil, South Africa and Australia have develop a variety of ways of tracking the Blue Jacaranda (J. mimosifolia) to produce a vital indicator for the Southern Hemisphere. This paper shares work from an interdisciplinary collaboration between this team and researchers in environmental humanities and information design, which aims to engage the wider public with the historical and recent phenological data being collected for this charismatic tree species. Exploring questions of how to communicate climate change through creative forms of data visualisation design, we will share works in progress that weave together local experiences of phenological recording and data collection with overall trends. We are particularly interested in developing forms of data visualisation that magnify, what Anna Lawrence (2009) has discussed as, the 'inner and outer dimensions of data collection'. We will suggest that in doing so, we can explore ways of making climate change more real for the general public, while also highlighting the richness of citizen scientists' experiences that go far beyond the collection of a series of dates.

Acknowledgement: This paper arises from a larger project that Bastian has been involved in with Patricia Morellato, Jennifer Fitchett and Marie Keatley. Funding has been provided by the British Academy GCP The Times of a Just Transition project. The Brazil group is supported by FAPESP (2021/10369-5, 2022/07735-5), and CNPq (401577/2022-8).

Poster session

FROM CLASSROOM TO CAMPUS COMMUNITY: INITIAL STRATEGIES FOR PARTICIPATORY PLANT PHENOLOGY MONITORING AT THE UPTC

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Flowering events are influenced by both biotic and abiotic factors, which shape seasonal sequences, spatial distribution, and the ecological roles of species. The analysis and monitoring of these events involve quantitative and qualitative approaches that enable the recording of variations in duration, seasonality, and resource frequency. In urban systems, citizen science serves as an accessible tool that provides valuable information and promotes improved management of resources and environmental decisions within the community. This study was conducted at the Universidad Pedagógica y Tecnológica de Colombia (UPTC) with the purpose of developing citizen participation strategies for phenological plant observation through teamwork and the collaborative construction of a macro-proposal comprising two components: a practical component, involving the monitoring of eight plant species on campus, and a participatory component, involving surveys conducted with 18 members of the university community regarding their perception of phenology, species identification, and data collection. Weekly phenological observations were carried out from September 2024 to April 2025. For three herbaceous and climbing species, flower abundance was quantified in five individuals, while for five tree and shrub species, five inflorescences per individual were quantified and extrapolated based on the total number of inflorescences. A potential relationship with precipitation was also assessed. Data were analyzed using the transformed Fournier Index (FI'), which estimates phenophase intensity using a five-category semi-quantitative quartile scale (0 to 4) in 25% intervals. The surveys revealed that none of the respondents were familiar with the term "phenology", although 60% reported being aware of seasonal changes and plant life cycles. Phenological monitoring revealed various flowering intensities; for instance, P. undulatum and T. granulosa exhibited continuous flowering patterns throughout the study period, whereas herbaceous species such as C. ciliata and A. arborescens displayed brief and irregular flowering events. Additionally, a decline in flowering was observed in T. stans and C. ciliata during December and January, respectively, with FI' values reaching zero, possibly linked to the lack of rainfall. The peak of flowering intensity occurred in September and October, with FI' values ranging from 0.32 to 0.6, coinciding with the increase

of precipitation levels at the end of 2024. This suggests that water availability may play a role in initiating or enhancing the flowering phenophase in several species. This pilot study underscores how phenological cycles observation in everyday environments can enhance awareness of local biodiversity and promote conservation strategies, thereby strengthening the connection between communities and their natural surroundings.

Acknowledgement: We would like to express our sincere gratitude to the UPTC community for their willingness to participate in the surveys; to the research group Biología para la Conservación for their valuable suggestions to improve the proposal and to the Universidad Pedagógica y Tecnológica de Colombia for providing access to laboratories and other facilities.

HISTORICAL DATA COLLECTION ON THE PHENOLOGY OF BLUE JACARANDA TREE: A LOOK AT BLUE FLOWERS THROUGH OLD NEWSPAPERS

Thalita Surian[1]; Maria Tereza Grombone Guaratini[1,2]; Leonardo Ganz[2]; Carolina Pontes Santos[4]; Leonor Patricia Cerdeira Morellato(1); Michelle Bastian[3]

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Blue Jacaranda is an ornamental tree of the Bignoniaceae family, native to South American countries. It has been widely used in urban landscaping, introduced and well adapted in about 80 countries due to the ornamental beauty of its blue flowers. This relating ecology and society, using phenological data from the world-renowned plant, Jacaranda-azul, in texts published in old media outlets, containing information about Jacaranda mimosifolia tree (jacaranda mimoso) as it is known in Brazil. Clearly the phenology of the jacaranda, with its massive production of blue or purple flowers, is highly appreciated in different regions of the globe. The aim of this study is to identify and to collect historical records of flowering, how they were represented, observing the records of blue flowers over time. The systematic search is carried out in digitized collections of media materials published in past years of last centuries whose content necessarily mentioned "jacarandá", through searches using the following keywords: "jacaranda-mimoso"; "jacaranda" and "blue jacaranda ou pourple". Were consulted the archives of the newspapers A Província do Estado, O Estado de São Paulo and Estadão; the archives of the newspaper Folha de S.Paulo and other newspapers available in the National Digital Library. We found the blue jacaranda species mentioned in many news articles indicating its use in urban landscaping, such as planting on public roads, sidewalks, avenues, squares and gardens and was also mentioned in indications for reforestation of degraded areas. However, the name jacarandá has been used to designate different species of trees from Brazil and South America. Regarding the results, we found in just one of the newspapers, O Estado de SP, around 6,845 mentions of the word "jacarandá" that include information about several species and families of plants. Therefore, we refined the search with the words "jacarandá mimoso", which reduced the collection to 191 occurrences, all published from 1900 onwards. The results correspond, for the most part, to the flowering of jacarandás and descriptive and informative topics related to the blue jacarandá. Analyzing this information can help us understand people's perceptions of the flowering of jacarandas, allowing us to observe the periods in which flowering has occurred and its distribution in Brazil over time.Acknowledgment: supported by the British Academy Global Convening

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Keynote

DECADAL FLOWERING PHENOLOGY AND POLLEN METABARCODING REVEAL CLIMATE-LINKED SHIFTS IN A TROPICAL MONTANE FOREST

Eric Fuchs Castillo(1); Gilbert Barrantes-montero(1); Alfredo Cascante-marín(1); Ruth Madrigal-brenes(1), Mauricio Quesada(2)

(1) Universidad de Costa Rica; (2) Universidad Nacional Autonoma de Mexico

Understanding how flowering phenology responds to climate variability in tropical ecosystems is essential for predicting the stability of plant-pollinator interactions and the resilience of ecosystems. Here we synthesize a decade of continuous observation on flowering phenology in the herbaceous and shrubby flora of tropical upper montane forests in Costa Rica-offering an unprecedented long-term perspective for this ecosystem. Monthly censuses conducted over eleven years along a 2 km transect recorded flowering activity in 70 animal-pollinated species. We used circular statistics and time-series modeling to characterize flowering seasonality, identify flowering peaks, and analyze interannual trends in phenological parameters. Most species exhibited a single, well-defined annual flowering peak, with 61% peaking during the dry season and 39% during the rainy season-contradicting expectations of continuous or sub-annual flowering in tropical floras. Our results suggest that pronounced seasonal climatic variation in high-elevation environments drives reproductive timing, with dry-season flowering likely influenced by pollinator activity windows and energy availability. We also detected a decadal trend toward reduced flowering duration and earlier peak flowering dates. Generalized additive models revealed a significant non-linear decrease in the timing of peak flowering over time, while generalized linear mixed models showed that 76% of species had shorter flowering durations over the study period. No significant phylogenetic signal was found for flowering onset, duration, or peak date, indicating that observed phenological shifts are likely ecological rather than phylogenetically constrained. To further assess the ecological validity of observed flowering phenology, we applied pollen metabarcoding techniques to insects visiting flowers in the same study area. Using high-throughput sequencing of the ITS2 region, we identified the taxonomic origin of pollen carried by floral visitors. Our results confirmed that insects collected during flowering peaks carried pollen from species observed to be flowering concurrently, validating the temporal match between insect-mediated pollen transport and plant reproductive phenology. Native bees and flies transported pollen from both early- and late-flowering taxa, while pollen from dry-season-flowering species dominated samples of this period. These findings demonstrate

that metabarcoding of transported pollen can serve as a precise and complementary method to detect effective phenological patterns-those that result in potential pollination-bridging observational phenology with functional pollinator-mediated dynamics in natural systems. Together, this integrated approach combining long-term observational data with pollen metabarcoding offers a powerful framework to evaluate climate-induced changes in phenological schedules and their implications for pollination services in tropical montane ecosystems.

Session 7

Tropical Phenology, Biodiversity Conservation and Restoration under global change

Oral Session

SHIFTS IN PHENOLOGY PATTERNS OF TREES AND HORNBILLS LINKED TO CLIMATE VARIABILITY IN THE EASTERN HIMALAYA

Aparajita Datta[(1)]; Soumya Banerjee[(1)]

(1) Nature Conservation Foundation.

We examine the changes in breeding cycle of three Asian hornbill species, and changes in fruiting patterns of their food plant species and climate, based on 25 years of long-term ecological monitoring of hornbill breeding, tropical tree phenology and local climate in a tropical forest site in the Indian Eastern Himalaya. We monitored nests of three hornbill species (Great Hornbill Buceros bicornis, Wreathed Hornbill Rhyticeros undulatus, Oriental-Pied Hornbill Anthracoceros albirostris) annually from 1997 to 2024 (ranging from 9 to 46 nests each year) to obtain data on nesting occupancy, nesting initiation, duration of nesting cycle and nesting success/chick fledging in the Pakke Tiger Reserve, Arunachal Pradesh. Data on climatic variables such as temperature, rainfall, solar irradiance and daylength were obtained from a weather station. We also monitored fruiting patterns of 545 trees of 33 animal-dispersed species monthly from 2011 to 2023. We recorded the presence/absence of reproductive phenophases and scored the amount of ripe fruit. The timing of breeding in two large-bodied hornbills appears to be linked to the El Nino Southern Oscillation events with early nesting in El Nino years and late nesting in La Nina years. There was also high variation in nest entry dates in recent years. There is a significant decline in nesting occupancy and increase in the nesting duration. Although there is no significant long-term decline in nesting success, there has been higher nesting failure for the two large-bodied hornbills in the last 6 years and the lowest ever nesting success in 2022. There has also been a significant increase in temperature from the past. Trends in fruiting intensity were significant for 14 of 25 tree species consumed/dispersed by hornbills with decline for 10 tree species, however time-series plots of trends showed high degrees of inter-annual variation. There is also a shift in fruiting with an earlier peak and more uniform fruit availability. These changes are possibly linked to climate change although causal mechanisms need to be understood.

