ATBC 2021 VIRTUAL MEETING

LESSONS, ADVANCES, AND OPPORTUNITIES IN THE FACE OF GLOBAL CHANGE

JULY 21-23, 2021

BOOK OF ABSTRACTS

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ASSOCIATION FOR TROPICAL BIOLOGY AND CONSERVATION

Association for Tropical Biology and Conservation

2021 Virtual Meeting

Lessons, advances, and opportunities in the face of Global Change

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Presentation

The Association for Tropical Biology and Conservation (ATBC) is pleased to distribute the Book of Abstracts from the 57th Annual Meeting, held between 21-23 July 2021 (ATBC2021). Due to the COVID-19 pandemic, the ATBC annual meeting was held virtually for the first time, providing an inclusive space for knowledge sharing and co-construction. This meeting aimed to showcase lessons, advances, and opportunities arising from Tropical Biology and Conservation towards remediation, adaptation, and mitigation of the effects caused by global change.

The ATBC2021 program included a total of 294 delegate contributions, divided into 15 symposia, 24 lightning talk sessions, and six open format sessions, distributed among the following themes:

- Trans-disciplinary Approaches to Biodiversity Science
- Biotic Interactions in the Face of Global Change Structure and Function of Tropical Ecosystems: Challenges and Opportunities
- Restoration Ecology: Current Status and Next Steps
- Climate Change: Adaptation and Mitigation
- Planetary Goals and the Sustainable Use of Natural Resources
- Human Dimensions to Biodiversity Science Paths Towards Constructing a Sustainable Future for the Tropics
- Tropical Ecology and Conservation in an Interconnected World: Implications for How we Practice and Teach Science Tropical Ecology in the Age of Extreme Events and Societal Upheavals

We were honored to count on the participation of leaders in tropical biology and conservation from various regions of the globe who kindly shared their expertise, knowledge, and ideas during the following plenary sessions:

- How Can Scientists Make Significant Contributions to the Biodiversity Crisis
- Ecological, Economic, and Social Dimensions of Tropical Restoration: Lessons and Opportunities
- Janzen-Connell 50th Anniversary: Where Are We? ATBC Diversity, Equity, and Inclusion

Despite the virtual nature of this meeting, it also provided opportunities for social interactions, collaboration, exchange of ideas, and the development of new partnerships through the following activities:

- Cascoland: Traditional Knowledge of Food Preservation Applied to Products From the Innovative Agroecological Food Forests
- Enhance Your Communication With Creative Photography How to Get Started With Keeping a Nature Journal
- Early Career Scientist Happy Hour
- Banquet/Concert

The organization of ATBC2021 was centered around six transversal aspects that represent some of our core values, including: (i) Gender balance; (ii) Geographical representation; (iii) Diverse career stages; (iv) Multi-scale dimensions, including local, regional and global perspectives; and (v) Cutting-edge tools for data analysis and synthesis.

This book of abstracts summarizes all papers and contributions presented during the virtual ATBC2021 meeting. Links to the recordings of all sessions are provided freely, allowing anyone to learn more about tropical biology and conservation. We hope that these resources will contribute to continuous knowledge sharing, collaboration, and co-construction of new solutions in the years to come.

The ATBC2021 Organizing Committee is deeply grateful to all participants, symposium and open format session organizers, social session organizers, telecommunications staff, and all of those who contributed to this event. Thank you so much for being part of the ATBC community and joining us in our mission to foster the scientific understanding and conservation of tropical biodiversity and ecosystems.

With our warmest regards and very best wishes,
ATBC2021 Organizing Committee

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Part I

Plenary sessions

[Panel Discussion] How Can Scientists Make Meaningful Contributions to the Biodiversity Crisis?

Panelists: Patricia Balvanera, Colin Chapman, and Raman Sukumar
Moderators: Bette Loiselle and Onja Rafindratsima

Biodiversity is a crucial component of all ecosystems and essential to the well-being of our Planet. Today we have more tools than ever to study biodiversity, but we also are up against a biodiversity crisis where under "business as usual" we may lose from one-third to one-half of all species by the beginning of the next century. It is essential that scientists become fully engaged and step up to help mitigate this crisis.

This panel includes three experts who have worked to understand and monitor biodiversity patterns, to understand the couplings between biodiversity and ecosystem services, and human well-being, and to apply their science to influence forest and biodiversity policies. They offer their insights as to how scientists can contribute to a better future.

Session Recording: `https://youtu.be/C6DArXUT6ic`

[Panel Discussion] Ecological, Economic, and Social Dimensions of Tropical Restoration: Lessons and Opportunities

Panelists: Pedro Brancalion, Susan Chomba, and Fangyuan Hua
Moderators: Robin Chazdon and Jaboury Ghazoul

As we slowly emerge from local and global dislocations wrought by Covid, we need to renew our efforts once more in addressing global environmental issues of climate change, biodiversity loss, and habitat degradation. Traumatic as Covid has been, it will be as nothing as compared to the far longer lasting legacies of these environmental crises, the implications of which have yet to be fully understood, let alone realised. In tackling these crises, we quickly recognise that solutions are partial, outcomes incomplete, and uncertainties rife. Solutions are, nonetheless, available to us.

Prominent among these is the concept and practice of Forest and Landscape Restoration (FLR). FLR is variously interpreted and applied, but is essentially concerned with the recovery of ecological functions to benefit environmental and human wellbeing based on a landscape approach. The recent launch of the UN Decade on Ecosystem Restoration (2021-2030) has given FLR renewed impetus as "a rallying call for the protection and revival of ecosystems all around the world" (United Nations, 2020).

How will this vision be achieved? Or rather, how should this vision be achieved? FLR is typical of environmental initiatives in that it is, inclusively, an ecological, economic, social, and political issue (Ghazoul and Schweizer 2021). Implementation should be equitably negotiated across competing interests, while projected outcomes should take account of distributional justice concerns. Trade-offs and conflicts need to be considered and mediated. Communities must be an active part in the design and implementation process with access to viable and attractive livelihood opportunities, and benefits must be fairly distributed across all stakeholder groups.

Monitoring systems are required to evaluate outcomes and ensure that the broad objectives of FLR are achieved, considering socioecological contexts. All of this needs to be enabled by appropriate policy frameworks and governance systems, and scaled up through substantive public and private financing. A diverse array of FLR projects are already underway across the globe, led by individuals, communities, companies, and governments (Aronson et al., 2017). If implemented well, these actions bring substantial and tangible benefits to people and nature within just a few years (Griscom et al., 2017; Chazdon and Brancalion, 2019; Ghazoul and Schweizer 2021).

This Panel Discussion will explore some of the opportunities and challenges of FLR by drawing on some of these case studies, reflecting the inter- and trans-disciplinary nature of FLR. We cannot cover all of the aspects in one session, but the discussion will provide food for thought on the urgent need to frame environmental challenges through a diversity of disciplinary and normative perspectives. The panelists will also present case studies to illustrate examples of FLR challenges, benefits, and outcomes.

Session Recording: https://youtu.be/d7OqJyoMQ_4

[Panel Discussion] Janzen-Connell 50th Anniversary: Where Are We?

Panelists: John Terborgh, Phyllis Coley, and Daniel Janzen
Moderators: Rodolfo Dirzo and Liza Comita

The exuberant physiognomy of tropical forests is largely imparted by the astonishing diversity of their predominant life form—trees. What maintains such tree diversity? Numerous ideas and hypotheses have been proposed to examine and explain that question, but none of them has been as influential, stimulating and productive as the now commonly known Janzen-Connell Hypothesis (JCH). Fifty years after the publication of the landmark papers by Dan Janzen and Joe Connell, this idea is still very much relevant, and important for us to reflect on where we are in our understanding of this fundamental question, and the role JCH has played in it. In this panel, three prominent ecologists, Lissy Coley, John Terborgh, and Dan Janzen himself will present their perspectives on the significance, remaining knowledge lacunae, and future avenues in the study of the maintenance of tropical forests in the context of JCH. Hopefully, the legacy of JCH will not only continue to fuel our collective aspiration to understand tropical biodiversity but will also help us reflect and act on the urgency of its conservation given the challenges of the Anthropocene.

Session Recording: https://youtu.be/PhE0t05Edzk

[Plenary Session] ATBC Diversity, Equity, and Inclusion: Lessons Learned from the Workplace Environment Survey

Facilitators: Farrah Carrasco, Lou Santiago, Bea Maas, and Becky Williams

ATBC is committed to promoting an inclusive culture within our Association and for tropical biologists in all workplaces. During this 1-hour session, we will present the results of a workplace environment survey that had participation of ATBC members. Participation in the survey has been completely voluntary and confidential. Also, we will have a space to hear reactions/suggestions/questions from the participants in the session that will help understand how ATBC can improve in DEI aspects.

Session Recording: https://youtu.be/ZvWncd7nrFg

Part II

Symposia

Natural Resources, Science and Political Processes

Organizer:
Patricia G C Ruggiero, University of São Paulo São Paulo, Brazil

Political processes and motivations are often neglected as crucial factors across multiple spheres of conservation science and practice. From high levels of decision making, through policy design life-cycle, to pulverized on-the-ground decisions on natural resources exploitation, political motivation influences conservation outcomes in both directions, either for good or bad. Conservation policies are a suite of tools conceived to reduce human activities causing natural resources depletion and ecosystem services loss in large scale, such as land use transformations. Such policy design should be based on the interaction of multiple knowledge across steps of co-production between scientists and non-scientists. And how science is uptaken into policy discussion and which policies are implemented should depend on previous resolution of conflicts of interests and values within societies – a political process. Not rarely though political interests of a few prevail instead of a broader common ground agreement of interests and values. This is frequently observed during elections when opportunistic politicians in the office with access to levers of political power manipulate social and economic policy instruments to affect the outcomes in the ballot. If politicians have access to environmental governance, why would natural resources, such as tropical forests, be spared from this type of phenomena? We propose a symposium to discuss the relations between conservation outcomes, science, policy and politics. We aim at shedding light on the possible pitfalls of the policy-science interface and the pathways for grounding conservation policies in science; the decision making concerning the design, funding and implementation of policies and the opportunistic political motivations that affect natural resources and may offset genuine efforts towards conservation. We expect this symposium to be of relevance for scientists, practitioners and policy-makers involved with different aspects of the science-policy interface. We aimed at promoting the discussion of conservation policies and the influence of political aspects on conservation, and also expect that this space of knowledge interaction may be the basis for improving partnership and future collaboration within the ATBC.

Session Recording: `https://youtu.be/__kzC6V6I9s`

COVID-19 Pandemic as a Learning Path for Grounding Conservation Policies in Science

Renata Pardini[1], Diana Bertuol Garcia[2], Beatriz D. Araújo[1], João Pedro Mesquita[1], Beatriz Moraes Murer[1], Marcella do Carmo Pônzio[1], Fernando S. Ribeiro[1], Mariana Laganaro Rossi[1], Paulo Inácio Prado[1]

[1]University of São Paulo, Sao Paulo, Brazil, [2]University of Victoria, São Paulo, Sao Paulo, Brazil

Introduction: In a period of societal discredit in science, COVID-19 pandemic has brought science to center stage and opened a window of opportunity for the public, scientists, and policymakers, to question and learn about the role and limits of science in democratic societies, and what is needed to ground policies in science. These are critical albeit overlooked topics, central to all scientific endeavors; yet they are especially relevant to mission-oriented fields, as conservation science. **Objectives:** Here, we take this opportunity to reflect on the following key science-politics-policy issues: What conditions facilitate science politicization and politics scientization? What can be done to avoid these dangers and effectively ground policies in science? Methods: We first present the science-politics-policy issues that COVID-19 pandemic brought to light. We then argue why these issues are particularly relevant for conservation. We end up by pointing out what is needed for effectively grounding policies in science. **Results:** The pandemic broadly exposed in the media examples of science politicization and denial counteracted by claims to just follow science recommendations (politics scientization), while triggering the engagement of scientists in producing relevant information. Science politicization and politics scientization are more likely when scientific knowledge refers to two aspects that are common in conservation – complex systems and issues with multifaceted consequences. Both facilitate manipulating scientific information to support a viewpoint or political discourse. However, the role and limits of science in decision-making have frequently been overlooked in conservation. A unidirectional perspective of knowledge transference from science to policy predominates in the field, implicitly assuming that science can directly lead to decisions, and ignoring conflicts of values and interests and the uneven distribution of power among actors in conservation. We propose that grounding policymaking in science requires recognizing that: (1) science is not value-free and should be immersed in a broader process that includes conflict mediation to agree on goals; (2) science-policy partnerships should function as transdisciplinary processes; and (3) changing scientific policies and training is vital to break the vicious cycle that maintains science disconnected from society. **Conclusions:** To tackle complex, multifaceted conservation problems, we need not only science but also politics. As such, science-policy partnerships should encompass and mediate values and interests, and integrate knowledge across disciplines and stakeholders. Failing to address this diversity of perspectives within science and society deters the potential for science to support decisions and can instead lead to increased controversy and prevalence of hegemonic interests.

Keywords interdisciplinarity, knowledge co-production, knowledge integration, science education, science-practice gap, transdisciplinarity

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Preparing Scientists for Science Diplomacy Requires New Science Policy Bridges

Liz Nichols[1], Karen Lips[2], Meredith Gore[2]

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Differences between the outputs of academic science and those of science policy contribute to a critical science-policy challenge — the inability of academia to sufficiently value either the outputs of the policy process as comparable to academic outputs, or the expertise required to maintain and develop policy. Few colleges and universities adequately prepare students to become scientists with expertise operating in science-policy spaces. Consequently, most academic scientists lack sufficient training in the policy process, exposure to science-diplomacy, and capacity to deliver science advice. We argue that this has significant and negative impacts on the understanding of researchers and practioners of the structure and international flows of ideas, power and finances, including in conservation, and describe ways that adjusting how scientists teach, research and engage with policy and policy-makers can better prepare future generations to address environmental problems and connect international processes to local solutions.

Keywords science-policy networks, science-diplomacy, international environmental policy

Environmental Policies to Reduce Deforestation in the Brazilian Amazon Provide Co-benefits for Natural Forest Regeneration

Francisco J. Oliveira Filho[1]

[1]University of Cambridge, Cambridge, United Kingdom

Amazon is the planet's largest tropical rainforest and plays a key role in global climate regulation and biodiversity safekeeping. Yet, deforestation continues, and the Brazilian Amazon lost over 11,000 sq km in 2020. This loss continued the trend observed since 2015 when a tipping-point of 76% yr^{-1} was observed during a decade of consistent decrease. A much less discussed, but equally important, phenomenon, has been how the persistence of secondary forest has benefited from the environmental policies that Brazil adopted during that successful decade. For the first time, we show how command and control have contributed to the persistence of secondary forests in the Brazilian Amazon. Persistence was identified when a pixel classified as secondary forest in 2004 still persisted as secondary forest over 2014 which suggests no detectable disturbance in the natural forest regeneration process. We estimate the co-benefit promoted by three environmental policies focused on deforestation of pristine forest on the persistence of secondary forest. First, we analyzed near 100,000 fines applied in the Amazon for 2004-2014 levied from deforestation of pristine forest and we found that each fine added a further 4.5 ha of secondary forest ($p < 0.01$). Second, as an Amazon Priority County receives special operations that on inspection adds up to 5,704 ha of persistent secondary forest. Third, registration of farms in the official Environmental Registration system (CAR) adds up to 7 ha of persistence for every 1000 ha registered ($p < 0.01$). In combination, these ostensible policies to combat deforestation as well as land regularization have proved to be effective in the persistence of secondary vegetation. Nevertheless, these policies have recently been neglected by the Brazilian government. The persistence of secondary forest signals a natural regeneration process which is crucial to Brazil, to comply with the Forest Code and its international agreements on climate change mitigations and adaptation. Our study has shown that over 2/3 of the Brazilian 2030 restoration target of 12M ha could be met by natural forest regeneration.

Keywords Environmental policies, Amazon deforestation

Political Deforestation Cycles in Brazil

Patricia G. Ruggiero[1], Paula Pereda[1]

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Tropical forest loss has always been associated with multiple factors, mainly economics, that directly or indirectly increase wood extraction, the advancement of agricultural frontiers and the expansion of urban and transport infrastructure over forested areas. In a different research area, economists have long debated how politicians respond to conditions that are created by electoral processes in democratic countries. For decades, it has been demonstrated that politicians' opportunistic behavior to win elections are responsible for a cyclic manipulation of macroeconomic determinants within what is referred to as the political cycle. If social and economic policies are manipulated as a consequence of political motivation, why wouldn't forest governance be too? A nascent literature shows that political cycles are important drivers of deforestation in the tropics and that elections create conditions that affect natural resource use and management. We examine evidence for political deforestation cycles linking federal-and-state and municipal elections with deforestation at the municipal level across the most extensive Brazilian biomes: Amazon and Atlantic Forest - two tropical forests, and Cerrado and Caatinga - the Brazilian savanna and semi-arid vegetation biomes, respectively. We created a longitudinal database with 5,393 municipalities from all 27 Brazilian states by combining deforestation and electoral data between 1991 and 2014. We implemented panel regression analysis comparing election years (federal-and-state and municipal) with no election years to explore the temporal relationship between deforestation and election events. Our results indicate that political deforestation cycles occur in all observed Brazilian biomes, mainly

related to municipal election years. Nevertheless, important differences are observed when biomes are analyzed separately. The effect of elections on the increase of deforestation is at least five times higher for the Amazon, the Cerrado and the Caatinga when compared to the Atlantic Forest, for which native vegetation regulation and governance are more strict and deforestation dynamic has reduced in the last decades. Other factors such as rises in commodities prices or political alignment between different levels of government may interact with electoral events enhancing its effect over vegetation loss. Depending on institutional, legal and cultural environment, electoral processes may be an important driver of deforestation and may offset genuine efforts towards conservation. As a direct measure to reduce the range of this phenomena, we suggest to increase real-time monitoring of forests and to make deforestation data broadly available to voters during election campaigns.

Keywords elections, deforestation, political motivation, tropical forest conservation, evaluation

Advances in the Knowledge of the Functional Ecology of Andean Forests

Organizers:
Selene Báez, National Polytechnic School of Ecuador
Emilio J Vilanova, University of California Berkeley

The work that Alexander Von Humboldt and Aimé Bonpland conducted in the Andes in the early 19th century, especially their classic work in Chimborazo Mountain linking the physical and biotic attributes of tropical mountains is one of the pillars of modern ecology and biogeography. Since then, we have learned that the tropical Andes are one of the most important global hotspots for species richness and endemism, for instance serving as habitat for as much as 30,000 species of vascular plants approximately (Rahbek et al., 2019). Different forest-types in this region are also critical in providing hydrological services (Bruijnzeel et al., 2011), while storing an important amount of carbon despite covering a relatively small area compared to other forest-types (Cuni-Sanchez et al., 2017; Spracklen and Righelato, 2014). Furthermore, compared to the their lowland counterparts, montane forests have received less attention with regard to understanding their ecology, structure and function, even when these areas have one of the highest deforestation rates (Aide et al., 2019). This symposium seeks to bring together a community of scientists from different parts of the world using plant functional traits to understand Andean forest ecology. We think this symposium offers an opportunity for researchers, decision-makers, practitioners, and community leaders from around the world to broaden our view about Andean biodiversity, ecology and conservation. More specifically, our aim for this symposium is to discuss potential answers to the following fundamental questions:

- What is the current availability of functional trait data for tree species in Andean forests?
- How do functional traits relate to climatic and soil conditions in Andean tree species?
- What are the most relevant environmental drivers of community scale functional trait composition in Andean forests?
- How functional trait composition and primary productivity could shift in response to ongoing climate change in Andean forests?

These questions would be addressed in four scientific short talks and a 20-min live discussion in which participants will present different views on scientific and conservation issues relevant to a wide range of forest types in the Andes. An ultimate goal of this symposium is to enhance scientific collaboration and networking among tropical ecologists working in one of the most diverse areas of the world.