TREE PHENOLOGY IN RELATION TO CLIMATE AND DISPERSAL MODE IN A TROPICAL WET EVERGREEN FOREST IN SOUTH ASIA

A. P. Madhavan[1]; Srinivasan Kasinathan[1]; Kshama Bhat[1]; G. Moorthi[1]; T. Sundarraj[1]; T. Vanidas[1]; Divya Mudappa[1]; T. R. Shankar Raman[1]

(1) Nature Conservation Foundation.

Influenced by biotic and abiotic factors, trees in aseasonal tropical forests may show annual peaks with extended-duration phenophase expression, subsuming variation among species, individuals, and functional guilds. Documenting such patterns and their climate correlates helps understand climate vulnerability and focus restoration efforts. As part of our long-term tropical rainforest restoration project at the Anamalai Biological Station in the Western Ghats, a climate refugium and biodiversity hotspot, in India, we observed tree community phenology patterns in four phenophases - leaf flush, open flowers, unripe and ripe fruits. We examined: (a) How phenological patterns varied with climate (rainfall, temperature, humidity, photoperiod, and irradiance), and (b) How phenological traits (phenophase frequency, duration, and timing of peaks) differed between functional guilds classified by seed dispersal mode: wind, gravity, bird, mammal, and generalist animal. We applied novel signal processing methods to quantify phenological traits using time series data of 1584 trees of 171 species recorded monthly over 46 months (2017-20), incorporating tuning parameters of minimum peak height, inter-peak distance, and amplitude change between months. Local weather station data were used for climate analyses. Leaf flush and flowering peaked around March (dry season), unripe fruits around May, and ripe fruits during June - August (wet season). Phenophase duration (mean ± SE across individual trees) varied between 6.6 ± 0.1 mon for leaf flush and 2.3 ± 0.1 mon for flowering. Across 46 months, 64% of species and 78% of trees had annual rhythms with an estimated 5.4 ± 1.3 peaks for ripe fruits. At the community level (proportion of trees in a phenophase), significant climate correlations ($|r| > 0.29$, $p < 0.05$, $df = 44$) included positive relationships of leaf flush with irradiance, unripe fruit with temperature, and ripe fruit with photoperiod. Leaf flush and flowering were negatively related to precipitation and relative humidity; the former also negatively with photoperiod. Timing of peaks but not phenophase duration or frequency differed by seed dispersal guild: wind (March), bird and mammal (May), generalist animal (August), and gravity (October). Ripening of generalist animal- and gravity-dispersed fruits were positively related to precipitation and negatively to irradiance. Bird and mammal dispersed guilds were positively related to photoperiod, wind dispersed negatively with photoperiod and humidity and positively with temperature and irradiance. Variation in the timing of peaks and in climate correlates across dispersal guilds imply that climate vulnerability of tropical trees may depend on functional guilds, with the diverse community

offering scope for resilience. Forest restoration efforts need to ensure year-round and multi-year seed collection to maximise diversity and resilience, including climate-influenced guilds with narrow phenophase durations.

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TRENDS AND GAPS IN NEOTROPICAL FLOWERING PHENOLOGY

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Flowering phenology is a critical aspect of plant ecology, shaping plant performance and offering valuable insights into how species may respond to ongoing climate change. While global interest in phenological studies has grown in recent decades, research efforts across the Neotropics remain disproportionately scarce compared to those in the Northern Hemisphere. In this review, we synthesized published studies on flowering phenology in the Neotropics by analyzing their geographic distribution, methodological approaches, and the flowering patterns observed across different vegetation types. We further classified the surveyed studies into six broader ecological research themes to assess the scientific progress in the area, knowledge gaps, and future directions. A systematic search was conducted across major electronic databases using the keywords "phenolog" and "flowering" in multiple languages. Only studies conducted at the plant community level were included. Preliminary results showed that out of 1,841 initial records, 246 met our inclusion criteria. Our results show a steady increase in flowering phenology research in the region between 1965 and 2024, with a peak in publications observed in 2021. Brazil accounted for most studies (60%), followed by Costa Rica (9%) and Venezuela (7%). Tropical moist forests were the most frequently studied vegetation type (55%), followed by tropical dry forests (21%), both with flowering peaks more regularly reported during the rainy season. Most studies relied on direct observational methods (88%), with marked individuals and plot-based sampling being the most common approaches. However, the sampling effort was often limited, with more than half of the datasets including only 10 to 50 plant species (51%) and having a duration of just 1 to 2 years of monitoring (66%). Only 12 sites across the region had phenological monitoring extending for ten years or more. Among broader ecological themes, the most frequent focus was the relationship between flowering phenology and local climatic variables (69%), particularly irradiance and temperature. The second most common theme was plant-animal interactions (18%), especially those involving pollinators such as hummingbirds. Despite increasing concern about climate change, only 11 studies explicitly addressed its effects at the community level. These studies primarily investigated the impacts of drought, elevated CO_2 levels, and El Niño events. In this context, long-term monitoring programs and herbarium data emerge as essential tools for detecting phenological shifts and improving our understanding of ecological responses to climate change. Our findings highlight both the progress and gaps in Neotropical phenological research, emphasizing the urgent need for expanded, long-term, and geographically diverse studies to better inform climate adaptation strategies in biodiversity-rich regions.

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EFFECTS OF THE EL NINO SOUTHERN OSCILLATION (ENSO) ON LONG-TERM TREE REPRODUCTIVE PHENOLOGY IN THE INDIAN EASTERN HIMALAYA

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(1) Nature Conservation Foundation.

Anthropogenic climate change can have significant effects on the timing and intensity of phenological activity. In tropical regions, climatic teleconnections such as the El Nino Southern Oscillation (ENSO) can mediate climate-phenology relationships. In this study, we highlight potential long-term climatic effects on the intensity of tree reproductive phenology in the semi-evergreen forests of Pakke Tiger Reserve in the Indian Eastern Himalaya. We recorded the occurrence of flowers and fruits for 716 trees of 54 species from 2011-2024, and concurrently logged climate data at a weather station.We used Bayesian phylogenetic generalized linear mixed models (pGLMMs) to determine mechanistic pathways by which ENSO could influence tree flowering or fruiting through the mediating effect of temperature, precipitation or solar irradiance. Response variables were de-seasonalized through the use of monthly residuals. Cross correlation functions (CCFs) were used to screen for lags for up to 24 months, and the respective lagged MEI (Multivariate ENSO index) and climate variables were used in pGLMMs which were used to build Structural Equation Models. Generalized Additive Models (GAMs) was used to examine long-term flowering and fruiting patterns over the study period at the community level and for 35 species. We found substantial support for a positive association between MEI and long-term flowering intensity (β= 0.41 (0.22, 0.60)) , indicating higher flowering in El Nino years, which was corroborated by visual examinations of GAM splines. Solar irradiance was included in the best-supported climate model, but it did not have a significant effect on flowering. SEMs indicated little support for the mediating effect of climate variables on ENSO-flowering relationships (indirect MEI effect β= -0.004 (-0.029, 0.020)). On the other hand, fruiting intensity was positively associated with the 3-month lagged effect of solar irradiance (β= 0.142 (-0.001, 0.290)). ENSO did not have a significant influence on fruiting. PGLMMs indicated moderate phylogenetic conservatism in long-term trends of flowering (H2=34.88%) and fruiting (H2=37.10%). Long-term phenological patterns showed low-frequency cycling for most species, with a periodicity of 3-4 years. In 2011-2020, 14 and 16 species showed significant long-term trends in flowering and fruiting respectively, with some animal-dispersed species (P.simiarum and M.hodgsonii) showing declines. Our study indicates that long-term reproductive phenological intensity may show low-frequency cycling, as opposed to more continuous patterns. Flowering and fruiting may show divergent responses, with the former responding to ENSO whereas the latter responded to long-term increases in solar irradiance. The absence of clear

mechanistic pathways mediating phenological trends may indicate intrinsic and possibly phylogenetically mediated patterns, in addition to the long-term effects of key phenological cues such as solar irradiance.

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YOU SHALL NOT STARVE: THE PRESENCE OF LEAVES GUARANTEES NECTAR FOR ANTS ALL YEAR ROUND

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Lianas are key structural and functional components of tropical ecosystems. The tribe Bignonieae (Bignoniaceae) represents the largest clade of lianas in the Neotropics, which is characterised by showing extranuptial nectaries (ENNs) that attract ants. Like other species in this group, Amphilophium mansoanum bears ENNs on vegetative and reproductive organs. Nectar from ENNs serves as food resource for omnivorous and aggressive ants that, while foraging, may repel or prey upon herbivores, establishing protective mutualisms with this plant species. In tropical forests, ant activity has been linked to the emergence of new organs during the dry season. Furthermore, there is evidence of a positive correlation between nectar productivity and ant activity. Elucidating the seasonality of ENN-bearing structures in the savannas, like the Cerrado, allows us to better understand how plant-ant mutualisms are modulated throughout the year in a highly seasonal ecosystem. In this study, we evaluate the seasonality of EEN-bearing organs in A. mansoanum and estimated nectar availability for ants on leaves. From March 2024 to February 2025, we conducted focal observations and recorded the presence of leaves, buds, flowers, and fruits in 30 plants located at the edge of a Cerrado sensu lato fragment in Águas de Santa Bárbara (SP, Brazil). To evaluate the seasonal variation of these organs throughout the year, we calculated the length of the mean vector, circular variance, and applied the Rayleigh test. Additionally, we compared nectar production in leaves between August and December (dry and rainy seasons, respectively) using the Wilcoxon test. Buds and flowers showed strong seasonality ($r = 0.73$ and $r = 0.78$; $p < 0.001$ for both) and low variance (0.27 and 0.22), both peaking in January. In contrast, fruits and leaves were not seasonal ($r = 0.44$ for both; $p < 0.001$ for both) and showed higher variance (0.56 for both), suggesting more scattered distribution throughout the year, though significantly different from uniformity. Total leaf nectar production did not differ between August and December ($p = 0.36$). Our results indicate that nectar availability for ants in the calix of buds and flowers is highly seasonal. Moreover, year-round leaf presence may ensure a relatively continuous nectar supply, in spite of its irregularity among plants. These temporal variations may directly influence plant-ant interactions. During the reproductive period, nectar distribution across structures may enhance protection of high-value organs (buds, flowers) and reduce potential ant-pollinator conflicts. Later, even as total nectar availability

declines, ants may switch among food sources, maintaining their defensive role during both dry (e.g., August) and rainny (e.g., December) periods, as a result of the continuous presence of leaves. Thus, nectar-bearing leaves may be key to sustaining protective mutualisms throughout the year.

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REPRODUCTIVE PHENOLOGY AFTER FIRE: A BRIEF ASSESSMENT OF A PLANT COMMUNITY IN A BIODIVERSITY HOTSPOT

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Fire plays a crucial role in shaping plant communities, particularly in fire-prone ecosystems. While fire can act as a disturbance, altering species composition and reproductive cycles, it may also promote biodiversity by triggering species recruitment and flowering. Therefore, understanding the effects of fire on species richness and reproductive phenology is essential for conservation and management strategies in these unique ecosystems. We compared flowering plant richness and flower production in burnt vs unburnt areas throughout 6 months after burning to uncover patterns of post-fire recovery and the role of fire in shaping plant reproductive strategies, in the biodiverse tropical mountainous campo rupestre vegetation. The study site was carried out in the Serra do Cipó National Park-MG, Brazil, and its buffer zone which presents a seasonal climate, with dry winters (April to September) and rainy summers (October to March), and species flower year-round. There, we sampled 144 plots of 1m^2, from each 74 were burnt and 70 unburnt distributed from 900 to 1420m a.s.l. There was an intense anthropogenic fire in August 2024, and we registered plant flowering richness and flower number every month after 15 days of this fire event until January 2025. We observed that, at the end of August, the unburnt sites exhibited a total of 24 species blooming, while the burnt sites exhibited 2 species flowering (Bulbostyles paradoxa and Guapira sp). From September onward, when the rainy season started, the burned plots gradually recovered and by January they showed a total of 34 species blooming, while the unburnt plots showed a total of 31 species flowering. The preliminary results suggest that fire initially reduces flowering species richness, but over time, burned plots can recover and even exceed unburned plots in the richness of species blooming. Moreover, in August 2024, the unburnt plots produced a total of 621 flowers while the burnt plots showed 186 flowers, mainly represented by the mass flowering of B. paradoxa, which is classified as a fire-dependent flowering species. From September to October, the number of flowers produced increased in unburned plots, peaking around October, while flower production remained low in burned plots. From November to January 2025 the burned plots showed a slight increase in flower number, but

unburned plots still maintained the highest flower production. Our study revealed that, species richness in burned plots start lower but gradually recover, eventually surpassing unburned plots. In contrast, flower production in burned plots remains lower than unburned plots for most of the period. This contrast suggests that richness and abundance show distinct patterns, which demonstrate a high complexity of the fire effects in the campo rupestre vegetation.

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AUTOMATIC OBSERVATION INSTRUMENTS FOR PHENOLOGY DEPLOYED NATIONWIDE IN CHINA

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With the escalating impacts of climate change and environmental degradation, understanding the dynamics of ecosystems has become imperative. Phenology, the study of seasonal biological events, is crucial for comprehending how climate variations affect the timing of life cycles in both plants and animals. Recently, advancements in a variety of techniques including sensors, communications have facilitated the development of a kind of automated phenological observation instrument. The instrument, equipped with a set of sensors for measuring biological traits and environmental conditions--including optical vegetation index sensors measuring Normalized Difference Vegetation Index (NDVI), hyperspectral sensor retrieving solar-induced chlorophyll fluorescence (SIF), thermal unit sensing canopy temperature (CT), LiDAR (Light Detection and Ranging) obtaining dimensional information such as XYZ and intensity of the target crop or plant, soil moisture senor adopting TDR (Time Domain Reflectance) for measuring soil water contents at 8 different underground depths, soil temperature sensor measuring temperature at soil depths same as soil moisture sensing, animal phenological sensor monitoring almost 500 series sounds made by birds, insects, fogs, etc., laser altimetry measuring an average height over a field plot with a few square meters, two RGB cameras capturing images of specific plant species at regular intervals and tracking of phenological phases, and a fisheye camera monitoring plant biodiversity, community dynamics and species interactions--enable researchers to monitor phenological changes effectively and study the interactions between meteorological conditions and ecosystems. So far, after nearly one-year operation of 304 sites in 31 provinces in China, it demonstrates that the combined performance of those sensors outperforms any individual one sensor with their respective advantages of observations on plants, animals and their growing environments. For example, using multi-camera and multi-time observations, we established the sample library of wheat, corn and other main crops development periods. Then, adopting a set of data preprocessing, enhancement processing scheme, and a deep learning technology, we realize the automatic identification algorithm of the main crops development periods, with an accuracy of more than 90%. The error between the crop development period and manual observation is less than 3 days, and fully meets the operation requirements. There is another example. Based on vegetation height, reflectance and density information of LiDAR point cloud, combined with vegetation coverage, we proposed a set of filtering, ground point removal, point cloud classification, segmentation and light transmittance calculation methods to estimate crop LAI and grassland biomass. Results show the accuracy of estimated magnitudes was above 90% comparing with manual observation, and the observation frequency was increased from 10 days to 1 day.

PHENOLOGICAL CYCLES OF STAPLE FOOD DIETARY ITEMS FOR THE SOUTHERN MURIQUI (BRACHYTELES ARACHNOIDES - PRIMATES, CR) IN THE SOUTHEASTERN BRAZIL'S ATLANTIC FOREST

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This study examines the phenological cycles of leaves, flowers, and fruits of ten staple food species consumed by the Southern Muriqui (Brachyteles arachnoides), the largest-bodied Neotropical primate and classified by IUCN species´ red-list as Critically Endangered. Research was conducted in Parque Estadual Carlos Botelho (Carlos Botelho State Park (> 41,000ha), located in the core area of the largest continuous fragment of the Brazilian Atlantic Forest in southeastern São Paulo State (> 300,000ha). Despite the ecological importance of food availability for endemic and threatened species, phenological data from continuous Atlantic Forest remains scarce. We monitored key food species within the core area of the muriqui home range over two non-consecutive 12-month periods (1995 and 2002). The study site, a submontane Atlantic rainforest, receives ~2000 mm of annual rainfall and lacks a pronounced dry season. Monthly assessments of food species phenophases (fruits, flowers and leaves) productions were conducted through fruit transect surveys, with data analyzed in relation to rainfall, temperature, and day length. Results indicate weak seasonality in fruit production, with fruits available year-round, albeit with slight reductions during the rainy season. In contrast, the production of leaf flushing and flowers exhibited strong seasonality, positively correlated with increased solar radiation but independent of rainfall. Leaf flushing and flowering occurred out of phase with fruiting, suggesting these resources may serve as nutritional alternatives during periods of fruit scarcity for arboreal frugivores. The dataset presented here represents a preliminary analysis from an ongoing long-term phenological study spanning more than two decades. Our findings reveal a consistently fruit-rich environment that supports the dietary requirements of the predominantly frugivorous Southern Muriqui, underscoring the vital role of continuous forest habitats in the conservation of this threatened primate species.

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DROUGHT EFFECTS ON THE FLOWERING PHENOLOGY OF A GLOBAL CROP: POTENTIAL CONSEQUENCES FOR POLLINATION AND FOOD SECURITY

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Climate change is a current threat for natural and agricultural ecosystems, which consequences range from local to global scales. Even though climate change is usually associated with increasing temperatures, it also affects rainfall regimes. Indeed, the latest IPCC reports predict that drought events will increase in frequency and duration in several regions of the planet. Drought can affect flowering phenology that strongly modulates plant reproductive success in natural and agricultural ecosystems. Thus, understanding how drought might affect flowering phenology, and how it may interfere in plant-pollinator interactions is a key issue in ecology. This topic becomes especially relevant if we consider that shifts in flowering phenology have the potential to severely hinder food production, especially in crops that depend on animal pollination. We investigated if drought causes shifts in flowering onset, ending and duration, and on the number of flowers produced per plant. For that, we used a globally cultivated monoecious and insect-pollinated plant, Cucurbita pepo (Cucurbitaceae), as our model species. We grew 30 plants under control conditions, in which the soil was kept at field capacity and 30 plants which were subjected to drought and were only watered when they showed clear signs of wilting. Overall, drought led to changes in flowering phenology. Drought delayed the onset of flowering (T-ratio = -3.389; $p = 0.0013$) and reduced the flowering period (T-ratio = 2.677; $p = 0.0099$). Although drought did not affect the production of male flowers (T-ratio = -0.529; $p = 0.5992$), it led to a reduction in the number of female flowers produced per plant (T-ratio = 3.640; $p = 0.0006$). Thus, the delayed onset of flowering and the shortened flowering period represent a reduction of the window of time in which pollination can occur in this crop. Moreover, these results coupled with the reduction in the number of female flowers, which represents less units that can be pollinated, may maximize the negative effects of drought on fruit production. These results raise concerns over the potential broad effects of climate change on flowering phenology and, consequently, on pollination and food production worldwide.