Session Recording: `https://youtu.be/lMUokx8ZMfk`

FunAndes
A Plant Functional Trait Database of Andean Tropical Forests

Luis Cayuela[1], Selene Baez[2], Juergen Homeier[3], Guillermo Bañares de Dios[1], Julia G. de Aledo[4], Esteban Álvarez-Dávila[5], Amira Apaza-Quevedo[5], Itziar Arnelas[5], Aida E Baca Gamboa[5], Natalia Bacca-Cortes[5], Marijn Bauters[6], Cecilia Blundo[7], Alexandra Bolaños-Guaranguay[7], Marian Cabrera[7], Felipe Cataño[8], Julieth Castillo-Rodríguez[8], Cayola Leslie[8], Carlos Ivan Espinosa[8], Belen o. Fadrique[9], William Farfan-Rios[10], Alfredo Fuentes[10], Claudia J. Garnica-Díaz[11], Mailyn Gonzalez[12], Íñigo Granzow-de la Cerda[12], Ana Belén Hurtado[12], Oswaldo Jadán[12], Denis Lippok[12], Rene López-Camacho[12], Manuel J. Macía[4], Lucio Malizia[13], Laura Matas-Granados[4], Esther Mosqueira-Meneses[4], Natalia Norden[14], Celina Ben Saadi[14], Hirma Ramírez-Angulo[15], Sebastian Saldarriaga Rivera[15], Beatriz Salgado-Negret[16], Norma Salinas[16], María E Solarte-Cruz[16], Sebastián Tello[16], Hans Verbeeck[16], Emilio Vilanova[16]

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Introduction / Background / Justification: The TRY initiative has the main goal of assembling and distributing published and unpublished data on plant functional traits to provide a comprehensive web-archive of the functional diversity of plants on a global scale. Despite the unprecedented data coverage of this database, there are still important knowledge gaps, particularly in highly diverse tropical areas, including the tropical Andes. To date, trait-based ecological studies in the Andes are scarce compared to other tropical regions, trait information is scattered and unstandardized, and comprehensive efforts using field information to investigate patterns of trait variability across the entire Andean region are inexistent. **Objectives:** This study aims at compiling, standardizing, and reporting the largest functional open-access trait database to date in the tropical Andes, FunAndes, which fills an important gap in global data sharing initiatives, including TRY. **Methods:** We compiled data from 17 different local trait databases in six Andean countries (from Venezuela to Argentina). Trait information includes the different axes of trait variation in plants related to leaves (e.g., specific leaf area, leaf compoundness, toughness, thickness, dry matter or foliar nutrients), wood (e.g., wood density, wood anatomy or bark thickness), and seeds (e.g. fruit type or diaspore size). Trait names and units of measurement were harmonized, and species names were standardized using the Plant List. Only records with species identifications were left in the final dataset (i.e., morphospecies were removed). **Results:** The FunAndes database has 115,306 trait records (individual trait measurements), 16,512 trait entities (individual plants or plant organs on which the measurements have been taken), representative of the functional responses of 2,829 tropical Andean species from 661 genera and 148 families. This database is composed of: (1) functional traits of vascular plant species; and (2) plot-level information, when available, including latitude, longitude, and elevation. Implications/Conclusions: Regional initiatives as the one presented here play a critical role in recovering scattered information collected at local scales to fill knowledge gaps and reduce data voids at regional scales, and thus contribute to global databases such as TRY. Furthermore, improving knowledge about functional traits in the tropical Andes will enhance our ecological understanding of a highly biodiverse region by focusing on the mechanisms that govern interactions between organisms and their environment, and can thus provide an invaluable resource to inform conservation and restoration initiatives and a baseline for knowledge regarding ecosystem functioning and services.

Keywords Functional traits; databases; tropical Andes; plants; leaf traits; wood traits

Elevation Influences Mean but Not Variance of Functional Traits in a High Andean Ecosystem

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Understanding plant species' responses to abiotic conditions is a persistent question in ecology. Mountains provide an excellent opportunity to undertake ecological questions over short spatial scales due to strong environmental changes along elevation. In the tropical high elevation Andean ecosystems, environmental harshness increases with altitude, shaping the plant's functional traits. However, understanding how to scale up this functional variation to the community level remains a challenge. As the higher environmental harshness may act as a selective filter, we expect changes in mean and variance of functional traits along the elevational gradient. Specifically, we expect conservative trait values as elevation increases, with high WD and LDMC and low SLA and Hmax. Additionally, we expect a reduction in the variance of traits in response to environmental harshness, reducing functional richness and dispersion with elevation. Five elevational transects were established in the northern area of the National Park Sumapáz, located in the Colombian eastern mountain range, encompassing High Andean Forest to shrublands at the top of the mountain. Individuals of all woody species were sampled in 97 50 m^2 plots. Four functional traits were measured: specific leaf area (SLA), leaf dry matter content (LDMC), wood density (WD), and maximum height (Hmax). Functional diversity at the community level was quantified using a single (CWM and CWV) and a multi-trait (FDis and FRic) approach. Variation across the altitudinal gradient was evaluated using a linear fixed-effect model. According to our expectations, traits associated with conservative strategies were dominant as elevation increased, and Hmax was the only trait filtered towards a narrower range. We did not find differences in functional indices along the elevation gradient. Our results showed a higher sensibility of single-trait metrics (CWM and CWV) to the environmental harshness than the multi-trait responses (FRic and FDis). Understanding how the functional composition of plant communities responds to climate gradients is critical for developing more accurate mechanistic, predictive models of ecosystem functioning under multiple climate change scenarios.

Keywords community weighted mean, community weighted variance, functional richness, Hmax, leaf

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Topography as a Factor Driving Small-scale Variation in Tree Fine Root Traits and Root Functional Diversity in a Species-rich Tropical

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Background: Fine roots, even though being crucial for multiple essential plant functions, are still understudied compared to above-ground plant organs, especially in tropical montane forests. By investigating functional traits of tree fine roots, we can gain valuable insights on below-ground resource uptake strategies, trade-offs between resource conservation and acquisition, and their association with changing environmental conditions. **Objective:** In the tropical montane forests of the Andes, local topography has an important impact on small-scale tree species distributions. There is very little species overlap between the ravine floors and ridges, even though they are only a few hundred meters apart. We wanted to find out if these differences are mirrored in the fine root traits of trees. **Methods:** We measured five fine root traits on 179 trees along a local topographic gradient in southern Ecuador. The trees were randomly selected within existing plots at 2000 m a.s.l. and represent 100 species. Using Bayesian phylogenetic multilevel models, we tested for the impact of topographic position, species identity and phylogenetic relationships on root functional traits. Furthermore, we tested if functional dispersion of root traits varied along the topographic gradient. **Results:** Roots at upper slope positions had thicker diameters, were less branched had lower nitrogen concentrations than at the lower slope. This implies that they cope with the more unfavorable soil conditions at the upper slope by a more conservative resource use strategy that favors long tissue life spans more than quick growth and high metabolism rates. Furthermore, functional dispersion decreased from the lower to the upper slope because the unfavorable conditions there lead to higher trait convergence. However, by far the largest part of variation in fine root traits was explained by phylogenetic relatedness. **Conclusions:** Our results imply that small-scale

topography is an essential predictor of ecosystem functioning in tropical montane forests, and community assembly is at least partly shaped by environmental filtering operating on fine roots. They also highlight the importance of studying functional traits on an individual or species level, and taking phylogeny into account.

Keywords Montane forests, roots, functional traits, Andes, topography, functional diversity

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Functional Traits in Neotropical Trees: The Role of Climate, Soil and Evolutionary History

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Introduction/Background/Justification: Understanding how tree functional traits vary across environmental gradients and the evolutionary origin of this variation is a central question in plant community ecology and macroecology. The Neotropical region holds a large fraction of tropical tree species (>20,000), yet large-scale studies exploring how tree traits vary with climate and soils are still scarce. **Objectives/Hypotheses:** Here, we explore how key tree functional traits (i.e., leaf size, specific leaf area, foliar nutrient concentrations, wood density and seed mass) vary in 4,000 species of Neotropical trees. **Methods:** We compiled the largest dataset to date, containing geo-referenced Neotropical tree trait data using global (e.g., BIEN, TRY), regional (e.g., FunAndes), and local databases (e.g., GEMTraits), and we constructed a phylogenetic tree for the recorded tree species. Then, the locality points of trait data collection were used to obtain climatic and soil data from various global extrapolated databases. We used Bayesian statistical techniques to explore the relative influence of climatic and soil parameters on tree trait distribution, while taking the phylogenetic effect into account. **Results:** Our initial analyses indicate that the environmental drivers of tree trait expression vary markedly between Neotropical lowlands and montane regions, and that some traits have strong phylogenetic constraints, whereas other respond in more plastic ways to environmental variation. **Implications/Conclusions:** This study provides insights into how macro-scale gradients of environmental variation and phylogeny shape the strategies of resource acquisition and use in Neotropical trees.

Keywords tree functional traits, soil, clima, Neotropics, macroecology, lowlands, mountains

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Sustaining Long Term Ecological Research in Venezuela: Opportunities and Challenges

Organizer:
Emilio J Vilanova, University of California Berkeley

Venezuela is one of the most biologically rich countries in the world. Located in the northern portion of South America, slightly above the equator, the combination of a wide range of climatic conditions with young and old geological formations, topography and elevation, influences the existence of distinct ecosystem types including different and diverse forest-types, savannas, wetlands, paramos, deserts and more across the country's landscapes. We, the organizers and presenters of this symposium, all Venezuelan scientists and citizens living inside and outside the country, in close collaboration with other international researchers and partners, have been working for decades to understand the complexity of ecological processes at multiple spatial and temporal scales. In doing so, we have followed the pioneering efforts of others that started in the 20th century making Venezuelan ecological research a key component of the scientific activity of the tropical region for many decades.

Sustaining ecological research, especially in the long-term, involves multiple practical challenges, including managing multi-institutional collaborations, complex intellectual property interests and permit processes, as well as implementing scientific training, health and safety protocols, all across multiple sites while complying with local and national regulations. In Venezuela, these challenges have become essentially insurmountable at least in the last decade because of the political and economic upheaval that has made scientific research at all levels practically impossible. This symposium seeks to bring together a community of Venezuelan scientists currently conducting important research under very complicated circumstances to highlight a few of the many long-term scientific efforts currently in place but that are also at high risk of disappearing. More specifically, our aim for this symposium is to discuss potential answers to the following questions:

- What is the current state of long-term ecological research across diverse ecological regions in Venezuela?
- How global change is affecting unique ecosystems across Venezuela?
- How the ATBC can help the Venezuelan scientific community strengthen capacity development and outreach?
- How Venezuelan scientists can collaborate in answering regional and global questions that are relevant to ATBC?

These questions would be addressed in four scientific short talks and a 20-min live discussion in which participants will present different views on scientific and conservation issues relevant to a wide range of ecological regions in Venezuela. An ultimate goal of this symposium is to enhance scientific collaboration and networking among tropical ecologists working in one of the most diverse areas of the world.

Session Recording: `https://youtu.be/NdQ4rJXc0Ag`

Synchronic and Monitoring Approaches for Understanding Climate Change Impacts in the Venezuelan High Andes

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Introduction / Background / Justification: Climate change is occurring at unprecedented rates in the high tropical Andes. An evident manifestation is the retreat of glaciers, which is happing faster than the world average. In fact, Venezuela is about to become the first Andean country to lose all of its glaciers in the midst of the worst crisis in its history, which is threatening the continuity of an important ecological research tradition in the Venezuelan Andes. Even so, understanding the consequences of climate and glacier change requires the combination of synchronic and diachronic research approaches and sustaining long-term monitoring efforts. **Objective(s):** Our general objective is to present a synthesis of current research efforts for understanding the impacts of climate change in the high Andes of Venezuela, combining long-term monitoring in permanent plots (within the context of the GLORIA-Andes network) with a pioneering chronosequence analysis of ecosystem dynamics and biotic interactions in the forefield of the last Venezuelan glacier at Humboldt Peak (4942 m). **Methods:** Since 2012 we established permanent plots in 7 summits between 3800 and 4600 m, analyzing changes in soil temperature and vegetation structure following the standard GLORIA protocol. We have also established a chronosequence of 4 sites based on a reconstruction of glacier retreat at Humboldt peak between 1910 and 2009. At each site, we studied key soil properties and estimated lichens, bryophytes, and vascular plant abundance. We also analyzed the possible role of changing growth form structure, facilitation, seed dispersal, and pollination on vegetation dynamics. **Results:** In our long-term monitoring summits we found an increase in total vascular plant species richness between 2021 and 2017, linked with an increase in the number of small herb species present. In the case of our chronosequence analyses results indicated that lichens and bryophytes play a key role as pioneers in these extreme environments. A slow buildup of soil organic matter and vascular plant cover and functional diversity could be linked to a combination of severe environmental filtering and limitations in the establishment of positive plant-plant and plant-animal interactions (e.g. seed dispersal, pollination). **Implications/Conclusions:** Results from both diachronic and synchronic studies indicate that climate change is having clear effects on vegetation structure and diversity in the high Tropical Andes of Venezuela, which could result in the development of novel ecosystems and the loss of high elevation endemics. For sustaining long-term comparative research efforts, regional/international cooperation and networking are essential.

Keywords succession, climate change, species interactions, tropical Andes, vegetation dynamics

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Recognizing the Stressors That Determine the Loss of Coastal Rivers and Their Fishes in Venezuela

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Introduction: The combination of impacts associated with global change and the expansion of the human frontier has profoundly affected the rivers and their biodiversity and today they are the most threatened ecosystems on the planet. In Venezuela the situation is dramatic because there are very few studies and programs dedicated to the spatio-temporal biomonitoring of rivers. To try to solve this deficiency, the project "Rivers at Risk in Venezuela" is being developed, where data and information useful for the conservation of hydrobiological resources are generated, collected and disseminated. **Objective/Hypothesis:** To present a summary of research efforts on biomonitoring in coastal rivers of Venezuela, specifically on the relationships of attributes of the fluvial habitats and their ichthyofaunas with the environmental and human stressors that act on different spatio-temporal scales. **Methods:** We used records (2002-2018) from piedmont rivers in western coastal drainages in Venezuela. The records include the characterization of the heterogeneity of the fluvial habitat (e.g. water types, substrate) and attributes of the ichthyofauna (e.g. diversity, abundance), among others. With these data, environmental variables (e.g. precipitation) and environmental stressors (e.g. forest cover and crops) were evaluated in spatial and temporal scales, from river stretches to entire drainages.

Results: We found gradients of integrity between rivers. The loss of heterogeneity of the fluvial habitat and fish diversity were related to a decrease in forest cover and the expansion of the agricultural frontier in the drainages. This was more evident in humid drainages with a predominance of primary and endemic ichthyofaunas. In those rivers, reference sites were chosen for future evaluations. Extraordinary drought events temporarily fragmented some tributaries, but later these were colonized by tolerant species, forming simplified communities. The above indicates a historical effect of the regional climate on the coastal rivers and the distribution of their fishes. **Implications / Conclusions:** The endemism of some ichthyofaunas makes them a reference of regional biodiversity, but the fragility of their habitats is worrying. It is necessary to continue with biomonitoring - which has been limited for many years- to recognize the trends and scope of the responses of rivers and their faunas to the impact of human and environmental stressors. Regional and international collaboration is essential for the training of human resources and the support of current and future research.

Keywords biomonitoring, climate change, integrity, stream ecology, biogeography, Ichthyology

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Impacts of Global Change on the Spatial Dynamics in Venezuela. Los Andes Ecoregion Case

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Introduction: Global change impacts biodiversity by different drivers acting at the global and regional scales. Two of these drivers are climate warming and the alteration of precipitation operating on a global scale and the land transformation, which works at a regional scale, but with consequences worldwide. In Venezuela, we have few studies about ecosystems' spatial dynamics affected by global impacts. The national network project: ECOMAP_CC, initiated in 2011, introduces a methodological approach to measure and monitor the effect of climate change on the transformation and distribution of the Venezuelan ecosystems. **Objective/Hypothesis:** In this work, we identify and analyze the impact of climate warming and land transformation as agents altering the Páramo forest spatial dynamics along the Venezuelan Andes' ecoregion altitudinal gradient. Forest loss is the main change observed at lower elevations. In contrast, a shrub encroachment into highland grasslands, and an increase in woody vegetation, is probably due to climate change. **Methods:** We carry out multitemporal studies of 57 years of land transformation at different landscapes of the Cordillera de Mérida. We present three studies based on the landscape ecology approach. A first study focused on the treeline zone and detailed the main transformation results and rate of change of the Paramo forest in almost six decades. A second study area centered on the densification of the woody vegetation. In the third study, we analyze and compare the ecosystem's potential distribution concerning the actual ecosystem cover on the high Andean mountain. **Results:** We found that the main ecosystem transition is from Páramo to the Páramo forest and from Páramo to the Montane forest. Based on the difference between the current lower Páramo limit and the Forest upper limit for 1952, the treeline border's displacement is 72.7 m in the 57 years of study, representing 12.8 m per decade. These changes are mainly driven by climate warming and are carried out through an ecological process of densification of the woody composition instead of the shrubland structure. We found that Páramo forest ecosystems practically have been replaced by the Pastures and fallow vegetation, and the Crops. **Implications/Conclusions:** The impact of climate warming, the alteration of rainfall, and deforestation on Venezuelan ecosystems, mainly in the mountain areas, shows us that it is necessary to continue this kind of research, even improving by monitoring the spatial dynamics and planning and implementing integrated global change adaptation strategies.

Keywords climate warming, treeline, land use, woody densification, páramo forest ecosystem

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More than Four Decades Monitoring the Structure and Function of Venezuelan Tropical Forests: Main Results and the Way Forward

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Have recruitment, mortality, stand dynamics, aboveground biomass and productivity of tropical forests in northern South America changed over recent decades? To answer these questions, multi-census tree data from 44 permanent sample plots distributed across Venezuela were used to analyze temporal trends and associated changes in recruitment (r) and mortality (m) rates, aboveground woody productivity (AGWP) and net biomass change (NetAGB). Generalized mixed models were used to differentiate between competition and climate or their interactions as potential drivers of forest dynamics. Venezuelan forests show increasing trends in AGB, AGWP, m and r over the last 30 years. Thirty-two plots showed a positive slope in m over time (avg. slope 0.02 % $year^{-1}$, $p < 0.001$), and regardless of region, elevation, soil fertility or climate seasonality classes, the increase in tree mortality was highly significant ($p < 0.001$) in all cases. A significant increase in the amount of biomass from dead trees (avg. AGBloss slope = 0.02 Mg C ha^{-1} $year^{-2}$, $p < 0.001$) was also found combined with a modest but steady increase in AGWP (avg. AGWP slope = 0.02 Mg C ha^{-1} $year^{-2}$, $p < 0.001$). Although a decline in AGB change was found, the magnitude was not sufficient to significantly affect the forest carbon sink (avg. slope for net AGB change = - 0.003 Mg C ha^{-1} $year^{-2}$, $p < 0.117$). Increases in AGB through time were partially and positively associated with gap-level stand dynamics (Gap Phase Index - GPI) a measure of increasing size complexity. AGWP was positively associated with gap dynamics and negatively with metrics of high stand density. Mean annual temperature was the single best predictor of the increase in m, while changes in stand dynamics (high Stand Density Index or advancing structural complexity [GPI]) were also important in some regions. In contrast, r were more responsive to stand dynamics overall, but often interacting with climate. While the effects of increasing temperatures on tree mortality is aligned with regional and global trends of massive tree die-off events in tropical and extra tropical regions, the results also suggest that natural stand dynamics in some of these long-term permanent plots is at least as important as changes in climate especially in explaining observed trends in recruitment, biomass, and productivity. Finally, we want to emphasize the great importance of long-term studies that are critical to advance our understanding of how climate change might affect tropical forests in the future.

Keywords Venezuela, Forest dynamics, Long-term permanent plots, Climate change

The Role of Agroforestry Systems in the Decade of UN Ecosystem Restoration

Organizer:
Manuel Toledo-Hernández, University of Göttingen, Germany

Human-induced ecosystem degradation, and the impacts to people and nature, shall be addressed by an unprecedent global action: The United Nations Decade on Ecosystem Restoration. Achieving ambitious UN restoration goals requires a thorough re-thinking of agricultural systems, given their fundamental importance for human development, but enormous impacts on ecosystems. Traditional agricultural systems seem to provide an alternative to intensive conventional production with robust evidence showing overall ecological, sociocultural, and economic benefits. One example is crop diversification in agroforestry systems, whereby shade trees or understory vegetation is added to tree crop systems such as cocoa, coffee or rubber, enhancing both farmer's income and ecological features. Agroforestry systems can, for example, increase carbon sequestration, secure biodiversity and ecosystem services in degraded agricultural landscapes and promote social equity in the tropics.

In this session, we will discuss the potential of cocoa, coffee, and rubber agroforestry systems in aiding global restoration efforts and human wellbeing. First, we will introduce the Global Agroforestry Network (GAN; https://www.globalagroforestrynetwork.org/),a global multidisciplinary research effort to use cocoa, coffee, and rubber production systems in the Americas, West Africa, and South East Asia as case studies to test the effects of crop diversification on socioecological systems. We will then show how the global implementation of ecological tools and machine-learning based monitoring technology affects the economics and restoration potential in cocoa production. In an example from Peru, we will discuss how biological and social diversity goes hand in hand in diversified cocoa systems and the role of farmers' involvement to inform the uptake of agricultural technologies. Finally, we look at rubber agroforestry and the opportunities diversified systems can offer for ecosystem restoration and farmer livelihoods. The session will try to facilitate collaboration between scientists from different parts of the world and will end with an open invitation to collaborate on the Global Agroforestry Network.

Session Recording: `https://youtu.be/BhBWxZ0REtQ`

The Global Agroforestry Network: Research Opportunities beyond Ecosystem Restoration in Cocoa, Coffee, and Rubber

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The key challenge for humanity in the 21st century is the role of agriculture to produce sufficient food, fibre and energy for an increasing human population. Current agricultural production systems are simplified ecosystems and rely strongly on chemical inputs to maintain crop yields under a changing climate. In contrast, recent research suggests that diversified and not simple agricultural systems can maintain crop yields and enhance biodiversity as well as various ecosystem services such as pollination, biological pest control, nutrient cycling, soil fertility, and water regulation. In major crops such as cocoa, coffee, and rubber, diversified agroforestry systems compared to monocultures play an integral role to provide benefits to people and nature. Key research gaps are the understanding of the long-term effects of diversification while taking a socioecological systems view. Here, I introduce the Global Agroforestry Network (GAN; https://www.globalagroforestrynetwork.org), a global agricultural research initiative on cocoa, coffee and rubber agroforestry to test new production strategies for instance based on large scale field experiments, machine-learning based ecosystem monitoring technology and taking a socioecological systems view. For example, field experiments in cocoa will help us to determine geographic variability of yield benefits from pollination. Automated ecosystem monitoring technology will provide high resolution data and knowledge about the ecology pollination and pest control agents in these crops. By working with farming communities we can determine downstream effects farmers' socioeconomic conditions and help effective decision making. Overall, the GAN provide important opportunities to advance on the path towards sustainable agricultural production in major crop commodities based on collaborations.

Keywords Global Agroforestry Network, Cocoa, Coffee, Rubber, collaborations, ecosystem services

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Ecological and Technological Innovations around Cocoa Pollination: A Global Perspective

Manuel Toledo-Hernández[1], Kevin Darras[1], Acheampong Atta-Boateng[2], Alma Lissette Sanchez Quiñones[2], Thomas C. Wanger[3]

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Cocoa (*Theobroma cacao* L.), one of the major traded crop commodities worldwide, is experiencing a paradigm shift towards sustainable and resilient production systems. Current global multi-stakeholder initiatives are committed to reduce cocoa-driven deforestation, preserve biodiversity and improve farmer livelihoods using farm-based innovations. However, such initiatives largely neglect the role of pollination to meet sustainable production goals, in spite of the strong crop dependance of a pollinator agent for fruit setting and yields. There are current major knowledge gaps on the identity and diversity of cocoa pollinators, their natural habitats, and their overall contribution to pollination services for improving yields sustainably. Here, we use an ecological approach (landscape and farm management) and technological innovations (i.e. pollinator monitoring methods, and hand pollination tools) implemented by farmers to address the above knowledge gaps, and identify their overall ecological and farmer benefits in key producing cocoa countries. First, we used camera-monitoring devices and sticky glue traps to investigate the effect of landscape (i.e. distance to primary forest, landscapes surrounding the farms), and farm management (i.e. shade canopy cover, and leaf-litter amounts) on pollinators in Indonesian and Brazilian cocoa agroforests. Second, we conducted large scale hand pollination experiments in Indonesia, Brazil, and Ghana to contrast the effect of pollination and chemical intensification on yields. Our results show that many insect groups, in particular small dipterans, parasitic wasps and ants, are potential pollinators and that increased shade canopy cover in agroforestry systems, but not forest distance or soil litter amounts, enhances pollinator abundance. Further, our large hand pollination experiments indicate that pollination intensification is a major contributor to enhancing fruit set, fruits harvested, and dry cocoa weight by up to 161%, in contrast to intensification with fertilizer and insecticide use. Overall, we observed that involving farmers in the implementation of ecological approaches and technological innovations helped improving their

knowledge on cocoa pollination ecology, and in case of farmers who used hand pollination tools it improved their income by up to 68%. We conclude that pollination is an important driver of cocoa yields and farmer livelihoods, thus it deserves a prominent position in current cocoa sustainability initiatives. In future, a global implementation of innovative pollination techniques will contribute to capture the full benefits of pollination services in cocoa agroforests, and hence promote sustainable cocoa production.

Keywords Agroforestry, cocoa, pollination, technical innovations, sustainability, farmer livelihoods, pollinator ecology

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Cacao Agroforests as Opportunities for Sustainable Socio-ecological Diversification in the Tropics

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Transforming tropical commodity crops, such as coffee and cacao, into diversified agroforestry systems offers multiple opportunities for improving socio-ecological production standards. However, the fast-growing demand for these commodities has led to unsustainable production, threatening associated biodiversity and human well-being. Our talk will report on some of the main findings from the DIFFCacao project, which uses Peru as a case study of fine flavor cacao systems diversification, integrating biological, social and marketing aspects. Peru is highly rich in native premium cacao varieties and biodiversity, and is the second largest producer of organic cacao worldwide. Nevertheless, limitations on farmers' access to market restrict the successful commercialization of native cacao. Through social and ecological data, we demonstrate how sustainable biodiversity management can maximize native cacao productivity and smallholder profits. With a focus on wildlife-friendly management, we investigated bird- and bat-mediated pest predation services inside smallholder cacao agroforests via functional diversity analyses. We found that distance to forest and season impacted the proportion of insectivorous bird and bat species that provide pest-control services in agroforests and adjacent ecosystems. Moreover, we found that avian insect consumption varied with the type of forest surrounding cacao agroecosystems. Our results highlight the relevance of locally-adapted agroforestry management practices and open new opportunities for wildlife-friendly cacao production in threatened and understudied ecosystems, such as tropical dry forests. With a focus on socio-economic potentials, we studied the best strategies to commercialize the biodiversity of Peruvian cacao varieties. We found that native fine flavor cacao varieties facilitate the creation of long-term commercial agreements between buyers and smallholders selling independently or through cooperatives. This promotes both socially and ecologically sustainable cacao commercialization. On the social side, such agreements guarantee premium prices for cacao, improving smallholders' livelihoods and preventing farm abandonment by increasing the chances for young farmer generations, including women with higher education, to make use of their knowledge inside the cacao value chain. Moreover, increased income and long-term commitment with buyers serve as a buffer for negative effects of market changes due to e.g. new international regulations or impacts of the current pandemic. On the ecological side, specialized markets open opportunities for cost-effective wildlife-friendly management of cacao agroforests and restoration of surrounding landscapes. All in all, cacao agroforests hold a great potential to bring together a diversity of knowledge —on farming, marketing and ecology—, which align global goals of socioeconomic development and biodiversity conservation with consumers' access to high-quality cacao.

Keywords Cacao agroforests, Ecosystem services, Sustainability, Fine flavor cacao, Functional diversity, Bean-to-bar, Smallholder livelihoods, Native cacao varieties

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Rubber Agroforestry Practices: Opportunities to Support Ecosystem Restoration and Livelihoods

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Restoration of cultivated lands can include the recovery of ecological functions and the provision of ecosystem services through changing management practices. The use of agroforestry and silvo-pastoral practices are good examples of how diversified production systems can provide multiple ecological and environmental benefits, while remaining highly productive. In the case of cultivation of Hevea brasiliensis trees for natural rubber, the area of production continues to expand, with 90% of production in Asia, and 90% of that produced by smallholder farmers. Despite a long history of rubber agroforestry in some parts of Southeast Asia, monocultural cultivation practices are now dominant in many places, and traditional agroforests continued to be converted to more intensified systems. However, there is strong evidence for soil and water degradation, biodiversity loss and some evidence for reduced climate resilience in monocultural systems, despite livelihood benefits from rubber as a valuable cash crop. Here, I present the results of a comprehensive literature review assessing the costs and benefits of rubber agroforestry systems for livelihoods, ecosystem services and biodiversity, as compared to monocultures. An increasing body of evidence shows that diversified agroforestry systems can improve soil quality, support increased biodiversity and offer livelihood benefits for farmers if designed to meet local needs. The evidence also shows the limits of agroforestry systems for supporting biodiversity and storing carbon and emphasises the clear need to protect remaining natural forests from conversion to natural rubber systems of any kind. Support for farmers to adopt agroforestry practices that work for them should be provided by government extension agencies, and by agents in the rubber industry, to ensure the long-term sustainability of natural rubber production, and contribute to forest and landscape restoration.

Keywords rubber; restoration; biodiversity; forest; ecosystem services; soils

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Plant Diversity Conservation and Agroforestry Systems: A Case Study in Seasonal Dry Tropical Forests in Colombia

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Cocoa is a major commodity crop mostly planted in small plots managed by family workforce in agroforestry systems (AFS). AFS are productive systems that combine a diverse canopy and provide opportunities for preserving biodiversity while sustaining rural livelihood. AFS are known to host a considerable amount of plant and animal diversity. AFS are not a replacement for natural forests because diversity is much lower, and they house an inadequate representation of mature forest organisms. However, AFS have a lot more diversity than monocultures with high agrochemical inputs. In Colombia, the areas of cocoa productivity overlap at large with areas of seasonal tropical dry forests (STDF). We evaluated the role of cocoa-based AFS (cAFS) in preserving plant diversity in STDF. We characterized the plant diversity in 8.1ha of cAFS, and 1ha of native forests in the department of Huila, in the upper Magdalena Valley. We found 79 species belonging to 33 plant families in the cAFS. In contrast, we found 115 species and 39 families in native forests. Eighty percent are native species, and 28% are shared with forest relicts. Farmers use plants in cAFS for food, timber and service, and up to 13% have no-declared use. Trees in cAFS include species that are important for the fauna creating ecological connectivity. Furthermore, cAFS are located near streams and rivers, contributing to the water balance in the region. We believe cAFS are instrumental for the conservation of STDF in Colombia. Promoting cAFS is an excellent productive alternative to protect this and other highly threatened ecosystems.
Project funded by Universidad Militar Nueva Granada INV-CIAS 2304, INV-CIAS 2945.

Keywords seasonally dry tropical forests (SDTF), plant diversity conservation.

Is Silvopasture a Sustainable Option to Help Tackle Deforestation?

Organizers:
Lois K Kinneen, University of Reading
Cristina Rosique-Esplugas, UK Centre for Ecology and Hydrology

Agricultural expansion is a leading cause of deforestation and biodiversity loss across the tropics. Driven by the increasing global demand for food production, the consequences of such land conversion are wide-ranging, including habitat loss, the loss of species and their key ecological functions, as well as having important environmental and social impacts. To ensure food security, whilst also mitigating negative effects of land conversion, we need research to understand and develop more sustainable approaches. Silvopasture is a well-established farming practice that has seen increased support throughout the tropics in recent years. Silvopastoral approaches are often promoted as sustainable as they may increase agricultural production per unit area and subsequently reduce the rate of forest destruction and area of land converted to agriculture.

Silvopasture research across the tropics has tended to focus on environmental impacts such as water availability, soil quality and carbon storage. Here, we take a broader approach and consider if silvopastoral systems are effective and if they can provide benefits to biodiversity and reduce deforestation, whilst also supporting the livelihoods of farmers. The symposium will cover a range of topics, including plant and invertebrate community diversity in silvopastoral systems, an exploration of farmers' perceptions of biodiversity, and the causal links that influence the uptake of this type of agri-environmental initiative.

A lack of coordination between projects on the ground, and poor communication between researchers from different disciplines can influence the longevity and success of agri-environmental initiatives. With a focus on biodiversity, we will bring together speakers from diverse backgrounds and disciplines to present different perspectives and host an engaging and dynamic discussion on the effectiveness of silvopasture to reduce the rate of tropical land degradation. Our speakers share a common ground of the same study region, in the department of Caquetá in the Colombian Amazon. This area continues to experience high levels of deforestation. Our results provide information for both farm management and policy recommendations that may promote agricultural sustainability.

Session Recording: `https://youtu.be/qP67LqCnb84`

Invertebrates as Indicators of the Conservation Value across Different Habitat Types on Farms Which Have Adopted Silvopasture

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Silvopasture, in which trees and shrubs are planted throughout pasture, is often proposed as a sustainable alternative to traditional pastureland that can increase livestock production per area, improve the livelihoods of farmers and alleviate the pressure for further land conversion. Several environmental benefits have been associated with this type of farming from improving soil quality, to promoting carbon sequestration and reducing GHG emissions. Impacts on biodiversity, however, are still relatively understudied. Invertebrates, including insects and spiders, are key components of biodiversity which perform essential ecological roles. They also respond rapidly to changes in their environments and can therefore act as useful bioindicators. By its very nature, monocultural pastureland simplifies ecosystems and results in a reduction in biodiversity and erosion of ecosystem service. Conversely, given the increased heterogeneity that comes with incorporating trees into pasture through silvopastoral practices we hypothesise that a wider range of biodiversity can be supported through this form of farming. To test this, invertebrate communities were surveyed across four different habitat types (silvopasture, pasture, forest and the transition zone between forest and pasture) across 16 different farms in the Colombian state of Caquetá. We used two sampling methods, malaise traps which were left in place for 7 days and sweep netting along three 50m transects in each habitat type. Individuals were sorted to Order and we compared patterns in abundance and community composition between the different habitats. A survey was also carried out to understand farmers' perceptions of biodiversity and see whether they had noticed any changes following the adoption of silvopastoral practices. 27,008 invertebrates were collected over two field seasons, representing 22 Orders of insects and arachnids. Significantly different community structures were surveyed using the two sampling methods, indicating that both were important in capturing the invertebrate communities across the farms. When comparing the different habitat types, the largest differences in community structure were detected between forest and traditional pasture with silvopasture hosting an intermediary community. All farmers viewed biodiversity positively and had noticed different species on their farm since implementing silvopasture. In particular, farmers observed increased visitation by vertebrate species but few noted any changes to invertebrate communities. Our results support the hypothesis that silvopasture can host a more diverse community of invertebrates compared to intensive pastureland and may support some components of forest communities. This suggests that silvopastoral systems may constitute a form of livestock management that is less damaging to biodiversity.

Keywords Silvopasture; invertebrates; biodiversity; Amazon

Effects of the Implementation of Silvopastoral Systems on Native Plant Diversity, in Pasture and Forest Habitats

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Silvopastoral systems are being promoted in tropical areas to encourage more sustainable cattle farming. Cattle ranching is one of the drivers of deforestation in the Amazon basin. The use of silvopastoral systems, where trees are planted in pastures, is considered to increase biodiversity, through their decreased need for herbicides and pesticides, and because they increase heterogeneity of the farming landscape providing a mosaic of different habitats. However, the effect of silvopastoral systems on plant diversity has been understudied compared to other well-researched environmental benefits such as increasing carbon storage, and improving water availability and soil quality. Our study investigated the effect of silvopastoral systems on plant diversity, compared to the traditional extensive grazing pastures. We also aimed to understand the effect of silvopastoral systems at a wider landscape scale, and the role they can have on the conservation of native forest. To address the impact of silvopastoral systems on plant biodiversity, we studied fifteen farms that had implemented silvopastoral systems in the department of Caquetá, in the Colombian Amazon. We carried out botanical surveys using 50m transects identifying plant species and their abundance. In total 90 pasture transects, in both the silvopastoral and

traditional pastures. In addition, using point centre quadrat transects we assessed tree species and diameter in remnant natural forest patches, and also identified and measured the size of the trees planted to make the silvopastures. A series of interviews were carried out asking the farmers their views on biodiversity and silvopastoral systems. We found 93 pasture species and nearly 300 tree species. Our results from the pasture surveys show that there was no significant difference in species richness between the silvopastures and the traditional pastures. However, we found distinct plant communities in each of the two pasture habitats. Silvopastures were mostly dominated by planted *Brachiaria* forage grasses but they had higher presence of rare species than traditional pastures. We found the remnant native forest on the farms to be very diverse, despite the fragmentation and degradation the forest in the region has experienced in the past decades. Protecting and regenerating this forest in the Caquetá region is a goal of the Colombian government. We have gathered data on how our study farms have used silvopastoral systems to intensify part of their land, which allowed other parts of the farm to be set aside for conservation purposes preventing further deforestation and allowing regeneration of the forest.

Keywords silvopastures, botany, community ecology, biodiversity, deforestation, agroforestry, sustainability, Amazon, Colombia

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The Work of Agri-environmental Initiatives in the Amazonian Region of Colombia: Uncovering the "projectitis"

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This presentation reflects on interdisciplinarity and the role of social science. It introduces the use of Institutional Ethnography (IE) to the field of biodiversity and conservation through a case study of interdisciplinary research currently being undertaken in the Colombian Amazon. The presentation identifies a key misunderstanding in interdisciplinary work and points out some of its implications in our case study to finish with some reflections. Our research explores how the offer of silvopastoral and agroforestry projects organise and re-organise the lives and environments of farmers. Using IE we began our research describing the lived experiences of farmers to then go beyond their immediate environment to map projects' offer and show how these are part of the wider economy that we have called the projectitis. The implications we point out refer to the dangers of bracketing out diversity and complexity, which include the predilection for one size fits all top down approaches to project design, funding and implementation, the curtailing of farmers' agency, autonomy and meaningful participation; the perpetuation or exacerbation of historical inequalities, losing sight of goals and marginalisation. Our methods combine ethnographic tools such as participant observation, semi-structured interviews, document analysis and mapping to explore dominant discourses that trickle down from international guidelines and agreements into national legislations, programmes and projects. These discourses translate into very concrete practices that organise and re-organise people's lives and ecosystems which we have mapped out.

Keywords social science, Ethnography, interdisciplinary research

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Silvopastoral Systems Adoption by Farmers in Caquetá: Analysis of Land Suitability

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Colombia lost more than 4.6 million hectares of forest in the last 20 years, accounting for 1.83Gt of CO_2 emissions released in the period, the main drivers being the expansion of the agricultural frontier and the transformation of forest into pastures for tropical cattle ranching. Agroforestry practices, such as Silvopastoral System (SPS), have been promoted as an alternative to conventional cattle farming, providing both environmental accountability and improved agricultural production, however the rate of adoption of these strategies by Colombian farmers is still low. This raise the question of what is the agroforestry potential for those areas with a high agriculture activity and under rapid forest cover loss? The main objective of this study is to determine the suitability of a typical department in Colombia, namely Caquetá as an example for adoption of Agroforestry and SPS from a soil quality and land use perspective. To test this a new parameter to assess the suitability of land for agroforestry was created together with an analysis of Land Use and Land cover (LULC) in the region, including a deforestation forecast for the 2020-30 period. This provides supporting evidence for in-situ studies with farmers, producers and policy makers. Using data from the Global Forest Change initiative we determined that 0.63 million hectares of forest were loss in Caquetá between 2001 and 2019, affecting 30% of the department located within the Colombian Amazon. In the next 10 years additional 0.30 million hectares of forest could be lost according to our prediction. Our agroforestry parameter shows that 83% of the area most affected by deforestation in Caquetá have a high potential to adopt more sustainable practices. Also, when recommended LULC data is added, indicates that 15% of the most deforested areas have the potential to adopt SPS or SPS-like practices. When considering our predictions for forest loss in the next ten years, the areas that could be more affected are within the municipios of Cartagena del Chaira and San Vicente del Caguan, land that at the same time have a high potential to adopt agroforestry and SPS, highlighting the importance of managing agricultural activities in the region in order to following the growing ambition within the Colombian Government to reduce greenhouse gas emissions whilst also sustainably increasing agricultural productivity, alongside conserving and restoring Colombia's forests and ecosystems.