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Poster Session

CLIMATE-INDUCED SHIFTS IN LONG-TERM TROPICAL TREE REPRODUCTIVE PHENOLOGY: INSIGHTS FROM SPECIES DEPENDENT ON AND INDEPENDENT OF BIOTIC POLLINATION

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The dependence on biotic pollination may constrain plant phenological responses because flowering time ultimately defines reproductive success. We proposed a local-scale study combining long-term phenology and experimental data to evaluate how a key functional trait-the dependence/independence on biotic pollination for reproduction-influences the phenological response of tropical plants to a locally shifting climate. We asked whether the flowering and fruiting durations and start and peak dates of trees differed over time according to the dependence or independence on biotic pollination; if species dependent on biotic pollination are more responsive to climate; and how phenological shifts affect co-flowering and the proportion of flowering individuals producing fruits (reproductive success). Our study was conducted in a diverse Cerrado savanna vegetation where long-term phenological monitoring has been conducted since 2004. We selected the 31 most-abundant tree species, monitored from 2005-2019 and categorized them by pollination type, reproductive system, and functional group (dependent/independent on biotic pollination). We applied generalized linear mixed models to test whether flowering and fruiting variables differ over time according to functional group and local climatic variables. We used circular statistics to extract phenological parameters and evaluate phenological changes between functional groups. We analyzed species co-flowering and the proportion of flowering individuals that produced fruits over time, according to their dependence on biotic pollination and a changing climate. Increasing temperatures were the key driver determining the significant reduction in flowering, and precipitation and relative humidity drove the decrease in fruiting duration for both functional groups. Overall, co-flowering decreased over time, but reproductive success of both functional groups did not change, suggesting community resilience to the changing climate. We highlight the relevance of reductions in flowering and fruiting durations for tropical plants in contrast to the early flowering observed for species from North temperate regions in response to climate change. Reduced duration of reproduction and increased flowering decoupling across species pairs did not affect the estimated reproductive success of either functional group. However, those responses may have far greater

consequences for plant-pollinator and plant-frugivore interactions, by reducing or changing resource availability over time in highly diverse tropical savannas.

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FRUITING PHENOLOGY OF ZOOCHORIC SPECIES IN A FRUGIVORE REINTRODUCTION AREA IN TIJUCA NATIONAL PARK, RIO DE JANEIRO

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Year-round fruit production is vital to support populations of large frugivores. The reintroduction of locally extinct frugivores has been considered an effective conservation strategy to restore plant-animal interactions in defaunated ecosystems. However, these interactions can only be recovered where diverse fruit resources are available. Monitoring fruiting phenology in sites where frugivorous animals have been reintroduced provides key knowledge to assess food availability and the restoration of ecological interactions. In this study, we monitored the diversity and relative abundance of fleshy fruits monthly, from August 2022 to March 2025 in the Tijuca National Park (TNP), Rio de Janeiro, Brazil, where the Brown howler monkey (Alouatta guariba) and the Yellow-footed tortoise (Chelonoidis denticulata) were reintroduced. To assess zoochoric fruit richness and abundance, we conducted monthly surveys (5 hours/day) for fallen fruits or fruiting plants within 2 m of both sides of trails within the reintroduced frugivores home ranges. A GPS device was used to mark fruiting locations. Then, we analyzed the seasonal variation in rainfall and temperature and their influence on the diversity and abundance of mature fleshy fruits. We recorded 179 fruiting plant species belonging to 113 genera and 56 families. The most representative family was Myrtaceae, with 28 species, followed by Lauraceae (12) and Fabaceae, Melastomataceae and Moraceae (10 each). The genus with the highest richness was Eugenia, with 15 species. In both years, November (Rainy season) was the month with peak and richness, while a fruiting shortage was observed during the first semester of each year. Dryer seasons were characterized by a higher abundance of the palm Euterpe edulis (Arecaceae). We found a high diversity and availability of zoochoric fruits in National Tijuca Park, highlighting the importance of long-term monitoring to ensure no supplemental feeding is required for reintroduced animals. Moreover, we show that climate variation can affect these patterns. Future research assessing the effects of fruit diversity and relative abundance on seed dispersal and natural regeneration could provide insights into how trophic rewilding contributes to forest functionality, dynamics, and maintenance.

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LONG-TERM FRUITING PATTERNS SHAPE BIRD-PLANT INTERACTION NETWORKS IN THE BRAZILIAN CERRADO

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The Brazilian Cerrado is the most biodiverse tropical savanna on Earth, hosting a rich array of native and endemic species. This biodiversity supports complex mutualistic interactions, particularly between fruiting plants and frugivores birds, the main seed dispersers in the biome. These interactions are key for maintaining forest dynamics, vegetation regeneration, and overall ecosystem resilience. Here, we investigated the structure and temporal stability of bird-plant interaction networks in a cerrado sensu stricto area in Southeastern Brazil using 15 years of fruit phenology data. We recorded 97 unique frugivory interactions involving 21 plant species and 37bird species. We used a probabilistic interaction model to complement this data with possible missing interactions. After estimations, we found an expected total of 287unique interactions between those species. We combined the estimated interactions with fruiting data to construct monthly interaction networks weighted by fruit availability.We than analyzed how the network connectance, the species strength and their expected weighted degree changed over the year and through the years. Despite interannual variability, the overall network structure remained relatively stable overtime. Bird community composition showed low temporal turnover, although the activity of some species fluctuated seasonally. In contrast, fruiting patterns among plant species were more dynamic. While some species exhibited reduced or irregular fruiting over the years, generalist taxa such as Miconia spp. maintained consistent fruit production, especially during periods of overall fruit scarcity. These species may playa critical role in sustaining frugivore activity during resource bottlenecks. Our results suggest that climate-driven shifts in phenology may alter fruit availability in theCerrado. While some plant species may shorten their fruiting periods potentially disrupting food supply for frugivores more resilient and generalist species could expand their fruiting windows under changing climatic conditions. Understanding these contrasting trends is essential for predicting future scenarios of plant-animal interactions and for guiding conservation strategies in this threatened biome.

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PLANT COMMUNITY PHENOLOGY OVER THREE YEARS IN THE BRAZILIAN ATLANTIC RAINFOREST

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The phenological seasonality of tropical plants has been investigated at different levels of organization, from populations to community, showing great diversity among life forms, functional groups and environmental conditions. The structure and function of plant communities is shaped by interactions among species, and changes in phenology can affect resource availability over time with cascading effects on ecosystem processes. In face of climate change and increasing degradation of tropical forests, it is crucial for conservation to understand how the phenology of communities with high diversity varies over time. Here we monitored the vegetative and reproductive phenology of 259 plant species (62 families) in the Atlantic Rainforest (Parque Estadual da Serra do Mar, Núcleo Picinguaba, São Paulo State, Brazil), aiming to evaluate community-level seasonality and relation to climate. We asked if there are differences between woody and herbaceous plants phenology: we expected a distinct reproductive pattern, more seasonal for woody component, and similar leafing patterns for the evergreen species regardless the habit. During three years (April/2006 to March/2009), we monitored monthly 2.531 individuals regarding six phenophases: flower bud, open flower, unripe fruit, ripe fruit, leaf flushing and leaf fall. We used circular statistics and generalized linear models (GLMs) to analyze phenological patterns. The plant community of Picinguaba presented the highest percentages of species and individuals with flower buds, open flowers, unripe fruits and new leaves during the super-humid season (October to April), with positive correlations with day length, precipitation and mean temperature. The community phenological patterns were similar among years, possibly reflecting the slight variation in climatic variables. Leaf fall and ripe fruit occurred throughout the year showing the high percentages in the humid season (cooler and less rainy). Reproductive and vegetative phenophases showed slightly seasonal patterns in the three years studied, except for ripe fruit and leaf fall, which were not seasonal. Woody and herbaceous plants differed in their phenology and relations with climate. Herbaceous plants initiated all phenophases one to three months earlier than woody plants and also showed greater synchrony in the reproductive phenophases. The seasonal phenological patterns and relation to climatic variables indicate that the Atlantic Rainforest plant communities monitored are potentially susceptible to climate change, that are shifting the timing of phenological events globally. We reinforce the importance of conducting comparative studies addressing different life forms and

more than one year of observations to better understand phenological patterns in tropical forests.

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A REVIEW OF HYDROCLIMATE OF DRYLANDS AND ASSOCIATION TO VEGETATION PHENOLOGY: PERSPECTIVES FOR FUTURE RESEARCH IN SEASONALLY DRY TROPICAL FORESTS (STDFS) IN BRAZIL

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There has been wide research on Dry Tropical Forests (SDTF) in Brazil. These forests are characterised by a distinct dry season and are found in the northeastern and central-western regions of Brazil. This paper is a review to evaluate the hydroclimate hypothesis (Guan et al., 2015) proposing that an annual rainfall threshold of 2,000mmyr-1 to sustain evergreen state in the dry season in tropical rainforests worldwide. The review sought to explore indications leading towards the threshold hypothesis, it's reference by other studies afterwards and evidence in support or to the contrary. We used a strategy of choosing relevant and indicative of studies before and after the theory, selected 30 years (1995-2025). A systematic review of 37 published papers, which explored vegetation phenology and seasonality, using selected search-words for drivers, leaf, behaviour was done. This would result in reduction of papers with addition of deeper search-words in a stepwise manner using AND as the Boolean operator. Literature was searched from the databases of; Web of Science, Science Direct, IEEE Explore, ACM Digital Library, and SpringerLink. The study is ongoing, but preliminary results have shown that studies have found that evergreen part STDFs exist in areas of annual rainfall < 2,000mmyr-1, which was hypothesised. Groundwater has largely been shown to support evergreen vegetation. Vegetation ecological patterns are affected by a broad range of factors beyond climatic seasonality. There has been heavy reliance on satellite data, but flux towers and Phenocameras monitoring increasingly being adopted. This review finds a need to further test the hypothesis in different regions and spatial scales. New studies need to consider influence interaction of hydroclimate and soil properties on leaf greenness index and phenology; atmospheric water budget influence on vegetation phenology expressions; and there is a need for models leaf phenology in the context of a wholesome environmental watershed to fully explore hydroclimate limits. Recent research has shown that Phenocameras useful for monitoring leaf phenology in STDFs.