Keywords Agroforestry Silvopastoral Colombia Caqueta Amazon Forest Sustainability

Functional Diversity Management to Generate Sustainability: A Transdisciplinary Approach to Prevent Tipping Points

Organizers:
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Jens Boy, Leibniz Universität Hannover

One of the main challenges to prevent crossing ecosystem thresholds of one state to the other is the rapid and often irreversible nature of tipping points. Additionally, in coupled natural and human systems, the impact of tipping points is not always recognized as a threat, and people usually see no reason to change their behavior towards ecosystem degradation as long as their livelihood, health, or economy are not impaired perceptibly. As such, addressing tipping points is complex, and requires a multi factorial analysis, and integration of natural and social sciences to understand the underlying processes governing ecosystem health and good science communication to engage society. For this symposium, we present scientific fundaments and motivations of studies of southwestern Amazonia as a potential blueprint of a trans disciplinary approach towards tipping points. The intention is to discuss and develop with the audience best practice approaches. Southwestern Amazonia is one of the epicenters of environmental changes leading to extreme events such as drought, wildfires, and flooding, with an increased frequency. The region shelters high diversity, and also indigenous groups and local peoples that culturally reproduce ecosystem goods and services for their livelihoods. We decided to start with soil ecosystems as the basis of the analysis of a cascade of tipping elements with respective tipping points. This is debatable as human interferences are the beginning of environmental changes, but we put societal factors to the end of the chain to accentuate the feedback to the human systems. Soil functioning plays a decisive role in the soil – plant – human chain but to what extent are they controlled by functional soil biodiversity in a biodiversity hotspot like the Amazon? Which are the biodiversity-driven underlying processes that control ecosystem resilience? How can soil biodiversity processes' knowledge be translated into viable management options? What are the key elements to develop policies to prevent the crossing of tipping points by human societies? We will focus first on ecologic indicators for the crossing of tipping points. Then, we will disentangle soil biodiversity and symbiosis as a driver of productivity and resilience in tropical regions. Furthermore, scenarios of biodiversity-based livelihoods will be discussed, and importantly, we will name societal and economic indicators necessary for policy options to manage ecosystems sustainably. On these grounds, we will identify and evaluate options to prevent passing crucial tipping points, by the governance of "functional diversity" across the biophysical, economic, and societal levels.

Session Recording: `https://youtu.be/FLsPG3-zIPI`

Exploring the Occurrence of Tipping Points in Social-ecological Systems Using Functional Diversity in a Cross-scale Resilience Approach

Alberto Andrino de la Fuente[1], Jens Boy[1], Rebecca Froese[1], Renzo Giudice[1], Diana Boy[1], Jürgen Böhner[1], Jan Börner[1], Daniel Callo-Concha[1], Elisa Díaz Garcia[2], Oliver Frör[3], Jan Goepel[3], Georg Guggenberger[3], Marcus Horn[3], Merel Jansen[3], Christopher Jung[3], Simone Kilian Salas[4], Markus Kilian[5], Elisabeth Lagneaux[3], Katharina Meurer[3], Claudia Pinzón[3], Sabina Ribeiro[3], Rüdiger Schaldach[3], Janpeter Schilling[3], Regine Schönenberg[6], N. Galia Selaya[7], Benjamin Stuch[7], Claudia Vega[7], Vanessa Vetter[7], Miguel J. Villavicencio[8], Hermann F. Jungkunst[8]

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A population of about 7 billion people is putting pressure on the Earth System, which is expected to respond not only through continuous changes but increasingly through abrupt ones undermining people's livelihoods. Adopting complex systems approaches, such as social-ecological systems (SES), support the identification of adaptive capacities of societies to these changes. Under an SES framework, humans are embedded in natural systems and profoundly affect their functions/services. An SES encompasses different interacting sub-systems, such as ecosystems (e.g. forests), production systems (e.g. timber), and governmental and non-governmental governance systems (e.g. environmental administrations or producer associations). These systems interact through feedbacks and cascading dynamics with other SESs at different spatial and temporal scales. SES's functions provide adaptability to disturbances. Such adaptability known as resilience, is a system emergent property derived from the nestedness of its components, allowing an SES to adjust its activities while performing generally the same functions and feedback processes against disturbances. An SES usually adapts to disturbances over time, but due to SES's non-linear properties, it thereby may undergo abrupt changes in its structures and functions, potentially crossing tipping points (TP) and reorganizing itself into a new, sometimes undesired different stable state. We aim to identify potential TPs, through an in-depth understanding of the SESs in the MAP region (Madre de Dios, Acre, and Pando) located in the Amazon rainforest. In our framework, we focus on relevant functions for the tipping dynamic relating land-use change and loss of ecosystem services. Since land-use change disturbances on ecosystem services are crucial to determine future directions of change towards detrimental or life-sustaining pathways for future societies. A better comprehension of MAP region's SES functioning will enable decision-makers to identify potential pathways towards fostering social-ecological resilience. We hypothesize that SES resilience is enhanced through cross-scale resilience interactions with functional social-ecological diversity and redundancy being its critical variables within and across scales. To this end, we have segmented the MAP region's SES into its interconnected underlying sub-systems: the soil ecosystem, the livelihood system, the MAP region's social system, and the regional climate system. We seek to identify early warning indicators for determining the two system thresholds of resilience; the one between resistance and resilience, and the one between resilience and a TP. The segmentation into different subsystems will provide an indication of the impact and legacy damage of disturbances, the regulatory feedback dynamics between the different subsystems, and the related potential scenarios within MAP region's SES.

Keywords Social-Ecological Systems, Spatial scale, Temporal scale, Madre de Dios, Acre, Pando, MAP region, Disturbance, Resilience, Tipping Point, Early Warning Indicator.

Unravelling Biodiversity Driven Processes and Tipping Points in Amazonian Forest Soils and Their Impact on Society and Politics

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Introduction: The critical zone, the vulnerable skin of earth, where all life-supporting processes originate, is increasingly under threat due to human intervention, especially in the tropics. Compared to the above-ground part of the critical zone in the tropics, the soil itself has received comparatively little attention when it comes to biodiversity-driven processes and the crossing of their tipping points. Filling this knowledge gap is crucial to improve preservation measures for tropical rainforests, where the main environmental threats are deforestation and the incipient change in the rainfall pattern caused by climate change. In the near future, the rainfall regime is predicted to shift to heavy precipitation events followed by longer periods of severe drought, likely to disrupt ecosystem functioning preceded by a loss in functional redundancy of the soil microbiome. **Hypotheses:** We hypothesize that natural forests offer highly different niches in soils, leading to a reinforced microbial functional redundancy and resilience to the crossing of tipping points, compared to soils under less biodiverse above-ground vegetation. Further, we hypothesize potential feedback-mechanisms of a functional-diversity driven loss in resilience of soil processes to economy, policy and governance. **Methods:** Here, we investigate into tipping point-crossing mechanisms in soil concerning the resilience of nutrient cycling as a function of microbial diversity and the resulting hot moments in greenhouse gas (GHG) emissions, both symptoms of a rapid change of habitat and livelihood. **Results:** GHG emissions directly relate to above-ground vegetation, below-ground microbial biodiversity and local and global anthropogenic human intervention: Especially during so-called "hot moments" in GHG emissions, the preceding loss of microbial functional redundancy becomes evident and therefore might be used as a proxy for upcoming tipping points in soil. Further, we found strong and short-term changes in spill-over of microbial communities from forests to adjacent agroecosystems, likely connected to observed crossings of tipping points, especially related to phosphorus mobilization from soil. **Conclusions:** Taking this together, understanding and managing of belowground diversity might be a viable tool to avoid crossings of tipping points in tropical rainforests and beyond.

Keywords tipping points, greenhouse gases, functional diversity and redundancy, resilience

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Functional Biodiversity and Local Stakeholders in Acre, Brazil: Challenges and Lessons Learned about Livelihoods and Their Contribution to Conservation

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We assume that biological diversity is directly related to sociocultural diversity. The State of Acre, located in the Western Brazilian Amazon, has around 16 indigenous peoples, as well as several riverine and extractivist communities. In all, there are 36 indigenous lands and 22 conservation units, of which 19 are for sustainable use, that is, they admit the presence of residents who share the conservation of nature with the rational use of resources. One of the instruments that contribute to the activities of use and sustainable management of protected areas, especially in indigenous territories, are the Territorial and Environmental Management Plans. These can be considered instruments of intercultural dialogue, by regulating productive activities in such a way as to establish internal and; guarantee the permanence of these resources for future generations. It is noteworthy that the state of Acre was a pioneer in the creation of these documents, which are produced in a dynamic way among indigenous peoples, civil society organizations, and the government. To exemplify an integrated social-ecological system of use and management of natural resources and biodiversity in this region, we approach a case study carried out in the Kaxinawá Indigenous Land of the Lower Jordan River with the Huni Kuĩ people. The research was carried out using transdisciplinary methods, such as focus groups, collective

guided trails, and interviews. The study portrays the relationship between the food use of forest and cultivated plant species and the maintenance of agro-ecosystems through traditional management techniques. A total of 145 food plant species were surveyed, of which 89 are native. Of these, about 60% are managed in backyards, plantations (slash and burn systems) and agroforestry systems. From this data, we infer that these integrated management systems enable the enrichment and conservation of natural systems. At the same time, it is verified that these practices are possible due to the indigenous way of life and the extensive traditional knowledge that they have built and build over thousands of years. Thus, we conclude that functional biological diversity is conserved in the dynamics of interaction between different native human groups and that this framework must be safeguarded in order to ensure the maintenance of cultures and the conservation of biodiversity resources.

Keywords Western Brazilian Amazon; Environmental Managenent Plans; Transdisciplinarity; Social-ecological system.

The Governance of Diversity: Dealing with Complex Societal and Legislative Systems to Prevent Tipping Points

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More than 30 years have passed since climate change and biodiversity loss appeared on the global political agendas. Since then, knowledge on these issues has grown considerably in all disciplines, but progress towards solving them has been very limited. Currently, climate change and biodiversity loss trigger policies worldwide, dominated by techno-scientific representations of quantifiable causes and effects often remaining alien to local perspectives. Although research, international development, and policy implementation would require thoughtful consideration and communication of the underlying concepts on the local level, time and financial limits cause a cascade of barriers regarding co-production of knowledge and implementation of environmental governance. Governance of functional diversity of ecosystems is related to a whole set of global, national and local governmental and non-governmental institutions, laws, policies and instruments. If we look e.g. at a current management plan of an indigenous land, we observe highly complex institutional and legislative settings embodying historic and current interests of the involved stakeholders who need to be heard to breathe life into regulation. Further, it requires adequate participation of the constituent groups and actors in a bottom-up approach. Policy makers and institutions need to be informed about the critical components of the system and to what extent critical levels are already reached or not. Our contribution describes a conceptual and practical approach to deal with the described context. First, we present an approach to entangle competing governmental institutions, local NGOs and other stakeholders of the MAP-region (Madre de Dios, Acre, Pando) in southwestern Amazonia. Limiting factors such as political turmoil, organized crime and the insufficient resources of environmental constituencies will be exemplified. Second, we investigate the relationship between ecosystem services, well-being and resilience to shocks of rural households in the MAP region by conducting representative surveys. In co-production with local experts and stakeholders we conduct workshops to identify the critical system components in the SES of the different countries. This information will then be used to derive indicators for system specific tipping points. We expect that critical system components vary between different socio-economic groups, depending on the sources and diversity of their livelihoods, their socio-political representation and institutional embeddedness. In our contribution we intend to propose prerequisites for good environmental governance and present for discussion which interfaces would have to be managed in a communicative way.

Keywords Governance, functional biodiversity, tipping points, MAP-region, Amazon

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Response to Wildfire: What Do We Know about Plant Community Regeneration

Organizers:
Geovana Carreño-Rocabado, CIFOR-ICRAF
Masha van der Sande, University of Amsterdam

The area of old-growth tropical forest worldwide has decreased by over 80 million hectares since 1990, and more than 100 million hectares of forest are affected by different drivers such as agricultural expansion and fires. Wildfires that destroy tropical forests are increasing every year. Between 2018 and 2019 Brazil, Bolivia and Peru were among the five countries with most forest loss due to fire. Nowadays there are millions of hectares of fire-affected forest ans savannas that are in the process of recovering. However, the speed and direction of recovery of such communities are still poorly understood. A better understanding of natural plant community recovery and resilience to fire will help design effective and efficient forest restoration plans.

Fire impacts depend on fire intensity and frequency and on local climatic conditions and global climate. To understand these responses, scientists have assessed short-term fire responses and long-term forest resilience by establishing permanent monitoring plots to. In this symposium, we will assess resilience across different forest types and using different approaches. This symposium will focus on the resilience and response to fire of tropical forest and savanna. We invite presentations of people working across different forest types including savannas, to show potential differences in their resilience.

Session Recording: `https://youtu.be/bFhG6vHiFNQ`

Drought Further Reduces Soil Water in the Forest That Has Been Burned

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Background and aims: Evapotranspiration is perennial in the Amazon Forest due to higher soil water availability. Changes in precipitation regime (due climate change) or in the forest structure can affect forest capacity to cycle water and carbon, but we still know little how soil moisture would respond to drought on a local scale or to forest degradation by fire. **Methods:** We used the Time Domain Reflectometry (TDR) method to monitored for eight years the Volumetric Water Content (VWC) in a long-term fire experiment in a transitional forest in the southeastern Amazon with three forest plots: an intact (Control), a forest burned every 3 years (B3yr) and another forest plot burned annually (B1yr; except 2008). The TDR sensors were set up to a depth of 8 m to measure for every 6 hour the VWC for eight years (2011-2018). Due to a drought event occurred in 2015/2016, we were able to test the hypothesis that extreme drought event causes a large soil water deficit, mainly in burned forests. In addition, we assessed the relationship between daily transpiration (indirect form) by the change in soil water in the dry months. **Results:** Our results showed the drought event reduced by 160 mm the VWC in the whole soil column (8 m) in the burnt forests, and a reduction of 90 mm in the unburned forest. We also observed that forests in this region can absorb water up to 8 m in drier months, and that there was an increase in the amount of water of deep soil being used by the end of dry season. **Conclusions:** The recurrence of major drought events such as 2015/2016 may start to overwhelm the recharge of water in the deep soil and have negative implications for the terrestrial carbon sink, such as increasing tree mortality in transition forests as direct effect. Our results indicate that the combination of wildfires and extreme drought events can result in abrupt reductions in soil moisture under forests, thus increasing uncertainties about recovery capacity.

Keywords Climate extremes, Wildfires, Soil moisture recharge, Forest transition ecosystems

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Fire Season Determines Tree Responses to Fire in the Neotropical Savannas - How Does It Inform Fire Management

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Fire plays an important role in ecosystem dynamics and fire regime influences the demography of plants and the vegetation structure in tropical savannas. In the Brazilian savanna (Cerrado) zero-fire policies have led to fuel accumulation and extensive late-dry season (LDS) wildfires. Since 2014, fire management has been implemented in federal protected areas centered in performing early- and mid-dry season (EDS) fires to fragment fuel over the landscape, change the predominant fire regime and protect fire-sensitive vegetation. We assessed woody plant responses to different fire regimes in shrublands and open savanna woodlands in three Cerrado PA in Northern Brazil. For four years we monitored woody species in permanent plots with time since fire (TSF) of two and three years, subjected to different fire treatments: no fire (NF); high intensity LDS fires (in September, emulating wildfires); high and low intensity EDS fires. High intensity EDS fires were associated with lower humidity (40-50%) and high air temperature during the afternoon (14-16h), while low intensity EDS fires were related to >55% humidity and lower air temperatures and were set between 17 and 19h. One year after fire, LDS and high-EDS fires resulted in higher stem mortality in two-year TSF plots, whereas in plots with three-year TSF, low-EDS fires presented higher stem mortality. Stem recruitment was remarkably lower in plots subjected to LDS fire (7%) in comparison with NF (18%) in plots with two-year TSF. Two years after fire, stem mortality was similar between treatments and fire histories. However, the rate of stem survival was significantly lower in LDS, two-year TSF plots (2-45%) compared to the other treatments (66-70%). Burned plots, especially in LDS (70%) had more stem topkill than unburned ones (2%). Fire in dryer and hotter weather conditions, especially during LDS caused more topkill in all study areas. Such information on fire effects on biodiversity can inform fire management decision, which in principle are centered in burning safety and intended to reduce wildfires size and impacts in fire-sensitive vegetation. Our data indicated that frequent

LDS fires can cause changes in vegetation structure reducing the density of woody plants. While EDS fires may benefit the recruitment of woody plants beyond the fire trap, allowing the persistence of savanna vegetation within the landscape, even under frequent fire regimes.

Keywords Cerrado; prescribed burns; vegetation structure; fire behavior

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Passive Restoration and Resilience of Dry and Sub-humid Tropical Ecosystems after Fire in Bolivia

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Passive restoration (natural regeneration) is one of the safest and most effective ways to recover areas after moderately degraded ecosystems. Likewise, although the dry and sub-humid tropical ecosystems in Bolivia were affected by fires that occurred in 2019, these apparently have an interaction with fire, which allows them to adapt to this type of event. The objective of this study was to demonstrate the ability of these ecosystems to regenerate naturally (passive restoration) and the survival that they have had after fire. The study was carried out in four dry and sub-humid ecosystems (Abayoy, Cerrado, dry forest, and sub-humid forest) in Santa Cruz state of Bolivia. Data was collected at 45 sampling points, both in burned and unburned areas. Two transect sizes were used at each point: a) 20x5 m, for tree species up to 2 m in height, and b) 50x5 m, for tree species <1 cm DBH. Species composition, number of individuals, regrowth, dead / alive, diameter, and height of individuals were recorded. The number of individuals were around 1000 to 10000 individuals / ha. The Abayoy and Cerrado have a greater number of individuals from sprout, while the dry and sub-humid forests came mostly from seeds. The Abayoy had little natural regeneration, but it was higher in burned areas and due to sprout. In Abayoy, 35% of the trees were fully alive, while in Cerrado it was 52%. In dry and sub-humid forests 70-71% of the trees remained fully alive. The complete mortality of trees, in the four ecosystems, was between 6 to 11%. In conclusion, the ecosystems studied only require management to promote passive restoration, since there are enough individuals and species that regenerate naturally and that these are higher in burned areas. Likewise, these ecosystems have a high resilience, since most could support fire and are currently alive. Survival by sprout has played a very important role in maintaining species composition.

Keywords fire, Bolivia, resilience, natural regeneration, seedling, tree survival, mortality

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Fire Resilience of Dry Tropical Forests in Bolivia

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Wildfires are becoming an increasingly dominant force in the tropics as a result of complex interactions between socio-economic, political, and ecological factors. Despite representing one of the most threatened biomes in the tropics and being at high risk of fire, seasonally dry tropical forests (SDTF) generally remain understudied and it remains unclear whether more frequent wildfires result in significant long-term changes for the vegetation. This study investigates how fire recurrence and environmental factors affect the resilience of the vegetation to fire disturbance in the Chiquitano SDTF in Bolivia, one of the largest dry tropical forest systems in the Neotropics. The impact of fire and post-fire vegetation recovery were monitored for forested areas across the Chiquitano SDTF that burned once, twice, and three times between 2000 and 2020 and compared to unburnt forests. Recovery was analysed using time series of the Normalized Burn Ratio (NBR) index derived from Landsat satellite imagery and various topographic, climatic, and environmental variables obtained from the cloud computing platform Google Earth Engine. Preliminary results suggest that the Chiquitano SDTF may show some adaptation to fire as fire frequency increases, with climatic and topographic factors playing an important role in attenuating the effects of fire. This study is the first to investigate the fire resilience of the Chiquitano SDTF at a large regional scale, in a region which has seen an unprecedented increase in fire intensity and frequency in recent years. The results help improve our understanding of the ability of the Chiquitano SDTF to withstand fire disturbance and transition into a more fire-adapted state, which is of importance to forest and fire management in the region and dry tropical forests globally.

Keywords Resilience, Dry tropical forests, Bolivia, Fire

Death by a Thousand Cuts: Insect Declines in the Anthropocene

Organizers:
Carlos Garcia-Robledo, University of Connecticut
David L. Wagner, University of Connecticut

We will first address the different anthropogenic factors generating insect declines, and how such declines affect virtually all ecological processes - from biotic interactions to ecosystem functioning. Finally, the symposium highlights two recent empirical studies on insect declines. The first explores long-term patterns in insect declines in a guild of tropical rain forest insects. The second study focuses on demographic processes of insect declines along tropical mountains, and how global warming is already affecting incipient insect speciation, specially in hybrid zones. The last section of the symposium will be a discussion on the challenges and actions needed to detect and mitigate global insect declines.

Session Recording: `https://youtu.be/OFNJ43wFP2Q`

Anthropogenic Assaults on Darwin's Endless Forms: A Synopsis of Global Insect Decline

David L. Wagner[1]
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There are an increasing number of reports of insect declines–in abundance, alpha diversity, biomass, and range sizes–from across the globe with reports from Europe and areas on North America the most well documented. With the exception of the recent reports from northern Costa Rica, the most severe examples of declines are from Northern Hemisphere anthroposcapes: regions of high human population density and intensive agriculture. Population trends vary considerably spatially, by guild, and taxon, which suggests that multiple stressors are in play that yield a heterogeneous set of winners and losers. Rates of decline for dietary and ecological specialists are steeper than those for ecologically generalized taxa. In temperate areas, many taxa limited historically by abiotic, particularly climatic, factors are increasing in range. The most important continental-scale stressors include reductions in quality and quantity of habitat resulting from land-use change, climate change, and atmospheric nitrification. Site-specific stressors include pesticide and herbicide use, light pollution, introduced biological control agents, fertilizer use, and other types of environmental pollution. Findings from tropical studies are emphasized.

Keywords insect decline; climate change, deforestation

Long-term Trends in Interaction Diversity in a Tropical Lowland and Tropical Highland Forest

Danielle M. Salcido[1], Lee Dyer[1]
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The fate of tropical insect diversity is at the confluence of extremes. Extremely constraining natural histories, physiologies and dispersal abilities convene with Anthropogenic extremes including rapid deforestation rates, unregulated pesticide use and increased incidences of climate anomalies. Scientists have predicted such a scenario can potentiate significant losses to tropical insect diversity and modifications to ecosystem structure and function. We examined long-term trends in plant-caterpillar-parasitoid interactions, to evaluate changes in species and interaction diversity and ecosystem function for two tropical sites: a lowland tropical forest in Costa Rica (22-yrs) and a cloud-forest in the Ecuadorian Andes (16-years). We applied time-series analyses to examine temporal trends, Bayesian hierarchical modeling to evaluate genus-level patterns in caterpillar encounter frequencies across years and structural equation modeling to test causal hypotheses among diversity trends and climate extremes. We found substantive climate-driven declines in caterpillar and parasitoid diversity and their interactions at the Costa Rica site- not the Ecuador site. Models for which there was the greatest support indicated increases in temperature and precipitation anomalies were associated with these reductions in diversity. Similarly, parallel declines in parasitism by specialist parasitoids were associated with precipitation anomalies and their one-year time lag. These results demonstrate that while not all tropical sites are experiencing extreme losses, where declines do occur, they do so rapidly and with major consequences to upper trophic levels. In addition to changes in flooding regimes and droughts, continued land-conversion to high-input high intensity agriculture in the periphery of protected lowland tropical forest threatens species assemblages within.

Keywords insect decline, tropical , climate-change, plant-insect interactions

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Tropical Mountain Passes Become Higher with Global Warming: Demographic Attritions and Extinctions of Incipient Insect Species along Tropical Mountains

Carlos Garcia-Robledo[1]
[1]University of Connecticut, Storrs, CT

The "mountain passes" hypothesis proposes that species present at different elevations along tropical mountains are adapted to the constant annual temperatures prevalent at each life zone. Although previous studies focus on the physiological responses of organisms, we argue that a more rigorous test of this hypothesis is to study how population dynamics and fitness change with elevation. A demographic approach will also allow us to predict if populations will increase or decline as global temperatures increase. *Cephaloleia belti* (Chrysomelidae) is a beetle species specialized on plants in the order Zingiberales. This species is broadly distributed from 50-2100 m asl along the La Selva-Barva Volcano transect in Costa Rica. We discovered that high and low elevation populations of C. belti have distinct mitochondrial haplotypes. The high-elevation haplotype is adapted to cold temperatures, and the low-elevation haplotype is adapted to warm temperatures. High and low elevation haplotypes mate and produce viable hybrids. Using an experimental demography approach, we raised >5000 individuals of both haplotypes and their hybrids in the laboratory, at temperatures from 10 °C to 35 °C. Using a novel modeling technique that connects fitness estimates with temperatures recorded along the Barva transect every half an hour for four years, we calculated fitness at current and future temperatures for haplotypes and hybrids. This study focuses on the following questions: 1) how close are insect haplotypes and hybrids' fundamental thermal niches to temperatures associated with population declines? 2) Will populations become extinct if they are unable to disperse to higher elevations? 3) Will high elevation ecosystems become suitable habitats as temperatures increase? Finally, 4) will climatic stability along tropical mountains promote physiological adaptation, and ultimately speciation? Our results show that with a temperature increase of 2 °C, haplotypes will become extinct in their low elevation ranges, but high elevations may serve as climate change refugia. Hybrids are maladapted and can only survive at middle elevations. Our results show that mountain passes are even higher than previously thought, because locally adapted insect populations, especially insect hybrids, display very narrow thermal ranges at which populations may persist.

Keywords Insect declines, global warming, demography

A Thousand Cuts to Costa Rican Insect Biodiversity: Be Kind to the Survivors

Daniel H. Janzen[1]
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Winnie and I have been superficially studying and living in a tropical insect refugee camp since the 1960's, and more attentively since the mid-1980's. As tropical biodiversity ecologists, "insectometers" if you will, we have been nudged and pulled into seeking solutions to the death and flight of the wild inhabitants from their former encampments, villages, farms and cities. We are not testing hypotheses so much as close-up observing the grim realities on which to base practical actions. Our focal animals are caterpillars and the multitude of their consumers and food. Our observational teams are Malaise traps, light traps, and the eyes and care of about 30 Costa Rican resident parataxonomists, They are all precariously integrated with a diverse array of national and international collaborators: taxonomists, molecular explorers, industrial biodevelopers, conservationists, administrators, private and government funders, and 5,000,000 Costa Rican citizens and their governments. The results, due to these diverse national and international collaborations, are 36 years of intense evolution of a classical national park structure (Parque Nacional Santa Rosa) into Area de Conservacion Guanacaste (http://acguanacaste.ac.cr) in northwestern Costa Rica. ACG is 1,690 km^2 of sustainably biodeveloped wild-land "hacienda" delivering social goods and services. Among these are massive restoration and conservation of at least 650,000 multicellular species wiggled among at least a million species of Costa Rican terrestrial wild residents throughout a quarter of the country's 50,000 km^2. These insects are glue, structure, nodes, partitions, vocabulary, syntax, regulators, nouns and verbs throughout. And they are now taking a massive hit from omniscient current impacts. This is quite aside from the 400+ years of European-style farming, hunting, burning, logging, pesticiding and deforestation that ACG suffered before it was flipped out of the broken agroscape and

into being a restoring national park in 1971. That restoration is in full swing, but it can no longer approach the "original" while enduring the climate change scenario we are living. Today's insect survivors, and all that come with them, are now tomorrow's colonists in their brave new world. Be kind to them. Come to know who they are, what they do, what they offer, where they live, and how to welcome them to the negotiation table. And get that on the web, public domain.

Keywords tropical biodiversity, conservation, sustainable use

Human Wildlife Coexistence in Africa

Organizers:
Leandra Merz, University of Florida
Tierney Shimansky, University of Florida

While humans have always interacted with wildlife, the scope and intensity of these interactions continues to increase. Many of these interactions are helpful or even neutral, but some can cause harm to human, wildlife, or both. These negative interactions are termed human-wildlife conflict and can include predation, crop raiding, habitat loss/degradation, disease transmission, poaching or killing of wildlife, and invasive species. When wildlife cause damage to humans and/or human livelihoods it can create animosity, which can lead to retaliatory or pre-emptive killing of wildlife. Finding ways to mitigate conflict and promote coexistence of humans and wildlife in shared spaces is vital for the survival and well-being of humans and wildlife.

This symposium will highlight some of the challenges and successes of conservation projects aimed at promoting human-wildlife coexistence throughout Africa. Our presenters will share insights from multiple projects throughout the continent. It will close with a roundtable discussion between participants on how we can use the insights and lessons learned to improve human-wildlife coexistence throughout Africa. While the symposium focuses on human-wildlife coexistence in Africa, the broad challenges and insights are relevant to other regions throughout the tropics.

Session Recording: `https://youtu.be/P_nkuxHOi7I`

The Complexities of Human-wildlife Coexistence in Zambia's Game Management Areas

Leandra Merz[1]
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Human-wildlife coexistence is vital for conservation, but can be challenging to successfully promote. Protected areas borderlands are often vital for both human and wildlife populations, but human-wildlife interactions can result in conflict. Human-wildlife conflict is an interaction that has a negative impact on one or both parties, for example, crop raiding, livestock predation, poaching, habitat destruction, and disease transmission. Tolerance, or the willingness to accept additional costs of living with wildlife, is necessary for human-wildlife coexistence. By understanding tolerance levels and how they are formed, conservationists can design interventions targeted at improving coexistence. For this study, the author conducted 68 semi-structured interviews in a Game Management Area (GMA) outside North Luangwa National Park in Zambia. Interviews included free-listing, pile sorting, and ranking of common wildlife species. Participants experienced many direct costs from living with wildlife, but a complex and nuanced understanding also incorporated the current and potential benefits of wildlife through the local community based natural resource management (CBNRM) project. While negative attitudes were correlated with intolerance, positive attitudes were not as strongly correlated with tolerance and varied greatly across species. Ultimately, tolerance for conflict species was low, despite many positive attitudes toward these species. This study highlights the complex factors involved in determining tolerance of wildlife and the ability of humans to coexist with wildlife.

Keywords Wildlife conservation, tolerance, human-wildlife conflict, North Luangwa National Park

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Human-dog Relationships across Communities Surrounding Ranomafana and Andasibe-Mantadia National Parks, Madagascar

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Introduction / Background / Justification: This abstract is based on ethnobiological research on human-dog relationships in several rural communities of eastern Madagascar. This research advances our knowledge of human-dog relationships, along with the threat to domestic animals and wildlife by dogs (non-native carnivores) in biodiversity hotspots such as Madagascar, where these are understudied and relatively unknown. Domestic dogs (Canis lupus familiaris) are estimated to be one of the most globally abundant invasive carnivores that threaten wildlife. Madagascar is not only home to large populations of free-roaming dogs but also has high diversity, endemicity and is an anthropogenically-threatened environment, making it one of the world's top conservation priorities. **Objective(s)/Hypothesis(es):** Here, we report on the results of surveys aimed at understanding human-dog relationships, gaining insight on free-roaming dog behavior, and assessing the acceptance of humane population control measures such as Trap and Neuter, across rural and anthropogenically-threatened landscapes. **Methods:** We surveyed rural and multi-ethnic dog owners and non-dog owners above 18 years of age, that brought their animals to mobile veterinary clinics to avail free spay/neuter surgeries, anti-rabies vaccinations, de-worming, and medical treatment, in communities within and around Ranomafana National Park (RNP) and Andasibe-Mantadia National Park (AMNP). **Results:** We found that amongst dog owners, the vast majority of respondents reported owning their dog for protection and a significant number had dogs for companionship. Free-roaming (owned, unconfined) dogs may be an underappreciated threat to endemic wildlife in the National Parks of Madagascar, as nearly half of dog owners reported that their dog killed at least one wild animal a month. Most dog owners in surveyed communities approve of spay/neuter/vaccine programs and stated that they would use them if freely available. **Implications/Conclusions:** Our results inform the complex and understudied human-dog relationships in rural and developing landscapes, highlighting the underappreciated threat of free-roaming dogs on native wildlife in biodiversity hotspots, and the significance of its cultural acceptance by local communities. Our results further indicate that in this protected landscape within Madagascar, veterinary intervention is locally accepted, and can be an important tool in humanely controlling free-roaming dog populations in these regions.

Keywords Madagascar, Dogs, Carnivore-predation, Human-animal interaction, Conservation biology, Biodiversity hotspot

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The Effects of Governance Type and Scale on Community Conservation in Southern Africa

Tierney Shimansky[1], Brian Child[1], Leandra Merz[1]

[1]University of Florida, Gainesville, FL

Community based natural resource management (CBNRM) concerns the governance, management and use of natural resources, and wildlife in communities where livelihoods depend on the natural environment. Despite the agreement on the importance of CBNRM, performance is often disappointing, frequently because of weaknesses in governance, participation, and equitable benefit sharing. This study assesses the importance of Ostrom and Murphree's call for inclusive decision making of all people impacted by the decisions through face-to-face participatory governance structure in small communities like villages. We examine how much indicators of governance (e.g., trust of leaders with money, general opinion about governance, use of money for community benefits versus other uses) vary, and how this variability is affected by the enabling environment (i.e., country), community size, and type of governance (i.e., participatory versus representational). Chi-squared and logistic regression models are used to analyze data from "governance dashboard surveys" from seventeen CBNRM communities in Botswana, Namibia, Zambia, and Zimbabwe that include both small village and multi-village communities. The findings of this study support the hypothesis that variability in member satisfaction is affected by factors such as country and the enabling environment, community size, type of governance, and overall satisfaction with the community-based organization. The results from this study imply that the design of CBNRM organizations and processes needs to be more cognizant of Ostrom's and Murphree's principles, suggesting that participatory practices that are possible in small communities provide significant advantages in terms of financial transparency, social capital formation (trust), participation, and member satisfaction.

Keywords Community Conservation, Southern Africa, Governance, Natural Resource Management, Human-environment interactions

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Weathering the Storm: Responses of Forest Wildlife to Hurricanes

Organizer:
Alison M Behie, The Australian National University

Over the last 13 years, the world has lost 43 million hectares of forest, meaning that wildlife that reside within these areas are being subject to habitat loss and increasing reliance on human modified landscapes. This alone will have significant impacts on both human and wildlife populations, however, when coupled with expected increases in natural disasters due to global climate change, this puts such wildlife populations in double jeopardy of extinction due to destruction of an already shrinking and modified habitat and a human population under greater stress. Despite this very real possibility, there are still relatively few studies that explore the impact of natural disasters on wildlife populations and those that do rarely compare responses across species. This symposium is designed to fill this gap by showcasing research done across different species of forest dwelling mammals that focuses on responses to and recovery from a hurricane event. While each presentation will focus on a single species, the discussion panel at the end will identify unified themes among animals to build a better picture of what features of species behaviour, biology, ecology or physiology provide the best resilience to natural disaster exposure. This symposium will thus provide novel information about how we may expect species to respond in the context of their overall behaviour and ecology to better mitigate future impacts of severe wind events in tropical forests.

Session Recording: `https://youtu.be/Csc-cLx5CxI`

Long-term Monitoring of a Primate Population following a Major Hurricane

Alison M. Behie[1], Mary Pavelka[1]
[1]The Australian National University, Canberra, Australian Capital Territory, Australia

The majority of the world's primates currently live in anthropogenically modified habitats. When coupled with predicted increases in natural disasters due to climate change, this will place numerous primate populations in double jeopardy of extinction. While many studies have documented the short-term impact of natural disasters on primate demography and behaviour, to date, very few have reported on the long term impacts. Such long-term data, however, is key to understand population adaptations in the context of bigger term ecological changes. In this study, we analyse 17 years of post-hurricane demographic data from a population of black howler monkey (*Alouatta pigra*) hit by a hurricane in 2001 to assess long-term patterns of population change. We collected pre-hurricane demographic data immediately before the hurricane and post-hurricane data was collected bi-monthly from 2002 – 2007 and then twice per year from 2008 - 2018. We also collected 20m x 20m ecological plots through the study site once per year. Before the hurricane, the population density was 101 individuals/km^2, which dropped to a low of 24 individuals/km^2 in 2004 where it remained until 2007. This then began to increase to a post-hurricane high of 88 individuals/km^2 in 2009 where it stabilised and remained through 2018. Group size followed a similar trend, with an initial drop from pre-hurricane levels of 6.67 individuals/group to a low of 5 individuals per group in 2002. This then increased to a peak of 8.3 individuals/group in 2009 where it has remained relatively constant since. This rise in both group size and population density is associated with changes to patterns of births and infant survival. Birth rate reached a high in 2009 of 0.65 infants born per female, higher than even the pre-hurricane rate of 0.41 births per female and while no infants survived in the first year post-hurricane, infant survival post-hurricane increased quickly to pre-hurricane levels. These results show that 17 years post-hurricane, group sizes have stabilised and birth rates increased, however, the population is still not at its pre-hurricane size. This is in part due to an overall reduction in the number of adult males in groups, indicating higher dispersal rates. It is also likely due to post-hurricane changes in forest structure including reductions in key food resources such as *Ficus* spp. and associated increases in pioneer species.

Keywords primates conservation, hurricanes, climate change, adaptation

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Invasive Mammal Responses to Experimental and Natural Hurricane Effects in Wet and Dryland Tropical Forests of Caribbean Islands

Aaron B. Shiels[1], Gabriela Ramírez de Arellano[1], Laura Shiels[1]
[1]USDA, Fort Collins, CO

Small mammals that are non-native and invasive species, such as rats (*Rattus* spp.), house mice (*Mus musculus*), and mongoose (*Herpestes auropunctatus*), occupy many of the world's tropical islands and threaten populations of native and endemic plant and animal species. Hurricanes are common to many islands where these invasive wildlife species reside. We studied the changes to invasive rodent and mongoose populations following natural and experimental hurricanes in four Caribbean islands. Our specific objectives were to determine: 1) how invasive small mammal populations change after severe hurricanes, 2) if islands suffer new invasions of wildlife following hurricanes, and 3) how the separate and combined effects of canopy openness and debris deposition (i.e., the major hurricane effects in forests) alter invasive rat populations and their effects on seed predation. We used tracking tunnels, which are baited ink cards placed in tunnels so that footprints of animal visitors could be identified, to determine presence and relative abundances of invasive small mammal species prior to and following two severe hurricanes (Irma and Maria) passing over Puerto Rico and three U.S. Virgin Islands (USVI): St. Croix, Green Cay, Buck Island. We used vertebrate exclosures and trail cameras to document animal species removing seeds of dominant trees from 30m x 30m hurricane gaps created in the Luquillo Experimental Forest (LEF) of Puerto Rico. In USVI, we found that: 1) black rats (R. rattus) invaded and established, possibly by rafting and/or swimming, Green Cay following the hurricanes, 2) house mice, rats, and mongoose were present before and after the hurricanes at Sandy Point, and house mouse abundance significantly increased ($>$ 2.5 times pre-hurricane levels) 9-months after the hurricanes, and 3) the

house mouse population more than doubled 15-months after the hurricanes on Buck Island. In the LEF, house mice invaded native forest from the roadsides following Hurricanes Irma and Maria, but the rat population abundance remained unchanged. Experimental hurricane effects did not result in differences in rat populations or seed predation, yet seed availability and seed predation drastically decreased after the two hurricanes. Land and resource managers benefit from knowing the composition and relative abundances of the small mammal communities, and the presence of house mice will make predator-free management efforts challenging. Surveillance using tracking tunnels enables rapid confirmation of new invasive species in isolated habitats and following large storms, as demonstrated by our finding that black rats established on Green Cay following the 2017 hurricanes.

Keywords Biodiversity, Cyclone, Invasive rodents, Non-native mongoose, Rapid wildlife surveillance

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Effects of a Major Hurricane on Bat Species Diversity and Functional Groups in a Gradient of Anthropic Disturbance

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Evidence shows that frequency of hurricanes is increasing due to climate change. Hurricanes contribute to cycle of heat and nutrients around the world; however their effects on biodiversity vary. These effects can be positive or negative, short- or large-term, direct or indirect, and can be observed in different ecological levels, having synergistic interactions with other disturbances. For bats, effects mainly in insular systems have been reported. Our objective was to analyze the short- and medium-term effects of Hurricane Patricia (category 5, October 2015) on the diversity of bats and the abundance of functional groups in a continental system with anthropic disturbance. We sampled bats with mist-nets before and after the hurricane in three locations, in distinct habitats (primary and secondary vegetation, and farmlands), in the Coast of Jalisco, Mexico. Pre- vs post-hurricane comparisons detected a decrease in the species diversity after the hurricane, a more similar composition of species among locations, and a greater stability in species composition and trophic structure in the location with more conserved forest. To a functional group level, the most vulnerable species were nectarivores, small, with low mobility, and with preferences for understory and cavities. Additionally, greater changes in abundance among functional groups were observed in more disturbed sites. Meanwhile, samplings during two years after the hurricane showed that species diversity was higher in the location with more conserved forest and was slightly higher in 2016 than in 2017. The species composition was not distinct between years. The abundance of trophic guilds varied according to seasons, being frugivores and nectarivores more abundant in the early rainy season. An increasing trend was detected in the abundance of bats in general and in the frugivore-generalists and insectivores in post-hurricane time; no trend was observed in the nectarivore guild. Our results indicate that communities of bats have a great resilience when facing large disturbances, but specific functional groups may be highly vulnerable and that maintaining primary forest and remnants of secondary forest is vital to mitigate the effects of major natural disturbances on biodiversity in continental regions.