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FLAMES AND FLOWERS: FIRE SEASON DRIVES REPRODUCTIVE TIMING IN THE CERRADO

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Fire plays a significant role in shaping the reproductive phenology of plant species in tropical savannas. In the Cerrado, post-fire flowering is particularly common in the herbaceous layer, with forbs typically peaking 15-30 days after fire and grasses around 30 days. However, when fire occurs may influence these phenological responses in different ways. In this study, we investigated the reproductive phenology of plants from the ground layer every three months for one year after fire in savannas of the Cerrado. Surveys were conducted in plots subjected to early-, mid-, and late-dry season fires, applied biennially since 2013. Reproductive phenology was recorded in 1×1m subplots across four 30×30m plots per fire season. We hypothesized that post-fire flowering would peak following late-dry season fires, because of the beginning of the rainy season. Our results revealed distinct seasonal patterns: following early-dry season fires, peak flowering occurred at 3 and 6 months post-fire, with 34% and 32% of species in reproductive phenophases, respectively. After mid-dry season fires, more than 30% of the species had reproductive structures at 3 and 12 months post-fire. In contrast, after late-dry season fires, 35.8% of species peaked in reproductive phenology 9 months post-fire. These results indicate that fire season strongly influences the timing of peak reproductive activity in Cerrado species. Notably, the highest number of species in reproductive phenophases (flowering and fruiting) was recorded during the dry season following each fire season. Understanding how fire season shapes plant phenology is essential for informing fire management and conservation strategies in fire-prone savanna ecosystems.

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LONG-TERM PHENOLOGICAL DYNAMICS OF AMAZONIAN TREES REVEAL SPECIES-SPECIFIC RESPONSES TO CLIMATE VARIABILITY

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Changes in tree phenology are important indicators of climate change across tropical forests. Detecting phenological shifts over time requires continuous long-term monitoring, but the scarcity of extended datasets limits our understanding of the cycles of long-lived tree species. Here, we use one of the longest phenological monitoring programs, based on over 50 years of monthly observations, to analyse vegetative and reproductive patterns of more than 100 tree species in the central Amazon rainforest. We characterized the timing, frequency, and duration of phenological events, and used Cox proportional hazard models to analyse their relationships with functional traits and climatic variables. Although flowering and leaf exchange tended to occur seasonally during the dry season and fruiting during the wet season, we found a gradient of interspecific variation. This highlights the complexity and plasticity of phenological responses among coexisting species. Species with higher wood density had lower reproductive frequency, suggesting a trade-off between growth/survival and reproductive investment. Lower precipitation and El Niño-Southern Oscillation (ENSO) events promoted the onset of flowering, reinforcing the hypothesis that drought conditions can act as an ecological trigger for reproduction in tropical forests. Flowering duration was shorter when fruiting had occurred in the previous semester, possibly reflecting resource allocation constraints. Fruiting frequency increased after new leaf production but decreased under ENSO drought event, suggesting that energy reserves built after leaf flushing may support reproduction, while climatic anomalies may suppress it. Fruiting duration was longer in early successional species, but also in species with denser wood which reproduce less often, and under higher rainfall in the preceding months, indicating that successional group and water availability modulate reproductive strategies. Higher temperatures shortened their duration, possibly reflecting heat stress induced on fruit development. Early successional species produced new leaves more frequently than late successional, consistent with their faster living strategies. Reduced precipitation increased leaf production, while previous reproductive events shortened the interval until the next leaf flush, suggesting linked

phenological cycles mediated by internal resource dynamics. The duration of new leaf production was longer for species with higher wood density and under higher precipitation and temperature, indicating that environmental cues and species traits jointly influence vegetative phenology. Additionally, prior leaf loss and fruiting increased the duration of leaf flushing. Overall, our results demonstrate how species-specific traits and short-term climatic variability interact to shape phenological patterns of Amazonian trees, with important implications for forest dynamics under future climate change scenarios.

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REPRODUCTIVE PHENOLOGY IN PLANT COMMUNITIES OF NEOTROPICAL SEASONAL FORESTS: IMPLICATIONS FOR CONSERVATION

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Plant reproductive phenology is a functional attribute that can provide information on biotic interactions (e.g., plant-pollinator, plant-dispersal), processes (e.g., seed germination), and ecosystem functions (e.g., pollination services and seed dispersal) for conservation projects. This information can be used in the context of restoring the conditions, processes and functions of degraded areas, as well as preserving and regenerating the natural vegetation still present. In Mexico, tropical seasonal forests comprise two major ecosystems, dry forests and temperate forests. These two ecosystems are among the most diverse, with a high degree of endemism; together they contain about 40% of Mexico's flora. However, they are the two ecosystems most threatened by human activities in the country, where more than 60% of their area has been degraded. Given this scenario of accelerated loss of vegetation cover, it is necessary to develop projects that integrate the different stages of reproductive phenology and the associated biotic and abiotic interactions. Our goal is to present a series of case studies where we explore different aspects of reproductive phenology in tropical seasonal communities of Mexico. Studies have been carried out in the dry forests of Balsas depression and the coast of the Pacific of Mexico and in the temperate forests of the tropical mountains of the Centro of Mexico. These studies are divided into a first phase of analysis of the reproductive phenology of plants and a second phase

in which we evaluate the phenology and interactions with floral visitors. Our results show that the phenology of flowers and fruits are seasonal events in the communities of tropical plants evaluated (dry and temperate tropical). The flowering of annual herbaceous species in both forests is closely related to the availability of water, mainly at the end of the rains. After the end of the rains, many herbaceous species disperse their fruits. The trees show greater variation between the forests studied, in the temperate forests they retain a flowering behavior in the spring as the species of temperate latitude and their design is highly variable. In the dry tropical forests, there are different periods of ripening of the fruits and this behavior can be explained by dispersal syndrome and the type of fruit. These results show the close relationship between the different reproductive phenophases. Therefore, community studies must try to include the complete phenological cycle of plants. On the other hand, diversity and pollinator interactions are dynamic and vary with flowering phenology and changes in successional and urbanization gradients. Our results show that the seasonality of phenological responses plays a key role in community diversity and network structure and highlight the importance of preserving sites with native vegetation to ensure the maintenance of critical pollination interactions in successional and urbanization gradients.

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REPRODUCTIVE PHENOLOGY OF ERYTHROXYLUM OVALIFOLIUM PEYR. (ERYTHROXYLACEAE)

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Erythroxylum ovalifolium is a distylous, deciduous, vulnerable species endemic to the restingas of the state of Rio de Janeiro. This study aimed to investigate the reproductive phenology of this species. The fieldwork took place at APAMAR, Maricá - RJ, involving a population of 30 individuals from March 2022 to February 2023 and from March 2024 to February 2025, totaling 24 months. Activity and intensity values were calculated for the phenophases of bud break, anthetic flowers, and immature and mature fruit. The collected data were compared against meteorological parameters, including maximum and minimum temperatures and rainfall for the city of Niterói, the nearest weather station (approximately 35 km away), from the National Institute of Meteorology (INMET), and day length data sourced from the SolarTopo website. Erythroxylum ovalifolium exhibited annual, regular, and synchronous flowering in both periods. The bud emission demonstrated high levels of activity (86% in Nov/22 and 87% in Dec/24) and intensity (56% in Nov/2022 and 58% in Dec/2024), indicating significant synchronicity and substantial bud production that occurs almost concurrently with the emergence of new leaves. Flowering lasted approximately from October to December, reaching a peak of 61% activity on Nov/22 and 70% on Dec/24, indicating high synchrony. However, the flowering intensity recorded was 23.5% in Nov/22 and 35% in Dec/24, with 2024 demonstrating the highest intensity of flowers in anthesis within the population. These characteristics resemble the "steady state" phenological pattern, where there are few flowers in the population daily over several months. This condition can favor cross-pollination, which is beneficial for distylous species. Spearman's correlation of 0.925 in 2022 and 0.843 in 2024 indicated a strong relationship between the increase in day length and flowering, showing that flowering coincides with the rise in photoperiod. Fruiting commenced in December, and ripening occurred in January in both years, with lower levels in 2022 (intensity of 44% for immature fruit and 20.5% for ripe fruit, and activity of 58% for immature fruit and 38% for ripe fruit) compared to 2024 (intensity of 37% for immature fruit and 32% for ripe fruit, and activity of 77% for immature fruit and 61% for ripe fruit). The months of January show higher levels of rainfall, which supports the dispersal of seeds germinating in Neoregelia cruenta (Bromeliaceae) ponds. We observed that the rainfall in October 2022 was lower than in the same month in 2024, when the phenophase of budbreak is more

intense. This disparity could have resulted in a lower availability of water resources in 2022, affecting the production of buds, flowers, and fruit. Climate change, influencing phenomena such as El Niño and La Niña, may affect Brazil's rainfall regime, which could potentially impact the species' reproductive success.