Keywords Chiroptera, disturbances, diversity, functional groups, tropical dry forest

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Effects of Seed Dispersal on Forest Regeneration During Succession in Human-Modified Landscapes

Organizers:
Nohemi Huanca-Nunez, University of Nebraska, Lincoln
Sabrina E Russo, University of Nebraska, Lincoln

Most of the original global extent of tropical forests has been lost to deforestation caused by anthropogenic disturbances and changes in land use. Even while human-modified landscapes are increasing in area throughout the tropics, the dynamics, drivers, and outcomes of successional processes in tropical forests remain poorly understood. The arrival of tree species during forest regrowth begins with seed dispersal followed by seedling establishment, which are key processes in forest regeneration as they determine colonization of deforested areas that establish initial conditions for secondary successional trajectories. In human-modified landscapes, seed dispersal can be disrupted in many ways. For example, animal dispersal services can be reduced because their movements can be impeded in fragmented landscapes, and their populations may be reduced by hunting. Dispersal may be disrupted for abiotically dispersed species as well, as many seeds will fall in inhospitable recruitment sites, causing recruitment limitation. Sources of seeds may be rare on the landscape or represent a subset of the former diversity that was present pre-fragmentation. These and other local and landscape factors operate to reduce seed arrival or alter the composition of the seed rain into forest, with consequences for forest regeneration during succession. The proposed Symposium aims to integrate results from successional forests in order to characterize how local and landscape factors affect seed dispersal in human-modified landscapes and their consequences for forest regeneration.

These local and landscape factors can have variables effects on seed dispersal across the different geographical scales and successional stages (early, mid, and late-successional sites). This variation will arise because these factors have their greatest effects at different successional stages and tree species. As a result, some tree species are favored over others in a singular successional stage, which will influence the trajectory of forest composition and structure across succession in these human-modified landscapes.

The research to be presented in this Symposium will assess the importance of local and landscape factors on seed dispersal in tropical forests. By examining specific responses by successional forest stages or tree species, the Symposium will analyze the potential challenges on the regeneration of human-modified landscapes. The Symposium will close with an interactive panel discussion moderated by the organizers and including the Symposium speakers to consider these challenges and how they can be addressed given current frameworks for research and conservation.

Session Recording: `https://youtu.be/cUxdtiu1ICs`

Proximity and Abundance of Mother Trees Affects Recruitment Patterns in a Long-term Tropical Forest Restoration Study

Rakan A. Zahawi[1], Leland K. Werden[1], Miriam San Jose[2], Karen D. Holl[3]

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The presence of remnant trees in agricultural landscapes can be crucially important as sources of propagules to facilitate forest recovery. However, many studies simply quantify percent forest cover in the landscape with no attention to the species present, and hence fail to detect an effect of the amount of surrounding forest cover on recruitment patterns. We assessed the relative importance of the spatial distribution and life history traits of 77 tree species on adjacent recruitment patterns in a well replicated long-term restoration study in southern Costa Rica. We censused and mapped potential mother trees in a 100-m band surrounding eight replicate 50 ´ 50 m restoration plots and quantified respective tree recruits within each plot. We assessed how mother tree abundance, species life-history characteristics (seed size, dispersal mode), tree size (DBH, height), and distance to restoration plot affected recruitment at both coarse (plot: 50 x 50 m) and fine (quadrat: 3 x 3 m) spatial scales. The presence of a mother tree within 100 m of a restoration plot resulted in a 10-fold increase in potential mean recruitment. Mother tree abundance was also an important driver of recruit density, and particularly so for large-seeded (5 mm) zoochorous species with a 5-fold increase in recruit density across the observed mother tree abundance range. An interaction between mother tree abundance and proximity demonstrated that the effect of mother tree abundance on recruit density was important but waned with increasing distance from restoration plots. At the fine spatial scale both height and DBH of the closest potential mother tree affected recruit abundance, but to a lesser degree than mother tree abundance and proximity to a quadrat. Results highlight the importance of remnant vegetation composition to recovery of adjacent degraded habitats, underscoring the outsized role nearby remnant forest and isolated trees can play for the persistence of localized biodiversity.

Keywords Costa Rica, dispersal limitation, fruiting trees, remnant forest, seed dispersal

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The Effect of Restoration Treatments on Seed Dispersal and Seedling Establishment Limitation in a Tropical Agricultural Landscape

Marinés de la Peña-Domene[1], Cristina Martínez-Garza[1], Neptali Sánchez[1], Marcos Andrés Suárez Álvarez[1], Henry Howe[2]

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Seed dispersal and seedlings establishment limitation are variable and depend upon the environmental conditions that habitats provide. We know that limitations are higher in degraded ecosystems, but little we know about effect of restoration on these limitations through time. Dispersal and establishment limitations change according to life strategies of species, their dispersal mode and the changes in the restored environment. We tested the changes in limitations in 12 common woody species from 2007 to 2015 in three different restoration scenarios (tree plantings of animal dispersed species, tree plantings of wind dispersed species and plots that simulate natural succession). Both types of planted plots had a higher decrease in dispersal limitation than under natural regeneration, with plots planted with animal dispersed trees showing up to 15% less dispersal limitation compared to the other treatments. Even though species had a different trajectory of dispersal and establishment limitations, general trend have an average reduction of 23$\pm$18% in dispersal limitation for animal dispersed species, while limitations for wind dispersed species increased on average 6$\pm$18% throughout time. Higher limitations for pioneers establishing in five-year-old plantings (2011 is still pre fruiting conditions for the most part) were expected, but for later successional animal dispersed *Bursera simaruba*, a small decrease in dispersal limitation meant a big decrease in establishment limitation. All in all, planted plots influenced seed dispersal and seedling establishment limitation even before general fruiting patterns were observed in the planted plots favoring animal dispersed trees over wind dispersed trees.

Keywords Seed dispersal limitation, seedling establishment limitation, tropical forest restoration, succession

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Effects of Landscape Structure on Seed Dispersal in Mexican Fragmented Rainforests

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Land-use change modifies the spatial structure of tropical landscapes, shaping key ecological processes, such as seed dispersal. These changes can modify the animal community (the main dispersers of tropical plants), affecting the seed dispersal patterns by animals. The climate (e.g., wind speed and incidence) and landscape structure differences between regions may also modify wind dispersal, but no study has evaluated the effect of landscape structure on seed dispersal in floristically similar regions with different degrees of anthropogenic disturbance and climate. We evaluated the effect of landscape structure on seed dispersal in two Mexican fragmented regions: the more deforested, defaunated, and windy Los Tuxtlas rainforest (LTX), and the better-preserved Lacandona rainforest (LAC). Particularly, we tested for differences between regions and between dispersal modes. We hypothesized that landscape structure and regional context affect seed sources and seed dispersal processes, shaping seed arrival to a site. We quantified the proportions of dispersed tree species and their seeds, separately evaluating wind- and animal-dispersed species in 20 forest sites per region (40 sites in total). Then, we assessed the effect of five landscape metrics (forest cover, matrix openness, forest edge density, forest fragmentation, and isolation) on dispersed seeds recorded. As we expected, in LTX we found a reduced abundance of animal-dispersed seeds, which may be limited by the regional lack of fauna. As predicted, the effects of landscape structure differed between regions and dispersal vectors. Landscape patterns were comparatively more important for wind-dispersed seeds in LTX. Particularly, proportions of wind-dispersed seeds and species decreased with increasing edge density and decreasing matrix openness, suggesting that forest edges prevent dispersal of wind-dispersed species, which may occur if edges create physical barriers that limit wind flow in treeless anthropogenic matrices. Surprisingly, the proportion of animal-dispersed seeds in LTX was positively related to matrix openness and patch isolation, suggesting that seed dispersers in more deforested regions may be forced to concentrate in isolated patches and use the available habitat more intensively. This study provides evidence that in more deforested and defaunated regions, the seed rain within forest remnants is dominated by wind-dispersed seeds and that these seeds are strongly affected by landscape structure. Conversely, animal-dispersed seeds are primarily favored by increasing forest cover. Conservation strategies should focus on the preservation of the frugivorous wildlife and the process of seed dispersal at a landscape scale in human-modified rainforests.

Keywords dispersal limitation, landscape-scale, natural regeneration, seed rain

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Seed Rain–successional Feedbacks in Wet Tropical Forests

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Tropical forest regeneration after abandonment of former agricultural land depends critically on the input of tree seeds, yet seed dispersal is increasingly disrupted in contemporary human-modified landscapes. Here, we introduce the concept of seed-rain–successional feedbacks as a deterministic process in which seed rain is shaped by successional dynamics internal to a forest site and that acts to reinforce priority effects. We used a combination of time series and chronosequence approaches to investigate how the quantity and taxonomic and functional composition of seed rain change during succession and to evaluate the strength of seed-rain–successional feedbacks, relative to other deterministic and stochastic mechanisms, in secondary wet forests of Costa Rica. We found that both successional niches and seed-rain–successional feedbacks shaped successional trajectories in

the seed rain. Determinism due to successional niche assembly was supported by the increasing convergence of community structure to that of a mature forest, in terms of both functional and taxonomic composition. With successional age, the proportions of large-seeded, shade-tolerant species in the seed rain increased, whereas the proportion of animal-dispersed species did not change significantly. Seed-rain–successional feedbacks increased in strength with successional age, as the proportion of immigrant seeds (species not locally represented in the site) decreased with successional age, and the composition of the seed rain became more similar to that of the adult trees at the forest site. The deterministic assembly generated by seed-rain–successional feedback likely contributed to the increasing divergence of secondary forest sites from each other during succession. To the extent that human modification of tropical forest landscapes reduces connectivity via factors such as forest cover loss, our results suggest that seed-rain–successional feedbacks are likely to increasingly shape regeneration trajectories in and amplify floristic heterogeneity among tropical secondary forests.

Keywords forest succession, seed-rain, Costa Rica, Seed Rain–Successional Feedbacks

Plant-Animal Interactions in a Changing World: Implications for Seed Fates in the Anthropocene

Organizers:
Erin Kuprewicz, University of Connecticut
Sandra B Correa, Mississippi State University

Tropical forests are among the most diverse ecosystems in the world and this diversity is maintained in part through complex multi-trophic interactions. Animal mediated seed dispersal is one such interaction and plays a major role in forest regeneration, community composition, and the maintenance of healthy ecosystems. Historically, accurately tracking the fates of seeds from primary dispersal by frugivores through to seedling recruitment presented researchers with an intractable problem. However recent advances in methodology and technology have allowed ecologists to track seed survival and treatment by dispersers and predators through space and time in complex habitats (e.g., tropical rain forests).

In 2005, the now-classic book Seed Fate was published to summarize the then-known state of knowledge on this diverse topic (Forget et al. 2005). Since then, rapid and unprecedented changes in forest ecosystems driven by mainly anthropogenic factors such as fragmentation, hunting, and climate breakdown have provoked new questions and necessitated the use of innovative technology (e.g., radio-tracking, molecular methods) to answer them. The time is now right for a review of these conceptual and technological advances regarding the fate of seeds in tropical ecosystems in a rapidly changing world.

In this symposium, we propose to assemble an international team of researchers to synthesize the current state of knowledge on the topic of seed fates in tropical ecosystems. Ultimately, the speakers in this symposium will be invited to submit papers to a book which will succeed Seed Fate (Forget et al. 2005) and comprise a collection of insights and advances in the field of seed dispersal ecology, especially regarding the fates of seeds. It is anticipated that taken together, the contributions from this symposium will advance our understanding of the likely consequences of global change drivers on seed fate. It is hoped that such knowledge will position us to better predict and manage plant-animal interactions in the Anthropocene for the long-term survival of tropical forest systems.

Session Recording: `https://youtu.be/-yTcmQyU8CQ`

Upslope Seed Dispersal Potential and Optimal Germination Temperatures Shape Current and Future Ranges of Lowland Plants in a Changing World

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Most tropical plants rely on seed dispersers to colonize new environments they will face as the climate changes. In a warming world, lowland tropical biota rely on elevational migrations to locate habitats that fit their ecological and physical requirements. The objectives of our study were to determine if upslope biotic or abiotic barriers currently exist to prevent plant range expansions. We investigated if pre- and post-dispersal barriers exist to delimit the ranges of low-elevation plants on a tropical mountain in Braulio Carrillo National Park, Costa Rica. Using upslope transplant experiments of seedlings at multiple elevations, we assessed seedling survival in native and novel habitats. Supplementing field experiments with laboratory work, we used temperature-controlled incubators to assess seed resilience in novel temperature environments. We tracked seed germination success for 12 large-seeded lowland species and found that, overall, lowland species germinated well, even at an artificially high temperatures they do not currently experience (35° C). Regarding seedlings, all nine transplanted species suffered complete mortality at high elevations (2000 m a.s.l.), but had highest survival at middle elevations (1000 m a.s.l.). This allows for potential upslope mobility, if seed dispersers deposit seeds as they move up mountains. The results of this study have implications for understanding and predicting plant ranges as mediated by seed dispersers in a changing world. Some plants do not face post-dispersal barriers to upslope migration (e.g., temperature limitations to survival) and may be able to colonize novel habitat to outpace global warming. However other species face pre-existing barriers to survival at high elevations (e.g., abiotic conditions). If plants are unable to colonize novel highland habitats as biomes shift upward, these barriers will prevent successful elevational migration, resulting in lowland biotic attrition. Altered plant-animal interactions, especially seed dispersal and predation, will play major roles in redefining tropical plant and animal communities as the world warms.

Keywords Climate change, seed elevator, seed fate, upslope migration

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Using Fruit Traits to Predict Mutualistic Vs. Antagonistic Interactions between Frugivores and Seeds

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Introduction / Background / Justification: Fruits are an important energy source for diverse vertebrates and exert a strong influence on their foraging behavior and food choice. In turn, frugivorous vertebrates commonly swallow seeds intact, thereby dispersing seeds away from the mother tree and contributing to enhancing its fitness through successful recruitment. Other vertebrate frugivores damage seeds during consumption through mastication and chewing thereby reducing seed viability and recruitment. Thus, the combined effects of animal-mediated seed dispersal and seed predation help structure plant communities and contribute to maintaining biodiversity in tropical ecosystems worldwide. Unlike most other vertebrate frugivores, frugivorous fish species can have mutualistic (seed dispersal) and antagonistic (seed predation) interactions with plants in tropical wetlands, yielding a gradient of positive to negative fitness values. **Objective(s)/Hypothesis(es):** Our goal was to test whether the outcome of fish interactions with seeds (i.e., dispersed or destroyed) can be predicted based on fruit traits. **Methods:** We measured fruit traits related to size, shape, and nutrient composition of species that produce ripe fruits during the flood season in a Neotropical wetland. We then combined fruit trait data with frugivorous fish diet data, compiled in the same wetland, and used machine learning classification techniques to predict the outcome of the interaction (i.e., dispersed or destroyed). Lastly, we conducted phylogenetically independent contrasts to test for selection (seed dispersal rate) on fruit traits across multiple fruit-frugivore interactions. **Results:** Preliminary analyses detected significant phylogenetic signal in traits related to fruit shape and size (pulp weight, fruit roundness, and seed roundness). However, there was a

detectable degree of phylogenetic signal in all traits. Multiple classification models revealed lower predictability of seed dispersal than seed predation based on fruit and seeds traits associated with shape and size. The most important predictors were seed weight, seed volume, and pulp weight. Phylogenetic regression depicted significant selection (i.e., greater seed dispersal rate) on seed volume and seed weight by the largest individuals of the biggest fish species within the frugivore network. **Implications/Conclusion:** Frugivorous fishes evolved prior to most frugivorous birds, monkeys, and bats in South American wetlands. Given the antiquity and duality of fish-fruit interactions, a better understanding of fruit-trait selection by fishes could shed light on the evolution of fruit traits and particularly on fruit-trait diversification in wetlands.

Keywords fruit evolution; seed dispersal syndromes; ichthyochory; flooded forest, fish, wetland

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Simplified Communities of Vertebrate Seed-dispersers on Edge Habitat Limit the Composition and Flow of Seeds

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Edge effects, driven by human modification of landscapes, can have critical impacts on ecological processes such as species interactions with cascading impacts on biodiversity as a whole. Characterizing how edges affect vital biotic interactions such as seed dispersal by animal frugivores is important for better understanding potential mechanisms that drive species coexistence and diversity within a plant community. Here, we investigated how differences between frugivore communities at the forest edge and interior habitats of a diverse tropical rainforest relate to patterns of animal-mediated seed dispersal and early seedling recruitment. We collected a year-long field survey of animal frugivores, measured seed dispersal rates, and monitored seedling recruitment in forest edge and interior habitats in a Malagasy rainforest bordered by a small expanse of successional old fields, which adjoined small-scale agricultural fields. We found that larger frugivores, especially lemurs, tended to avoid the disturbed habitat in the forest edge. Also, the forest-edge habitats had lower species richness and density of frugivores than the forest interior. These patterns did not translate into different overall rates of seed dispersal by animals into these habitats. However, seeds that were actively dispersed by animals in forest edge habitats were smaller in size than seeds dispersed in the forest interior, reflecting the prevalence of smaller-sized frugivores in the forest edge. This pattern was found despite a similarity in seed size of seasonally-fruiting adult trees and shrubs between the two habitats. Altered dispersal patterns did not translate into any observed differences in the rates of seedling recruitment or seed-size distribution of successful recruits. Our results suggest that frugivores may act as a potential biotic filter, acting on seed size, for the arrival of certain plant species to edge habitat. However, further research is needed to better understand the potential long-term impacts of altered dispersal regimes on the successional dynamics of edge communities. Our findings are important for understanding potential ecological drivers of tree community changes on forest edges and have implications for conservation management and restoration of large-seeded tree species in disturbed habitats.

Keywords edge effects, habitat fragmentation, species interactions, seed dispersal, tropical forests

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Secondary Metabolites in Fruit Development, Defense and Dispersal: Hypotheses and Case Study

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In plants, both attraction of mutualists and defense against antagonists are thought to be mediated by secondary metabolites, but the chemical ecology of wild, fleshy fruits is relatively unexplored. Deciphering the ecological roles of plant secondary metabolites requires integrative studies that assess both their allocation patterns and function in ecological interactions. We described 10 alkenylphenol compounds from the plant species *Piper sancti-felicis* (Piperaceae), quantified their patterns of intraplant allocation across tissues and fruit development, and examined their ecological role in fruit interactions with both mutualists (seed dispersers) and antagonists (potentially pathogenic fungi). We found that unripe and ripe fruit pulp had the highest concentrations and diversity of alkenylphenols, followed by flowers; leaves and seeds had only a few compounds at detectable concentrations. We observed a nonlinear pattern of alkenylphenol investment across fruit development—increasing as flowers developed into unripe pulp then decreasing as pulp ripened. This pattern is consistent with the hypothesis that alkenylphenols function to defend fruits from pre-dispersal antagonists and are allocated based on the contribution of the tissue to the plant's fitness. To assess the impacts of alkenylphenols in interactions with antagonists and mutualists, we performed fungal bioassays, field observations, and vertebrate feeding experiments. In fungal bioassays, we found that alkenylphenols had a negative effect on the growth of most naturally-occurring fungal taxa. In field observations, nocturnal dispersers (bats) removed the majority of infructescences, and diurnal dispersers (birds) removed a larger proportion of unripe infructescences. In feeding experiments, bats exhibited an aversion to alkenylphenols, but birds did not. This observed behavior in bats, combined with our results showing a decrease in alkenylphenols during ripening, suggests that alkenylphenols in fruits represent a trade-off (i.e., they defend against pathogens but reduce bat disperser preference). Together, this research provides a broad overview of the ecological significance of a little studied class of secondary metabolites in seed dispersal and fruit defense. It can also serve as a roadmap for integrating the study of intraplant spatiotemporal allocation patterns with ecological experiments to further our understanding of the evolutionary ecology of plant chemical traits. Looking forward, it is unclear how our changing climate will affect plant chemical traits and frugivore foraging, and if different organisms in these multi-species interactions will have similar or mismatched responses. Comprehensive information on these systems is becoming increasingly important, as we strive to understand and mitigate anthropogenic effects in the chemically and biologically diverse neotropics.

Keywords Antagonism; Alkenylphenols; Defense trade-off hypothesis; La Selva Biological Station; Mutualism

Climate change effects on species interactions in the tropics

Most predictions of climate change effects in the tropics are based on anticipated alterations to ecosystem productivity, resulting from bottom-up changes in biogeochemistry or growth responses to greenhouse gases. However, the future functioning of ecosystems may be more strongly impacted by shifts in species composition and abundance that are determined in large part by species interactions. Four talks will highlight critical classes of interaction that influence tropical biota and their sensitivities to climate change: (i) mycorrhizal mutualisms interactions associated with nutrient uptake; (ii) plant-pollinator interactions; (iii) seed dispersal mutualisms; (iv) density-dependent population regulation resulting from herbivores and pathogens. Our discussion will focus on how to develop a framework to incorporate species interactions into climate change projections, guidance for researchers interested in documenting and detecting change phenomena, and potential case studies/systems that can be investigated across multiple sites.

Session Recording: `https://youtu.be/Vt9u7OHEDeQ`

Enemy-mediated Species Coexistence in a Changing World

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Introduction: Natural enemies, principally phytopathogens and insects, regulate plant populations and facilitate species coexistence and diversity within tree communities. Interactions between plants and their natural enemies respond to environmental conditions, for example rainfall, but the extent that this influences species coexistence is currently unknown. Altered precipitation patterns through the tropics due to climate change makes understanding these relationships particularly important. If environmental change disrupts interactions between plants and their natural enemies, it may accelerate biodiversity loss. **Approach:** We consider two mechanisms through which natural enemies might stabilize coexistence of similar plant species and might be affected by altered precipitation patterns: the Janzen-Connell mechanism and storage effects. **Results:** General circulation models indicate that precipitation may decrease in large parts of the Neotropics and seasonality may intensify through much of the tropics. Both decreases in precipitation or aseasonality could disrupt the mechanisms discussed here. Theoretically, the Janzen-Connell mechanism would better support tree species coexistence if wetter climates increased the intensity of natural enemy attack (up to a point) or increased their host-specificity. Observed relationships between precipitation gradients and natural enemy attack are not straightforward. Neither the incidence of foliar pathogens, nor the strength of negative density dependence, appears to vary consistently along a precipitation gradient in Panama. Tree seedlings are particularly vulnerable to pathogens during the first two weeks after germination, providing opportunities for opportunist, generalist pathogens. Seedlings emerging simultaneously might transmit generalist pathogens among each other, leading to apparent competition. Rapid early seedling mortality means that species germinating at different times encounter each other at low density, reducing competition through storage effects. Increased seasonality of precipitation patterns will likely synchronize seedling germination times among species, intensifying apparent competition. **Implications:** While current evidence is mixed, the implications of climate change and other anthropogenic disturbances for the mechanisms responsible for biodiversity should not be underestimated. Empirical work is urgently needed to determine which hypothetical effects of environmental change on coexistence mechanisms actually influence biodiversity.

Keywords Natural enemies, phytopathogens, Janzen-Connell mechanism

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Effects of Climate Change on Mycorrhizal Mutualisms in Tropical Forest: What Are the Questions We Need to Tackle?

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Most plants host symbiotic fungi in their roots that help them to obtain limiting nutrients from the soil and to adapt to abiotic stress. The most abundant functional group being mycorrhizal fungi. Recent research has shown that tropical plants are migrating upwards in the mountains at faster rates than their temperate counterparts. However, it is unknown how their root associated fungal communities will respond to shifts in their host distributional range. By looking at plant species distributions in the Colombian Andes for example, it has also been shown that the mean altitudinal distribution of plants forming different mycorrhizal types (like arbuscular mycorrhizal, ectomycorrhizal, and ericoid mycorrhizal) along altitudinal gradients are influenced by different climatic and edaphic variables. With arbuscular mycorrhizal plants being more dominant at lower altitudes and ericoid and orchid mycorrhizal plants being more dominant at higher elevations. Therefore, changes in temperature and precipitation could potentially alter the abundance and distribution of plants according to their type of root associated symbionts. Temperate studies have found that different groups of mycorrhizal fungi can respond differently to climate change and that these effects could be context dependent. Based on the available literature, mostly from studies carried out in the northern hemisphere, I highlight what, from my point of view, are the most important challenges to answering questions about the impacts of climate change in plat-mycorrhizal interactions in tropical communities. First, it is important to improve our understanding of the species composition of root-associated fungal communities in tropical ecosystems. Metagenomic studies

have demonstrated that tropical fungal communities show a significant number of undescribed species which could make it more difficult to define distributional ranges for a lot of species. Second, understanding the Influence of fungal dispersal capabilities might be the key to predicting plants dispersal limitation when colonizing new habitats due to limited inoculum sources. Finally, it is important to document the degree of host specificity of fungi and host dependency on mycorrhizal fungi and their contribution to plant fitness under different environmental conditions. To address these challenges, it would be necessary to initiate coordinated efforts to establish replicated studies across the tropics and to increase the use of experimental approaches under controlled conditions

Keywords Climate Change, symbiotic fungi, mycorrhizal, plat-mycorrhizal interactions

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The Ecological Theatre and the Evolutionary Play of Seed-dispersal Interactions in the Anthropocene

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Seed dispersal interactions involve key ecological processes that help to maintain ecosystem functioning and climate regulation. Yet this functionality may be threatened by increasing anthropogenic disturbances. We explored the structure of a bird seed-dispersal networks from the Atlantic Forest of Brazil to test whether habitat fragmentation and defaunation affect eco-evolutionary process at the local and landscape scale. We found significant species–, interaction–, and net- work–area relationships; the metanetwork is interaction-rich, modular and poorly connected, showing high beta-diversity and turnover of species and interactions. Persistent interactions were performed by small-seeded, fast growing plant species and by generalist, small-bodied bird species able to cross the fragmented landscape. Interactions involving large-seeded plant and large-bodied bird species showed the highest evolutionary distinctness and were the first to van- ish. Hence, we estimate a loss of 3.5 to 4.7 x 104 million years of cumulative evolutionary history of interactions due to defaunation; however, the persistence of less evolutionarily distinct bird species may exerts a phylogenetic rescue effect through seed dispersal of evolutionarily distinct plant species in highly human disturbed scenarios. The local extinction of partner species, paralleled by a loss of interactions and specialist bird–plant seed dispersal associations, suggests the functional homogenization of the system as area is lost and defaunation increases, and may generate long-term deficits of carbon storage while delaying forest regeneration at the landscape level.
Financing: Sao Paulo Research Foundation (FAPESP: 2014/01986-0, 2015/15172-7, 2016/18355-8, and 2017/25605-3); Severo Ochoa Excellence Award (SEV-2012-0262, grant CGL2017-82847P), Science Without Borders Program (CNPq, PVE-401258/2012); Ecometas excellence network (CGL2016-81706-REDT)

Keywords Seed dispersal interactions, seed-dispersal networks, Atlantic Forest, local extinction

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Andean-Amazonian Forests Responses to Climate Change

Organizers:
William Farfan-Rios, Washington University in Saint Louis
Belen O Fadrique, University of Miami

Tropical forests are facing a rapidly changing world. One of the central questions in current ecology is to understand how these tropical forests are responding to climate change. Climate change is hypothesized to cause shifts in species distributions and changes in community composition and tree performance across environmental gradients, potentially leading to novel species assemblages and shifts in ecosystem properties. However, the question of how tropical plant communities are responding to climate change across large-scale environmental gradients remains largely unexplored, in particular across the continuous Andean-Amazonian elevational gradient. The overarching goal of the proposed symposium is to congregate researchers from different parts of the world working in the Andes-Amazon regions to advance our mechanistic understanding of species- and community-level responses to environmental changes. Our focus is to integrate studies based on long-term inventory forest plots with multiple censuses overtime. In this symposium, we aim to share results from studies that scale from individual species- to community-level. Specifically, we will be discussing results on the effects of climate change in (1) species composition, (2) biotic attrition, (3) taxonomic homogenization, and (4) tree growth across Andean-Amazonian forests of Bolivia, Brazil, Colombia, Ecuador, Peru, and Venezuela. We believe that the proposed topic will have broader interest for the ATBC community because it will be centered in one of the most diverse regions of the world where changes in land use and climate change are the main threats to biodiversity. In addition, we endeavor to identify studies connecting the Andes and Amazon regions that represent the current stage of knowledge of tropical forests' responses to environmental changes, which are important to land managers and conservation efforts.

Session Recording: `https://youtu.be/DPa6SkVnP-o`

Thermal Tolerance and Physiological Performance Explain Dominance in Andean Trees Species: A Glimpse on the Potential Effects of Global Change

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Habitat loss and climate change threaten a significant number of rare species in tropical mountain ecosystems. Commonly, species rarity is explained by three attributes local abundances, range size, and niche breadth. Understanding how these attributes change across space and ecosystems could be helpful to assess their response to global change. Species responses can be related to one or multiple attributes, as well as their interactions. For example, small-ranged species but broad niche breath can be more tolerant to climate change than wide-ranged species with narrow niche breadth, or low abundant and narrow niche breadth species could be sensitive to fragmentation. In this study, we developed (i) a comprehensive database from the tropical Andes ($>$ 1000 m elevation) that includes 188 permanent plots with at least two measurements from RAINFOR network. (ii) For each dominant species we calculate the overall geographic distribution using a minimum convex polygon corrected by the species elevation range based on GBIF/BIEN records. (iii) We further calculate the amplitude parameter of a Gaussian model describing niche unimodal expectation of high performance at intermediate conditions. The model is fitted between climatic variables (temperature and water availability) and tree growth rate as a measure of performance. Our results from 77000 individuals in 2063 species indicate that 47% of the abundance is represented by only 80 species, and only 36 of them are responsible for 48% of the stored biomass. Dominance is positively related to elevation, such that fewer species concentrate more abundance and biomass as elevation increases. Further, dominant species have broader thermal tolerances than rare species, which partially explains their overall success and niche breadth. Our results, which are pioneer in combining multiple databases from different locations in the Andes highlight the potential consequences of rapid temperature change on the composition of these highly diverse, yet hiper-dominated ecosystems.

Keywords Dominant species, Andean forest, broad niche, thermal performance

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Functional Dynamics of a Tropical Montane Forest: Spatial Variation and Temporal Stability

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Introduction: Understanding tree trait distribution along topographic gradients and through time provides insights into the processes that will shape future community composition and ecosystem functioning. In montane environments, complex topography affects critical aspects of forest composition, yet its role in determining tree trait composition, community climatic indices and responses to changing environmental conditions is not fully understood. **Objectives:** This study investigated how functional trait composition and community climatic indices vary for the tree community as a whole and for its demographic components over eight-years in a topographically complex tropical Andean forest in southern Ecuador. We hypothesized that climate change had favored species with more acquisitive traits and higher thermal optima, shifting floristic and functional trait composition. Methods: We used eight-year census data of 18 monitoring plots. To test our hypotheses we evaluated changes in floristic composition, community weighted means (CWM) for ten functional traits, and community temperature and precipitation indices as a function of topography and time. **Results:** We identified a strong influence of topography on functional tree composition and on species' climatic optima, such that communities at lower topographic positions were dominated by acquisitive species adapted to both

warmer and wetter conditions compared to sites at upper positions dominated by conservative cold adapted species, a response that was possibly mediated by soil conditions and hydrology. Forest functional and climatic composition remained stable through time; and we found limited evidence pointing to trait-based responses to environmental change among the compared tree demographic groups. **Conclusions:** Our findings confirm that fine-scale environmental conditions are a critical structuring factor of plant communities in tropical forests, and suggest that slow environmental warming and community-based processes may promote community functional stability. This study highlights the need to explore how diverse aspects of community trait composition vary in tropical montane forests, and to investigate thresholds of forest response to environmental change.

Keywords tropical montane forest, functional traits, topography, forest dynamics

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Is Tree Diversity in Amazonian and Andean Forests Changing over Time?

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Introduction / Background / Justification: Global change is predicted to erode species diversity at multiple spatial scales in the tropics, with important consequences for biodiversity and ecosystem functioning. Despite the growing evidence that biodiversity is declining due to anthropogenic forces (e.g., climate change), debate persists as to whether plant communities are gaining or losing species at local spatial scales. Recent studies suggest that climate change is causing shifts in the species composition of tropical plant communities and geographic ranges of plant species. However, studies on temporal changes in tree species diversity across the tropics are lacking, in particular across environmental gradients such as the Andes-to-Amazon elevational gradient. **Objective(s)/Hypothesis(es):** The overarching goal of this study is to evaluate whether tropical tree diversity is changing over time. Using null models, we test the hypothesis that regions with cold climates are increasing in species richness while warm regions are losing richness across broad-scale elevational gradients from Amazonian to the Andean forests. **Methods:** We compiled data from 1-ha permanent forest plots (n=145 plots) across the Eastern Andes and Western Amazon along a 3500 m elevational gradient. The forest plots include all stems equal or greater than 10 cm in diameter at breast height with multiple censuses over time. The observed temporal change in tree species richness was calculated for each permanent plot. Changes in richness were calculated as the difference in the number of species present in the plot at the second census minus those in the first census. **Results:** Preliminary results for the central Andes showed that temperature is a significant predictor of variation in richness change across elevational gradients. These results also showed that species richness is increasing in cold climates and decreasing in warm climates. This suggests that tree communities in the Amazon may lose species, while communities in the Andes might gain species. Although these results showed this trend in the central Andes, we expected similar patterns in the Northern and Southern Andean-Amazonian regions. **Implications/Conclusions:** The Amazon-Andes ecosystems are one of the most diverse regions of the world where climate change is one of the main threats to biodiversity. Our study suggests biotic attrition in lowland forests, while highland forests are experiencing species enrichment. However, climate change may be maybe influencing biodiversity at different spatial scales. For instance, making tree communities more compositionally similar over time, even if there is no net change in species richness.

Keywords Climate change, biodiversity, Andes, Amazon, tropical forest

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Resilience of Carbon Stocks of Andean Forests to Shifts in Composition Due to Climate Change

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Biodiversity may be critical in influencing the timing and nature of terrestrial ecosystem responses to climate change. However, to understand and quantify potential resilience provided by biodiversity requires long-term observational studies that relate the compositional change to changes in ecosystem structure, which are largely absent in the tropics. We used data from 94 long-term forest inventory plots across Andes-Amazon region, focusing on mid-elevation forests (1000-2000 masl) in replicated plot transects in the rapidly warming central Andes, here we explore how ecosystem compositional shifts are linked to carbon stock changes. Community-wide changes in the temperature preference of the tree genera in each plot, or the thermophilisation rate, were used to assess compositional shifts in relation to climate change. While these rapidly warming forests have shown rapid shifts in composition due to selective losses in cold-affiliated genera, aboveground forest biomass simultaneously increased. This suggests that, to date, the range of life-history strategies found in these forests has buffered aboveground forest carbon stocks from on-going changes in composition. Continued monitoring of long-term plots is required to track how changes in climate, forest composition and structure interact into the future. In terms of conservation strategies, the compositional rearrangement that is happening across the altitudinal gradient strongly indicates that establishing biological corridors across altitudinal gradients is important to allow migration and potential recruitment of species in climatically suitable habitat, as climate change proceeds.

Keywords Forest resilience, thermophilisation, climate change, AGB, forest changes, Andes-Amazon region.

Combining Climate, Microclimate, and Species' Traits to Assess Climatic Vulnerability for Tropical Species

Organizers:
Agustín Camacho, Doñana's Biological Station
Maria Paniw, Doñana's Biological Station

Guiding conservation strategies to tackle the consequences of climate change requires integrating species' traits and their ability to cope with environmental stress into demographic models. However, this task is still in its infancy, needing a better understanding of fine-scale variability in climate, species traits, and demographic stochasticity. In this symposium, Gabriela Montejo-Kovacevich, Pol Pintanel, Maria Paniw and Agustín Camacho will showcase different approaches to study adaptative, behavioural, and demographic responses to climate variability in tropical South America and Africa, which ultimately will determine their vulnerability to climate change. Gabriela will show the importance of microclimatic datasets for understanding the challenges that small organisms face in complex habitats across elevations. By studying phenotypic variation in thermal tolerance and wing shape across populations and species, as well as rearing individuals in common-garden environments, she will show how phenotypic plasticity and adaptation may enable some species to thrive across a wide range of elevations and climates. Pol will talk about how unexpected variation of thermal tolerance in small spatial scales may impact vulnerability estimates for tropical anurans. Maria will present her results on how climate-demography relationships determine population persistence among tropical mammals of short life-span. Finally, Agustín will show how geographic patterns of the climatic vulnerability may change according to combined effects of thermal stress and dehydration on the behavior of tropical lizards". After that, Agustín and Maria will guide the arising discussion and questions among audience and speakers.

Session Recording: `https://youtu.be/-o0mB4cE1RA`

Microclimate Variability and Butterfly Thermal Tolerance in the Andes

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Climate change will test organisms' ability to move to new areas or adapt locally. Tropical insects are estimated to make up half of animal species on Earth. Insects are ectotherms, which depend mostly on external sources of body heat and thus are highly influenced by their immediate environmental conditions. In the tropics, temperatures are relatively constant throughout the year but decrease more rapidly with altitude than in temperate zones. This low temporal but high spatial variation in temperatures is predicted to select for narrow thermal limits in tropical organisms, especially those found in montane habitats. Thus, to better predict which species are at higher risk from climate change and habitat degradation it is crucial to understand climatic variability at the scale at which organisms experience it (microclimates) and, at the phenotypic level, disentangle heritable traits from plastic responses to the environment. With a year-long microclimate dataset across elevations, thermal tolerance tests in the wild, and common-garden rearing experiments, we show that forests buffer temperature and humidity across elevations and that these microclimates are largely not captured by WorldClim2. We found strong differences in wild thermal tolerance across populations and species inhabiting a range of elevations. However, our common-garden rearing experiments showed that thermal tolerance is highly plastic in a widespread species, indicating that some species may be able to readily cope with a wide range of temperatures. With these results in hand, I will discuss the implications of cryptic microclimatic variability, thermal buffering across elevations and species' heat tolerance differences in our ability to predict ectotherms' vulnerability to climate change.

Keywords Thermal tolerance, Lepidoptera, phenotypic plasticity, microclimates

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Implications of Microhabitat in Amphibian Evolution and Vulnerability to Global Warming

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Evidence suggests that heat tolerance is less variable than cold tolerance, which leads to the prediction that species have a reduced evolutionary potential to respond to global warming. This heat-invariability hypothesis has also been employed to predict that the impact of anthropogenic climate change will have the most deleterious consequences in tropical areas, because tropical organisms are currently living very close to their thermal tolerance limits. Nonetheless, even though these hypotheses have been supported by large-scale geographic studies they are not necessarily supported by local-scale studies. Here, we illustrate how contrasting variation of extreme environmental temperatures between local and large geographical scales influence thermal tolerance asymmetries. Maximum temperatures are more variable locally than minimum temperatures but less variable at large geographic scales. Using thermal tolerance measurements of amphibians and other ectotherm species, we show how heat tolerance is more variable than cold tolerance at local scales but not at large scales, which is consistent with the higher variation of maximum temperatures locally. Our results suggest that fragmentation and habitat destruction may have more detrimental effects than climate change in tropical species. Thus, conservation strategies should consider local spatial heterogeneity in physiology and environmental temperatures for the conservation of biodiversity under the scenario of global change.

Keywords Brett's hypothesis, climate change, microclimate, thermal tolerance, warming tolerance

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Are Tropical Mammals Threatened by Climate Change? On Filling Some Important Knowledge Gaps

Maria Paniw[1]

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Approximately 25% of mammals are currently threatened with extinction, and many of these mammals are found in biodiversity hotspot in tropical biomes. Their extinction risk is amplified under climate change, and we need to understand how species respond to climate via changes in survival and reproduction to optimize conservation management. We performed a systematic review of literature on demographic responses to climate, focusing on terrestrial mammals, for which extensive demographic data are available. Our synthesis revealed that for most mammals in tropical hotspots potentially highly sensitive to climate change, holistic demographic responses to climate remain unknown. At the same time, we reveal that filling this knowledge gap is critical as the effects of climate change will operate via complex demographic mechanisms: a vast majority of mammal populations display projected increases in some demographic rates but declines in others, often depending on the specific environmental context, complicating simple projections of population fates. Assessments of population viability under climate change are in critical need to gather data that account for multiple demographic responses, and coordinated actions to assess demography holistically should be prioritized for mammals and other taxa particularly in understudied tropical regions.