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REPRODUCTIVE PHENOLOGY OF A DIOECIOUS SPECIES OF SAPINDACEAE

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Members of the Sapindaceae primarily have unisexual flowers and are mostly monoecious. Dioecy may occur in certain tree species, such as Matayba marginata Radlk, an endemic Brazilian species. This study aimed to investigate the reproductive phenology of a population of M. marginata in Parque Estadual do Ibitipoca - PEI (MG). The population's phenology was assessed from February 2022 to January 2023, and activity and intensity indices were calculated. We monitored 60 individuals of the species, 28 of which were female, 30 male, and two without a defined morph. Intensity and activity values were calculated for the phenophases of bud emission, flowers in anthesis, and fruiting. The data obtained were compared with meteorological parameters (average maximum and minimum temperatures, humidity, dew, and rainfall) from the National Institute of Meteorology - INMET and day length from the SolarTopo website. Data from previous field visits (2019 - 2021) were used to complement observations on the duration and regularity of the flowering. The M. marginata population exhibited annual, regular, and prolonged flowering. The emission of flower buds showed higher activity and intensity in October (act: 42%; int: 20%) and November (act: 65%; int: 34%). In male individuals, the emission of buds began in August and reached the highest levels of activity (66.7%) and intensity (35.6%) in November. Female individuals started the phenophase later than males, in September, and reached maximum activity (32.1%) in October and intensity (71.4%) in November. The flowering of the population was observed from August to January, showing the highest values of activity (65%) and intensity (34%) in November. The flowering of male individuals began in August, with low values for activity (6.75%) and intensity (3.3%), while that of females started in October, presenting higher values (act: 43%; int: 20%). Flowering synchrony peaked in November (65%), the only month in which this value exceeded 50%. Male and female individuals exhibited different flowering strategies, with males displaying longer blooms and starting earlier, a behavior consistent with expectations for dioecious species. Fruiting occurred from October to January and recorded the highest levels of activity and intensity in December (act: 68%; int: 43%) and January (act: 68%; int: 42%). PEI experiences significant rainfall seasonality, and the peak of M. marginata fruiting coincided with the rainy season. Fruit development requires substantial

mobilization of resources, especially for forming fleshy structures such as the arils of the species' seeds, which can be restricted due to seasonal rainfall. By evaluating the relationship between phenological strategies and environmental variables, fruiting intensity demonstrated a positive correlation in the Spearman test with rainfall (0.641) and photoperiod length (0.706). These results emphasize the importance of resource availability for developing M. marginata fruit.

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SEASONAL VARIATION ON LEAF FUNCTIONAL TRAITS OF CERRADO: A COMPARISON OF LIANAS AND TREES

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Lianas are structural parasites that remain rooted in the soil and use trees as hosts to reach and remain in the canopy. Both anthropic disturbances and climate change have favored the abundance and biomass of lianas, as well as host occupation. Still, we know little about differences in environmental responses between lianas and their host trees, particularly in seasonally dry ecosystems such as the Brazilian savanna. In this study, we examined how functional group (lianas, host trees, and non-host trees) and season (dry and wet) influence leaf traits associated with photosynthesis and spectral resource acquisition in woody species within a Brazilian cerrado savanna in southeastern Brazil. During both the dry and rainy seasons, leaf samples from lianas and canopy trees were collected within a 260-hectare remnant area in the municipality of Itirapina. Thirteen leaf traits related to water, nutrient, and light responses were measured in the most frequent liana species, their respective host trees, and non-host trees. We directly observed liana leaf fall and analyzed phenological leafing patterns from a dataset collected in the same area. We found seasonal variations in leaf functional traits between lianas and trees. During the rainy season, lianas and trees (host and non-hosting) exhibited greater similarity in leaf photosynthesis-related and resource acquisition traits. Compared with host and non-hosting trees, during dry season, lianas exhibited higher chlorophyll concentrations (both Chla and Chltotal) and consequently a greater photosynthetic efficiency in this season. In addition, after the adjustment for phylogenetic effects, in the dry season we observed slightly higher specific leaf area (SLA) and leaf N and P content in lianas. Data showed that lianas exhibited photosynthetic attributes that may confer competitive advantage over trees during the dry season. Our findings indicate that lianas not present strong evidence of "liana syndrome" probably because they are mostly evergreen while their studied hosts are predominantly semi deciduous and deciduous . These findings highlight the importance of investigating season differences in photosynthetic traits and traits belonging to the leaf-economy spectrum in Brazilian cerrado savanna communities, suggesting that ecological dynamics and liana colonization strategies may be influenced by ecosystem characteristics, such as diversity and vigor of plant species of the dry season.

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HOW DROUGHT STRESS SHAPES LITTERFALL DYNAMICS IN VEREDAS OF NORTHERN MINAS GERAIS

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In tropical forests, the amount of litterfall production varies seasonally, reflecting the phenological patterns of species over time. This study evaluated litter deposition dynamics in veredas with similar climatic conditions but different levels of water deficit in northern Minas Gerais, Brazil. Veredas are wetlands characterized by groundwater discharge, acting as infiltration and water recharge zones, and maintain constant water flow in the Cerrado (Brazilian savanna). Litter data were collected between 2019 and 2024 using 30 litter traps in two veredas: Almescla (Rio Pandeiros Protection Area) and Peruaçu (Veredas do Peruaçu State Park). The Almescla vereda has surface water from the water table, supporting typical hygrophilous vegetation. In contrast, the Peruaçu vereda suffers from groundwater depletion, loss of springs, upstream river retraction, and high tree mortality. The collected litter was sorted into leaves, branches, reproductive material, and detritus, then weighed separately, and monthly deposition averages were calculated. Abiotic variables (temperature, precipitation, and photoperiod) were obtained from Brazil's National Institute of Meteorology. Data were analyzed by generalized linear models. In Almescla, stem and detritus deposition showed a positive correlation with precipitation, suggesting that increased rainfall enhances the liberation of woody detritus and stem. Reproductive material exhibited a negative correlation with temperature but positive correlations with both photoperiod and precipitation. This implies that reproductive phenology (flower/fruit fall) is suppressed by higher temperatures but favored by longer daylight hours and wetter conditions, a pattern typical of tropical wetlands. Conversely, in Peruaçu, abiotic drivers had divergent effects. Leaf was negatively correlated with temperature, likely due to drought-induced early abscission. Stem and reproductive material remained positively tied to precipitation, highlighting dependence on water inputs, and detritus and total litter showed a dual response, leading a reduced deposition under higher temperatures but increased with precipitation. These results underscore a critical shift in ecosystem functioning under water stress. The hydromorphic soils of vereda exhibit distinct characteristics in terms of fertility and moisture dynamics, remaining water-saturated and creating unique edaphic conditions. While naturally nutrient-poor with low fertility, the continuous deposition of litter leads to organic matter accumulation in surface layers. This process enhances nutrient retention capacity

in the wettest zones, forming a biogeochemical filter. These specialized soil properties show ecosystem vulnerability to climate change and drainage alterations. Thus, the lowering of the groundwater table has fundamentally altered phenological patterns, effectively decoupling litterfall dynamics from climatic drivers and threatening overall ecosystem sustainability.

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LEAF STRATEGIES IN SEASONALLY DRY TROPICAL FORESTS: THE TRADE-OFF BETWEEN INVESTMENT AND LONGEVITY

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Morphological and phenological leaf traits are functionally linked, reflecting plant strategies to optimize resource use. A high leaf construction cost requires a sufficient lifespan to maximize resource return. Therefore, we expect a positive correlation between functional traits related to leaf investment and phenological traits associated with leaf longevity. In this study, we investigated whether species that invest more in leaf construction, with high leaf mass per area (LMA), have long leaf lifespan (LLS). Furthermore, we assessed whether this relationship is influenced by aridity levels in seasonally dry tropical forests (SDTFs), using growing season length (LOS) as a proxy for LLS. We used phenological monitoring with phenocameras to track leaf phenology in 27 tree species across four Caatinga sites. Additionally, we tested for phylogenetic signal in LOS to assess whether phenology is a conserved trait among species. Our results reveal a divergence in the leaf economics spectrum. Under extreme conditions, higher LMA offers limited gains in leaf duration, suggesting trait adjustments to environmental constraints. Bimodal LOS and leaf senescence patterns indicate distinct phenological strategies independent of LMA in areas with more evenly distributed rainfall. The majority of the variation in LOS was primarily explained by species identity (20.2%), followed by site conditions (7.85%) and individual variation (7.69%), with inter-annual variation contributing to a slightly lower proportion of the variation (6.94%). Together, these factors accounted for 43.2% of the variation in LLS. When averaging values per species and mapping them into a phylogeny, we found a strong phylogenetic signal for LOS, with phylogeny accounting for approximately 50% (λ=0.49; p=0.03) of the differences among species. Phylogenetic identity overall explained ~10% of LOS variation. Our approach highlights the interplay between functional traits, phenology, and phylogeny, revealing how species identity and environment shape phenology in SDTFs.

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CHANGES IN FLOWERING PLANT COMPOSITION FROM ROCKY OUTCROPS IN THE BRAZILIAN CAMPO RUPESTRE OVER TWO DECADES

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The Brazilian Campo Rupestre is a biodiverse Neotropical ecosystem, characterized by an open fire-prone vegetation, in which plant species present adaptive strategies that can improve their resistance in face of recurrent fires. These adaptations, however, can suffer impacts when the frequencies of fire events are increased by human activities. In this study, we assessed how fire influences flowering species richness and abundance in three distinct time frames (2012, 2016 and 2024), but in the exact same sites, during the peak flowering period (from October to December) in the Campo Rupestre plant community from the the Serra do Cipó National Park and its buffer zone in the state of Minas Gerais MG, Brazil. We sampled plants in six rocky outcrop sites, placing one transect of 200m for each outcrop site, distributed from 1073 to 1205 m a.s.l. In August 2024, before the last sampled time frame, there was an intense anthropogenic fire which completely burned two of the sites, and partially other two sites, while the remaining two stayed intact. We observed that all sites, while comparing 2012 to 2016, species richness increased 45.5%-121.0% within sites (mean ± 21.50, SD 5.31), but abundance has dropped 13.8%-43.9% (mean ± 61.33, SD 46.24). This pattern indicates that within the isolated rocky outcrops, plant communities may experience some tradeoff between richness and abundance, as a consequence of competition within this space constrained environment. When analyzing changes between 2016 and 2024, plant communities showed a decline of 16.7%-61.5% in species diversity (mean ± 19.00, SD 8.79) in all the sampled areas, while an increase abundance of 8.3%-35.0% (mean ± 9.50, SD 37.48) occurred in four out of six areas. In the two completely burnt areas, species' richness and abundance were lower than those from 2016. Our results showed that species richness dropped drastically after events of fire, as seen by contrasting the areas with different levels of fire impact in 2024, but there is also significant variation through time even without considering fire (by comparing 2012 with 2016). Other important findings are that there are only few species which were common across most of the study sites, including in the completely burnt ones, such as Palicourea rigida, Cuphea ericoides, Barbacenia flava and Trigonia cipoensis. Interestingly, Vellozia nivea appeared in all the time frames, but with higher abundance in post fire

areas.Increasing knowledge about fire responses in these species will be key to understand Campo Rupestre resilience to fire disturbances.

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PHENOLOGY OF 50 TREE SPECIES ACROSS 8 YEARS IN A SOUTH ASIAN TROPICAL RAINFOREST INDICATES COMPLEX INFLUENCE OF CLIMATE, TRAITS, AND PHYLOGENY

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Tropical tree species display a diversity of phenological patterns in relation to climate, phylogeny, and functional traits. In tropical Asia, few long-term studies have monitored a high diversity of species to explore the influence of these factors. Here, we examine phenological patterns of leafing, flowering, and fruiting of 50 tree species (920-1077 trees, 10-42 trees/species) monitored monthly over an 8-y period (2017-2025) in a tropical rainforest in the Anamalai Hills of the Western Ghats biodiversity hotspot, India. Given the short duration (<3 months) dry season and absence of water limitation, we examined whether leafing and flowering were primarily related to irradiance, with fruiting distributed across the long wet season. We then quantified species-level phenological traits (number of peaks, peak month, amplitude, and duration) using signal processing analysis of monthly time series data of the proportion of individuals expressing each phenophase. We examined correlations between climate and phenological traits using local climate data. We explored whether similarity in monthly phenology was directly related to similarity in functional traits (wood density, seed size, and maximum height) or to phylogenetic relatedness using Mantel tests and investigated the phylogenetic signal of phenological traits using Pagel's lambda. Leafing and flowering were mostly (32-33 species) correlated positively to irradiance and negatively to precipitation. Fruiting of 19 species showed an opposite pattern and fruiting of 25 species was also positively related to daylength. Most (28) species showed annual patterns in fruiting, 19 supra-annual, 2 sub-annual, and 1 indeterminate (although sub-annual and continuous leafing was observed even in annually reproducing species). Dissimilarity in phenology (all phenophases) was not correlated to dissimilarity in functional traits or phylogeny, with the exception of dissimilarity in fruiting phenology (proportion of individuals with ripe fruits across months) being positively correlated with phylogenetic distance (Mantel $r = 0.12$, $p < 0.02$). Among phenological traits, peak month of fruit ripening exhibited a strong and significant phylogenetic signal ($\lambda = 0.97$, $p = 0.027$), indicating that phylogenetically closer species that have diverged recently are also closer in peak fruiting month. Species in families Lauraceae, Sapotaceae, and Myrtaceae tended to peak in pre-monsoon (April-May), Meliaceae and Phyllanthaceae in the first wet season (June-August) and Rutaceae, Euphorbiaceae, Ebenaceae, and Anacardiaceae in the second wet season (October-December). The results suggest

that climate may wield both proximate and ultimate influence on phenology, with variation in timing of fruiting constrained by phylogenetic relatedness. As phylogenetically-related species and families exhibit different fruiting windows across the year, they may be differentially impacted by ongoing climate change.

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SPATIAL AND TEMPORAL PATTERNS OF THE PHENOLOGICAL RESEARCH ON CAATINGA

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The Caatinga, a seasonally dry tropical forest in northeastern Brazil characterized by pronounced wet and dry seasons, has driven unique plant adaptations such as deciduousness and timing of phenophases. This literature review synthesizes the current knowledge on Caatinga phenology, describing observed numeric, spatial, and temporal patterns and identifying gaps for future research. A Web of Science database search yielded 16,931 publications, which were filtered to approximately 300 relevant articles. The earliest publication dates to 1997, with an average of 12 articles published annually post-2010, peaking at 25 in 2022. Geographically, 76% of publications originated from three states: Pernambuco (34%), Bahia (25%), and Paraíba (17%). The majority of studies (90%) employed ground-based phenology or herbarium analyses, while only 2% utilized near remote sensing. When reported, 50% of data collection periods were 12 months or less, and 30% ranged from 13 to 24 months. The two longest studies (8 and 18 years) used NDVI analyses, while the longest community-level ground-based studies spanned about 4 years but lacked systematic observation of the same individuals over time. Most studies focused on single species at the population level (58%), with only 5% providing community data for over 40 species (41-418). Reproductive phenology was documented in 70% of studies, vegetative in 10%, and both phases in 20%. Seasonal patterns revealed leaf fall peaking in the dry season (89% of 37 studies) and leaf flushing in the rainy season (88% of 35 studies). Flowering and fruiting occurred predominantly in the rainy season (61% of 59 flowering studies; 65% of 51 fruiting studies). Despite being a threatened biodiversity hotspot with limited remnant areas, research on Caatinga plant phenology is relatively recent (>30 years). The growth of this knowledge in last decade reflects scientific investment and the establishment of research centers, particularly in Bahia and Pernambuco. Sergipe, Alagoas, Minas Gerais, and Piauí (11% of publications) are states warrant further investigation. Long-term ground-based phenological studies, crucial for monitoring climate change impacts, are absent. Given the region's distinct seasonality and deciduous patterns, integrating near remote sensing offers a promising avenue for future research. This review highlights the current state of Caatinga phenological research and underscores critical directions for future studies in this important biodiversity hotspot.

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PHENOLOGICAL PATTERNS AND LITTER ACCUMULATION IN VEREDAS: SUSTAINED ECOLOGICAL MONITORING

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(1) Unimontes.

The study of plant phenology is fundamental for understanding the vegetative cycles of plants and how they relate to the environmental conditions of their habitat. Analyzing the periodicity of phenological phases contributes to investigations into plant responses to climate change and environmental disturbances. Litter, composed of leaves, branches, reproductive material, and debris deposited on the soil, represents an important source of organic matter, essential for nutrient cycling. The dynamics of this material's accumulation vary according to the seasonal patterns of species, reflecting phenological trends over time. In this study, we analyzed the phenological variation of litter input in two veredas with different levels of water deficit (drying), aiming to understand how hydrological conditions influence the deposition of plant material on the soil. Data were collected between 2019 and 2024 from 30 litter collectors distributed across two veredas: Almescla, located in the Rio Pandeiros Environmental Protection Area, and Peruaçu, located in the Veredas do Peruaçu State Park in northern Minas Gerais (southeast Brazil). In the Almescla vereda, surface water from the water table is present, giving the vegetation a structure typical of hygrophilous environments. In contrast, in the Peruaçu vereda, the lowering of the water table has caused spring loss, retraction of the upper course of the river, and high tree mortality. The collected material was dried in an oven and weighed on an analytical balance. The monthly averages of deposition over the years were subjected to circular statistical analysis, with phenological patterns compared using the chi-square test in the Oriana software. The results showed significant differences in total litter deposition between the two veredas. Both exhibited higher deposition concentrations at the end of the dry period, but with different peaks, in October (Almescla) and November (Peruaçu), indicating that litter production may be changing and becoming more associated with specific environmental factors. The lowering of the water table in Peruaçu has caused changes in floristic composition, leading to alterations in community phenology. The more affected Peruaçu vereda experienced a later peak in deposition compared to Almescla, suggesting that drying influences the dynamics of leaf fall and other plant debris on the soil. Thus, water deficit can modulate the dynamics of litter deposition in veredas, altering the timing of peak input. These findings contribute to understanding the effects of climate change and drought in wet ecosystems, highlighting the importance of monitoring phenological variations for the conservation of these environments. Future studies should investigate the predominant plant species in each vereda to elucidate the physiological mechanisms behind these phenological differences.

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Keynote

THE INTERNATIONAL PHENOLOGICAL GARDENS NETWORK - IMPORTANCE, CHALLENGES, RECENT FINDINGS, AND FUTURE PROSPECTS

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(1) Physical Geography / Landscape Ecology and Sustainable Ecosystem Development, Catholic University of Eichstätt-Ingolstadt.

Climate change has profound effects on natural ecosystems, and shifts in plant phenology represent one of the most well-documented indicators. Phenological onset dates are strongly correlated with preceding temperatures; however, genetic variation among individuals within a species can influence this relationship. To minimize the effects of genetic variability, trees and shrubs within the International Phenological Gardens (IPG) network are vegetatively propagated from mother plants, ensuring genetic consistency. Established in 1957, the IPG network offers a unique, long-term dataset focused on forest trees, used by researchers globally. Since 2024, the Global Phenological Monitoring (GPM) program, which specializes in fruit trees and ornamental shrubs, has been integrated into this valuable database.This keynote presentation will provide an in-depth overview of the IPG network, covering its history, core objectives, ongoing challenges - such as issues related to propagation and data continuity - and future prospects. We will also highlight recent key findings: First, our analysis of phenological plasticity in beech and spruce reveals that temperature sensitivity varies significantly by genotype and geographic location. Second, we will present long-term trends in the growing season across Europe, comparing recent decades with earlier periods to assess the extent of phenological change.These findings offer critical insights into the adaptive potential of tree species in the face of climate change and underscore the immense value of the IPG network in tracking climate-driven shifts in plant phenology.

Acknowledgement: I gratefully acknowledge the efforts of the phenological observers from the International Phenological Gardens of Europe.

Session 8

Urban Phenology and Global Change

Oral Session

PHENOLOGY IN URBAN TREE MANAGEMENT

Giuliano Maselli Locosselli[1,2]; Leticia Figueiredo Candido2[2]

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Urban tree management is essential for enhancing well-being in cities. It is built upon three key pillars: ecosystem services, species resilience to adverse conditions, and disservices. Phenology is a critical trait used to assess all three. Ecosystem services, such as thermal comfort, rainfall interception, and carbon sequestration, are directly influenced by seasonal cycles, including bud break, leaf expansion, and senescence. Additionally, cultural services are often linked to both vegetative and reproductive phenological phases. Tree resilience to extreme climate events also depends on phenological strategies, such as leaf shedding during heatwaves and droughts. Conversely, some reproductive phenology stages, such as anthesis, can contribute to allergenic impacts, one of the main disservices of urban trees worldwide. By integrating phenology into urban tree planning, cities can maximize benefits while minimizing negative side effects. Given its significance, it is no surprise that phenology is one of the most commonly measured traits in studies addressing urban afforestation.

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IS URBANIZATION INTENSITY ASSOCIATED WITH MASS FLOWERING PATTERNS IN A BRAZILIAN NATIVE PLANT SPECIES?

Kaio Murilo Leite[1]; Maria Luisa Passos Frigero[1]; Elza Maria Guimarães Santos[1]

(1) São Paulo State University.

Urbanization is a major driver of environmental change, altering local microclimates, hydrology, and ecosystem processes through the expansion of impervious surfaces. Urban environments modify local climate through the Urban Heat Island effect, creating higher temperatures compared to surrounding rural areas. This thermal change accelerates plant metabolic rates and alters evapotranspiration, directly affecting phenology. In water-limited regions, impervious surfaces reduce soil moisture, creating an Urban Dryness Island effect that further disrupts plant phenological patterns. In this context, Handroanthus impetiginosus (Bignoniaceae) was selected as a model species for this study. This mass-flowering deciduous tree is widely used in urban afforestation across Brazil and its synchronized flowering occurs during the driest period of the year. As other Bignoniaceae species, H. impetiginosus can be highly sensitive to water stress, relying heavily on internal water reserves and pre-established environmental cues. This study aimed to assess whether the proportion of impervious surfaces in urban areas is associated with beginning of flowering and its duration in H. impetiginosus. We hypothesized that greater impervious surface coverage would correlate with delayed beginning of flowering and reduced flowering duration due to increased water stress and modified microclimatic conditions. We analysed the flowering phenology of 213 individuals across the city of Botucatu, São Paulo, Brazil. The impervious surface coverage was quantified at a 10-meter resolution using land cover classification. Spearman's correlation was used to evaluate the relationship between impervious surface proportion and (1) beginning of flowering and (2) flowering duration. Beginning of flowering in H. impetiginosus showed weak, but significant negative correlation with impervious surface coverage. Conversely, flowering duration exhibited a weak positive correlation with impervious surfaces. Our findings indicate that impervious surface coverage can be related with the flowering phenology of H. impetiginosus, with an earlier beginning and longer duration in more urbanized areas. This contrasts with studies on tropical deciduous trees from Bignoniaceae family, such as Jacaranda mimosifolia and Tabebuia rosea, which typically exhibit delayed or shortened flowering periods in urban environments due to water stress and elevated temperatures. However, the presence of outliers and weak correlations suggest that other factors may also influence our findings, such as microclimatic local variations and light or atmospheric pollution effects. Future studies could explore

direct measurements of soil moisture, microclimatic conditions, and other urban factors to better understand the mechanisms behind these changes.

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Poster Session

REPRODUCTIVE PHENOLOGICAL PERIODS OF JACARANDA SPP. IN URBAN AREAS OF THE CITY OF BELO HORIZONTE, BRAZIL

Carolina Pontes Procópio-Santos[(1)]; Pietro Kiyoshi Maruyama Mendonça[(1)]; Maria Tereza Guaratini[(2)]; Leonor Patrícia Cerdeira Morellato[(3)]

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Urban environments lead to the introduction of various non-native species, creating novel ecosystems, including species that did not previously co-occur in natural environments. Jacaranda species are commonly used in urban landscaping worldwide, but how congeneric Jacaranda species modulate their reproductive phenologies and the potential consequences for interactions with other organisms remains poorly understood. In urban areas of Belo Horizonte, were monitored weekly the reproductive phenofases of trees of J. mimosifolia (non-native to the study region; 93 individuals), J. cuspidifolia (16), and J. brasiliana (8) to characterize their reproductive phenophases between September 2023 and December 2024. We observed the presence or absence of flowers, immature and ripe fruits and calculated the proportion of individuals of each species per month. All species flowered from mid-August to late November, with small variations between the three species. The flowering peak of J. brasiliana occurred at the beginning of September, with 83% of intraspecific synchrony for 2023 and 100% for 2024, while in J. mimosifolia and J. cuspidifolia the peak occurred at the end of September (84%of synchrony for 2023 in both species and 100% of synchrony for 2024 in both species). J. mimosifolia showed a longer flowering period, with more than 60% of trees producing flowers in early September and decreasing at the end of November. Differing from the other two species, that reached 60% of synchrony in early September, decreasing rapidly by mid-October. The three species showed a temporal overlap in the flowering periods, which is a matter of concern, as they exhibit flowers with similar morphology and may generate reproductive interference between non-native and native trees, with possible reduction in the efficiency of pollination. Some studies in the literature have already shown that J. mimosifolia and J. brasiliana are frequently visited by the same medium to large-sized bees, such as Xylocopa spp. and Bombus spp., and that J. mimosifolia and J. cuspidifolia are also attractive to other pollinators, such as hummingbirds. However, it is important to recognize the methodological limitations of phenological activity analyses, since other factors, such as flowering intensity, also influence plant-pollinator relationships. Therefore, to determine the actual

impacts of novel interactions in anthropogenic environments, it is necessary to further investigate the phenology and pollination ecology of these species.

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PHENOLOGICAL MONITORING OF BLUE JACARANDA IN BRAZILIAN URBAN GREEN SPACES: ASSESSING SOCIAL MEDIA ENGAGEMENT TO BOOST CITIZEN SCIENCE PROGRAMS

Leonardo César Rocha Ganz[1]; Maria Tereza Grombone Guaratini[1]; Pietro Kiyoshi Maruyama Mendonça[2]; Carolina Santos[2]; Thalita Surian[3]; Leonor Patrícia Cerdeira Morellato[3]

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Phenology is the study of periodically recurring life-cycle events of growth and development of organisms during the year which are directly influenced by temperature and precipitation. However, accurate studies on phenological shifts due to climate change remain limited by the scarcity of large-scale research. The era of online data collection facilitates the evaluation of public interest and trends in biodiversity conservation, utilizing digital tools to analyze engagement across various taxa of flora and fauna. Furthermore, recent advances demonstrate that online records, as part of digital iEcology, can provide valuable data on phenological behavior. This work seeks to: i) track Blue Jacaranda phenology to create a collaborative monitoring network aimed at enhancing awareness of climate change and ii) assess the potential of these species to stimulate public engagement in citizen science initiatives. Blue Jacaranda trees were marked, georeferenced, and monitored in urban parks, squares, avenues, and streets across São Paulo, Belo Horizonte, and Rio Claro. Data was analyzed using the Activity Index method (also known as the percentage of individuals). Seasonal patterns and differences in mean start and peak dates of phenophases were analyzed using circular statistics. Additionally, a systematic search for Instagram posts was conducted utilizing the hashtag #jacarandamimosifolia and its derivatives to monitor the global occurrence of Blue Jacaranda observations. This approach facilitated the survey of post captions, dates, and locations using targeted hashtags. Buds and flowers were recorded from September to October in the cities of São Paulo and Belo Horizonte. In contrast, Rio Claro exhibited a unique phenological pattern characterized by: (i) exceptionally prolonged floral activity extending until April; (ii) a consistent occurrence of flowering events during the summer; and (iii) a gradual transition between reproductive cycles. This behavior contrasts with seasonal pattern recorded in Belo Horizonte and São Paulo, where flowering showed more clearly defined temporal boundaries. Mature fruits were

consistently present throughout the study period, with immature fruits appearing from November on. A total of 2,050 posts were identified, of which 69% were georeferenced, covering 60 countries. This dataset allowed the analysis of monthly and annual posting frequencies related to Blue Jacaranda trees. By examining the number of posts over the months, we inferred the flowering period of the blue jacaranda, suggesting that this tool is effective for both assessing community engagement and monitoring its phenology. While online data requires validation, its synergy with traditional field methods improves reliability. Integrating traditional phenological data with culturomics reveals the Blue Jacaranda's dual value for climate studies and public engagement in urban nature.

Acknowledgement: FAPESP (2023/13377-7; 2021/10936-5), Instituto de Pesquisas Ambientais (IPA)

CAN URBAN SURFACE TEMPERATURE BE ASSOCIATED WITH FLOWERING PATTERNS OF A BRAZILIAN SPECIES WIDELY USED IN URBAN AFFORESTATION?

Maria Luisa Passos Frigero[1]; Kaio Murilo Leite[1]; Elza Maria Guimarães Santos[1]

(1) São Paulo State University.

Climate change is associated with alterations in timing and intensity of annual biological patterns, including plant phenology. These changes may cause mismatches between plants and their interacting organisms, increasing the risk of disrupting ecosystem processes such as pollination. However, changes in flowering phenology have been more frequently observed in temperate cities and are less commonly reported in tropical species. While tropical tree phenology appears mainly driven by water availability and soil moisture, rising temperatures have also been linked to earlier flowering. Urbanization replaces vegetated areas with impervious surfaces like concrete and asphalt, which absorb solar radiation and convert it into sensible heat, especially in densely built environments. This absorption contributes to urban heat islands, exposing street trees to temperatures up to 4°C higher than in surrounding green areas. We therefore hypothesize that rising surface temperatures would correlate with the timing of flowering onset in a model species. For this study, we used as species of interest Handroanthus impetiginosus (Bignoniaceae), a mid-autumn and early winter-flowering tree species native to Brazil and widely used in urban afforestation. Our aim was to evaluate whether surface temperatures in the urban landscape are associated with the flowering phenology of this species. We monitored the beginning of flowering in 213 H. impetiginosus individuals in the city of Botucatu, São Paulo, Brazil. Surface temperature values were derived from Landsat 8 imagery using MODIS RSLab emissivity, based on a time series of seven maps from March to August, corresponding to the reproductive period of H. impetiginosus. Data were analyzed using Spearman correlation. Our results showed a weak positive correlation between a high surface temperature and the beginning of H. impetiginosus flowering. In this study, the flowering onset seems to be happening earlier in the city regions with a higher surface temperature. However, we found a weak correlation between those two factors which may be explained by the fact that other parameters may be associated with changes in flowering patterns. Reduced soil moisture in urban areas can be a major triggering factor for the onset of flowering, which was not accounted in our study. Moreover, studies in tropical regions show that the association pattern between flowering onset and temperature remains unclear, with some species flowering earlier at higher temperatures and other species showing no association between these variables

at all. This was also observed in studies with other Handroanthus, which, contrary to our findings, showed no association between urban temperature and flowering onset.

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