Keywords Life cycle analyses, demography, climate extremes, G200

Climatic Vulnerability and the Thermohydroregulation of Tropical Lizards

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Climate change is already striking organisms all across the world. Across them, the climatic vulnerability of ectothermic species from tropical rainforests has been posed as specially at risk. This is because these ecosystems have been historically warm, wet, and relatively stable, leading to the evolution of species with relatively low tolerance and low capacity to control their levels of body temperature and hydration. However, how they avoid stressful temperatures and dehydration is yet unknown. These skills can be integrated in the voluntary maximum temperatures (VTMAX) of individuals. This trait represents the maximum temperature they can withstand before they are forced to seek for a thermal shelter, restricting their activity and habitat use. However, the variation of this trait in response to other limiting factors, such as water availability, has been so far rarely observed, nor if these changes may alter our perception of thermal risk. During an expedition to the Rio Negro, at the Brazilian Amazon Basin, I measured the VTMAX of two typically thermoconformer lizard species with different levels of body hydration. Then, I used their responses to mechanistically model how the geography of climatic vulnerability would change as a function of their changes in behavior, compared to changes in tree cover and rainfall. Despite considered thermoconformers, the two species were actually able to alter their VTMAX with respect to their hydration level and experimental heating rates. Further, dehydration-induced changes in the VTMAX had major effects on the predicted geography of climatic vulnerability across the Amazonian Basin, comparable with potential changes in tree cover and rainfall, as expected from climate change. During the talk, I will discuss potential implications for species conservation from climate warming in the Amazon.

Keywords Amazon, climatic vulnerability, ecophysiology, voluntary thermal maximum, dehydration, lizards.

Part III

Lightning talks

Ecosystem Services in the Face of Global Change

Session Recording: https://youtu.be/uDcF8oi6K1M

Restoring Multiple Ecosystem Services with Evidence-based Strategies in Degraded Rangelands in Lesotho

Jazz Johanna Maria Kok[1], Madelon Lohbeck[1], Leigh Ann Winowiecki[1], Tor-Gunnar Vågen[1]

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Vegetation sustains ecosystem services, and land degradation may result in their loss. Yet, a holistic understanding of how woody and non-woody vegetation and their functional traits drive ecosystem services is limited, especially for managed systems. In a recent, still unpublished work we study rangelands in Lesotho affected by degradation and aim to systematically assess the role of management and vegetation on the supply of multiple ecosystem services. We argue that having a better understanding of these linkages is needed to design evidence-based restoration strategies. We used the Land Degradation Surveillance Framework (LDSF) at three sites and 446 plots to assess the impact of land management (grazing, fire, firewood collection), woody and non-woody vegetation (cover, biomass, functional traits) on the supply of ecosystem services (climate regulation, biodiversity, soil health). We also evaluated synergies and trade-offs between ecosystem services. Our optimal models reveal the importance of land management and suggest a role for plant functional traits in explaining ecosystem functioning and services. Specifically, we found that carbon stocks (proxy for climate regulation) were positively affected by grazing and by leaf dry-matter content (LDMC) of the woody and non-woody community. Simpson Diversity (ISDI; proxy for biodiversity) was negatively affected by non-woody aboveground biomass and positively by the proportion of shrubs. Soil erosion (inverse proxy for soil health) increased with grazing, fire and decreased with firewood collection, while it increased with woody and non-woody vegetation cover and with abundance of tussocks and decreased with aboveground non-woody biomass. Though services had specific drivers, we found that reducing grazing pressure, removing invasive species and decreasing tussock plants is likely to simultaneously enhance supply of all studied ecosystem services. Synthesis and applications: Our findings revealed a complex web of relations between land management, vegetation and ecosystem services and that setting specific restoration goals is needed to target the right strategy. Reducing grazing pressure, removing invasive species and stimulating non-tussock plants should be prioritised for effectively restoring carbon stocks, biodiversity and soil health in Lesotho's rangelands.

Keywords Lesotho, Rangeland, Restoration, Management, Grazing, Functional Traits, Biodiversity, Ecosystem Services

Sustaining Ecosystem Services of Tropical Forest under Agricultural Expansion: A Study Case of Sulawesi, Indonesia

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Tropical agriculture relies on ecosystem services that tropical forest ecosystems provide, such as soil fertility regulation and pest control services. These ecosystem services are essential to sustain forest regeneration and crop production simultaneously. Therefore, understanding the capacity of human-modified tropical landscapes to support biodiversity and ecosystem functions and services could become key in sustaining tropical forest and agriculture by conserving the ecosystem services. The objectives of the study were 1) to investigate how multiple ecosystem functions and services vary spatially in a human-modified tropical landscape, 2) to examine the ecological interactions among the invertebrate community in providing ecosystem function under changing environment, and 3) to assess the effectivity of practical solution of agroecosystem management to sustain ecosystem services in the adjacent agriculture. We investigated the decomposition (using litterbag and cellulose bait methods) and predation of herbivorous insects (using plasticine caterpillar method) across a gradient of anthropogenic habitat modification (forest, shrubland, and corn farmland) within Panua Nature Reserve, Sulawesi. These ecosystem functions are linked to forest regeneration and crop production. The influence of forest fragments to support ecosystem functions in adjacent small-holder seasonal crop agriculture was investigated experimentally by measuring ecosystem functions within transects. These results confirm that even small-scale agricultural areas adjacent to forest fragments can experience impaired ecosystem functions. These changes can be linked to impaired invertebrate activity, indicated by reduced decomposition and caterpillar predation by invertebrates. Decomposition mediated by invertebrates is not spilt over from tropical forest to adjacent agroecosystems, while predation of herbivorous insect is forest-dependent. The use of locally available organic matter and forest fragment restoration appeared to be practically effective in sustaining ecosystem services in agriculture, supporting soil fertility and pest control services. Therefore, effective management of human-modified landscapes will be needed to sustain nutrient cycling and trophic level interaction, even in areas where agroecosystems and tropical forests occur in close proximity.

Keywords Tropical Forest, Agriculture, Ecosystem Functions, Ecosystem Services, Invertebrate, Indonesia

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Cacao Pollination Services Are Driven by Shade Management, Forest Proximity and a Minimum Threshold of Pollen Deposition

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Across the tropics, livelihoods of over 6 million smallholder farmers are sustained by yields of the Amazonian chocolate tree (*Theobroma cacao*), both in- and outside of its native range. Successful fruit set relies heavily on pollination services, but pollination ecology of the tree crop is poorly understood, particularly in its region of origin. Multiple interrelated factors drive pollination services, such as flower-visiting insects that deposit pollen; landscape and management features that affect flower visitation rates; and pollen quantity required for successful fruit set. Recommendations to improve cacao productivity are constrained by our lack of regional understanding of the identity of the main pollinators, the degree to which flower visitation rates depend on management factors, and how much hand pollination can improve production. Here, we aimed to improve understanding of these factors in cacao's center of origin with three studies. First, to assess flower visitor abundances and the impact of management on visitation rates, we applied insect-sticky glue on flowers to sample visitors from 20 cacao agroforests in northern and southern Peru, across gradients of shade cover and forest proximity. Second, to relate pollen quantities to fruit set success, we estimated pollen deposition from ultra-macro-photographs of flowers. Lastly, to evaluate local gains from hand pollination, we compared fruit set rates between manually and naturally pollinated flowers. Interestingly, midges, the assumed main

cacao pollinators, were not the main visitors. In contrast, aphids and thrips in northern and southern Peru, respectively, were the most abundant visitors and hence might be promising candidates as potential pollinators. The opposing trends of visitation rates along medium to high shade cover (40 – 95%) and forest proximity (0 – 1.5 km) between regions indicate the need for locally adapted landscape management that maximizes flower visits. Based on our findings, we recommend maintaining high shade cover and nearby forest to improve flower visitation, but only in dry regions. Pollen deposition of > 115 grains was necessary to increase fruiting success, and hand-pollination of flowers enhanced fruit set from 2% to 7%. However, because hand pollination gains are low, location-specific landscape and farm management and clarifying pollinator identity will remain crucial to improve cacao pollination services and smallholder farmers´ livelihood.

Keywords Hand Pollination, Flower Visitors, Forest Proximity, Pollen Deposition, Shade Management

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Putting a Price on the Menu: Evaluating Bat and Bird Ecosystem Services in African Cocoa Farms

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Sub-Saharan Africa is home to one of the largest areas of tropical rainforest in the world. About 70% of the world's chocolate is grown in Africa and an increase in production is expected in the next 20 years. Cocoa insect pests can cause losses of hundreds of millions of euros annually; however, no studies from Africa have yet addressed the role of flying vertebrates as pest suppressors in cocoa farms. By establishing an exclusion experiment in which we used netting to block the access of bats and birds to cocoa trees for one year, we quantified how the consumption of insects by these taxa affected arthropod communities, herbivory, and cocoa crop yield. Our preliminary dietary analysis based on metabarcoding results from bat and bird faecal samples showed that 5 bat and 11 bird species consumed the main pest of cocoa in Cameroon (Hemiptera: *Sahlbergella singularis*). Hence, we hypothesized that these taxa would contribute to the suppression of cocoa pests and thus increase crop yields. Overall, our exclusion experiment showed that controls trees (trees without netting) had almost 30% more pods than excluded trees, with differences being dependent on farm management (e.g., degree of shade cover). Responses of arthropod communities were order-specific, with some important pest groups such as Mealybugs and Hemiptera being more abundant in exclosures compared with control trees. Our results show the potential of African bats and birds as pest suppressors in cocoa farms but highlighted that their role is dependent on the arthropod communities present on trees, farm conditions and environmental factors. Understanding how these interactions between species are connected to productivity and farm characteristics is critical to correctly implement fine- and large-scale management recommendations that help farmers improve yields while at the same time contribute to biodiversity conservation.

Keywords Bats, Birds, Cocoa Farms, Pest suppression, Exclusion experiment

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Pest Control, Pollination and Other Sweet Services by Birds, Bats and Insects: Findings from Cameroon's Sustainable Cocoa Project

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Cocoa, which fuels the multi-billion dollar chocolate market, is grown in tropical rainforest—mostly in Sub-Saharan Africa on small, family owned farms. African farmers typically rely nature for pest insect removal and pollination, but neither farmers nor biologists know which birds, bats or arthropods provide these services. Insectivores presumably also eat many disease-carrying insects—most importantly malaria-carrying Anopheles mosquitos—which put the lives and health of farmers and their families at constant risk. Critically, it is still unclear how management of cocoa farms affects the ecosystem-service providing biodiversity within. Here we will provide an overview of the Sustainable Cocoa Project in Cameroon. Specifically, the project seeks to understand: 1) How cocoa management affects bird and bat diversity, 2) Which birds and bats consume cocoa pests and malaria-transmitting Anopheles mosquitos (via diet DNA metabarcoding), 3) How much these insectivores save farmers (via exclusion experiments), and finally 4) Which insects pollinate cocoa flowers (via eDNA on flowers). Alpha diversity of birds in cocoa was, perhaps surprisingly, similar to that of primary forest; however, insectivores, forest specialists and ant-followers were much less common in cocoa—particularly as cover from shade trees decreased. We have found a diverse community of 11 bird and six bat species that eat brown capsids (Hemiptera, *Sahlbergella singulars*), considered the primary cocoa pest in Africa. We have also found one bird and 10 bat species that eat Anopheles mosquitos—the genus that transmits human malaria. We have started designing a species-specific DNA primer to detect short sequences of Anopheles DNA in bird and bat faces. Our exclusion experiments (netting around cocoa trees) show that trees excluding insectivorous birds or bats have more pest arthropods and produce fewer cocoa pods—shortly we will quantify savings for farmers. Finally, our pollination studies are in their infancy, but show great promise for using eDNA to identify pollinators. Well-managed cocoa agroforestry can be a valuable component of an ecologically functional landscape; however, it is not a substitute for primary rainforest. It can be valuable as a corridor or buffer for primary forest, in land sharing approaches, and can be extremely biodiverse. As the demand for cocoa continues to increase, we week to build a win-win framework in which both biodiversity and African farmers benefit through inexpensive, sustainable and profitable management of cocoa.

Keywords agroforestry, bats, biodiversity, birds, faecal metabarcoding, pest control, productivity

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COVID-19 Pandemic as an Emergent Phenomenon of the Nature-society Relationship of the World-System

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The globalized human economy associated with the global ecological crisis constituted a fertile ground for the emergence of the new COVID-19 pandemic (SARS-CoV-2). The origin of the spread of COVID-19 has a strong relationship with human activities and with an economic bias that alters the dynamics of ecosystems, increasing the risk of human beings coming into contact with new diseases. But the impact of the pandemic has not been the same for everyone. The historical asymmetrical power relations in the World-System, is crucial to understand the impacts and thinking about solutions in the post-pandemic world. Here, we carry out a critical review of several primary studies about the pandemic of COVID-19, from July 2020 to March 2021. We considered research articles and discussions published in Web of Science and Redalyc database, with a focus on articles in the area of conservation sciences and humanities. We also defined the COVID-19 pandemic as an emerging phenomenon of nature-society relations in the globalized World-Economy, through Wallerstein's World-System theory, with the additional aim of providing an interdisciplinary approach. Far from exhausting the topic, we found that consequences generated by the pandemic vary geographically, but that

the pattern is repeated throughout the world, the most vulnerable populations were the most affected, with severe consequences for the environment. Illegal extractivism, deforestation and poaching have increased with pandemics, along with food insecurity, social inequalities and structural violence. We note that the COVID-19 crisis highlights how biodiversity conservation is intrinsically linked to socioeconomic structures. The systematic processes of exploitation, the conflicts of power emerging from the domain of land, and the complex situation of abandoned local populations, interact and reinforce themselves, playing a dominant role in driving the dynamics of future trajectories on biodiversity and society. We also observe that, despite the pandemic being prioritized by Science as a whole, this process is fragmented and tends to accumulate information that needs to be analyzed from an integrated approach. Thus, we reinforce the need to develop an interdisciplinary perspective, aiming to attack the bases of production and reproduction of the inequalities that undermine the practice and success of biodiversity conservation and human well-being goals.

Keywords Biodiversity conservation; coronavirus; globalization; ecological crises; social inequality; interdisciplinarity

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Forest Pattern and a Household's Livelihood, Health, and Wellbeing

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Research on planetary health has pointed out how deforestation can have enormous effects on human health, food production, air quality, water availability, loss of biodiversity, and climate change. However, how does deforestation affect those who live closest to the forest? Forest dwellers and rural communities depend on the forest to maintain their wealth, supplement their diets, and provide ecosystem services for their survival. Changes in forest cover are often associated with emerging tropical diseases by creating favourable microclimatic conditions. Furthermore, the remoteness of rural households limits their access to health services, markets, and products. Thus, when deforestation or forest degradation occurs, it is they who are likely to be most affected. This work focuses on the socioeconomic and health implications of deforestation in rural communities in the Peruvian Amazon between 2015 and 2019. I use Geographic Information Systems tools to gather information from Demographic and Health Surveys (DHS) with spatial data on forest cover to identify casual links, as well as synergies and trade-offs between deforestation, poverty level, the incidence of diseases (fever/diarrhea) and dietary diversity. We hope the results of this work will inspire further multidisciplinary research to understand the dynamics between local livelihoods, human well-being, and nature conservation.

Keywords forest, poverty, livelihoods, well-being, nature conservation, amazon, Peru

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Understanding the Changing States of Colombia's Land Cover, Multiple Ecosystem Benefits and Socioeconomic Factors following the Peace Agreement

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Colombia is one of the most megadiverse countries and home to over 51 million people. Sixty years of internal armed conflict has led to environmental and socioeconomic impacts. Since the peace agreement between the Colombian government and the Revolutionary Armed Forces of Colombia (FARC, Spanish acronym) in 2016, Colombia now faces new challenges from increased access to forests and changing land use. These new challenges have further implications on ecosystems and socioeconomic factors. The Colombian government would need to address these challenges if it is to achieve sustainable development and post-conflict recovery. Using geo-environmental satellite data and spatially explicit socioeconomic data, we aimed to understand how land cover, multiple ecosystem benefits and socioeconomic factors have changed inside and outside areas of

conflict across Colombia's landscape pre- and post-peace agreement. We explore patterns of change inside and outside conflict areas, before and after the peace agreement, considering the intensity of conflict. Finally, we identify high risk areas where funding or interventions should be invested to improve multiple ecosystem benefits and socioeconomic factors.

Keywords Sustainable future, Armed conflict, Ecosystem services, Biodiversity, Socio-environmental system, Tropics

Loss and Fragmentation of Tropical Ecosystems

Session Recording: https://youtu.be/ib3jbIRaD4c

Emerging Frontiers of Deforestation in Southeast Asia

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Deforestation threatens the global persistence of biodiversity and compromises the carbon sequestration potential of Southeast Asia. Faced with limited time and resources, there is a need to effectively monitor forest change to direct site-specific conservation interventions. Recent studies combined spatial statistics and trend analysis to identify regions where high rates of forest loss are increasingly clustered over time; also known as emerging hotspots. Although these studies provide critical information on developing threats, deeper analytical insights into the application of emerging hotspots, and how they relate to the evolution of deforestation drivers over time are required to further facilitate forest conservation. Here, we capitalize on a 27-year annual forest change database (1992 – 2018) to fulfil our primary objective: the identification of deforestation drivers in emerging hotspots across SE Asia. A regional overview of forest change showed that gross loss (219,833 km^2) dominated the landscape, particularly in insular SE Asia. Quantification of the net and gross changes across 26 interannual intervals revealed six temporal patterns of subregional forest change [consistent losses/gains; attenuating losses; forest/reverse transition; oscillating] that highlight important forest change trajectories. Emerging hotspots of forest loss covered 27.4% of the landscape and accounted for 61,140 km^2 of interannual, gross forest loss. We then quantified the drivers and outcomes of 2000 – 2017 forest loss in 571 samples that were randomly and spatiotemporally assigned within eleven emerging hotspot regions. Conversion to tree plantations was the primary driver of deforestation (53.2% of samples), with oil palm and rubber as the primary tree crops in insular and mainland SE Asia respectively. During this period, oil palm intensified in Kalimantan and Papua, whereas rubber was important in Cambodia and Tanintharyi. Degraded landscapes were a major outcome of forest loss (44.0% of samples) but half of the samples represented intermediate transition states that were eventually converted into tree plantations and mixed farming/homegardens landscapes by 2021. Quantification of remaining forest cover allowed us to gauge the conservation importance of emerging hotspot regions. We show that new deforestation frontiers are forming on the peripheries of the two largest forested landscapes in SE Asia; Borneo and Papua. In mainland SE Asia, forest loss hotspots are developing in the Dawna Tenasserim and Annamite Cordillera mountain ranges, possibly leading to declines in biodiversity. Lastly, most of Sumatra's forest cover has been depleted, except for the last remaining peat swamp forests. We hope our findings provide opportunities for forest conservation in the region.

Keywords forest conservation, deforestation, Southeast Asia, emerging hotspot, drivers

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The Permanence of Deforestation Reduction May Depend upon the Adoption of Alternative Livelihood Activities: Evidence from an Amazon REDD+ Site

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REDD+ emerged in 2007 as a nature-based solution to mitigate the climate crisis mainly through deforestation reduction. Recent impact evaluations have shown that local REDD+ initiatives have some level of success in reducing deforestation and conserving forests. However, there have been few efforts to evaluate the permanence of these outcomes, as well as the causal mechanism responsible for sustaining outcomes after REDD+ interventions are suspended. Because it is unlikely that funding for REDD+ initiatives will be guaranteed permanently, understanding how to boost self-sustained deforestation reduction is warranted. Through the use of quasi-experimental methods, we investigated the long-term outcomes for forest conservation of a REDD+ initiative in the Brazilian Amazon. This initiative combined Payments for Ecosystem Services (PES) and sustainable livelihood (e.g., agroforestry systems, intensive cattle ranching) alternatives to "business-as-usual" activities (e.g., swidden agriculture, extensive cattle ranching), between 2012 and 2017 to reduce deforestation by smallholders. We then evaluated whether the adoption of alternative livelihood activities was a causal mechanism for self-sustaining forest conservation outcomes by searching for heterogeneous effects among households that adopted/did not adopt those activities. Data came from face-to-face interviews with 98 households (control: 46; treatment: 52) in a panel design (2010; 2019). Results indicate no significant average outcomes to forest cover. Since a previous study found the initiative saved ∼4.3 ha per household while it was being actively implemented, we may at first conclude that forest conservation outcomes were non-permanent over time. Yet, when searching for outcomes separately among households that adopted/did not adopt new livelihood activities, we found heterogeneous effects. Treated households that adopted new activities (N=25) had an average of 14.67% to 16.90% more forest cover (∼10.40 to ∼11.98 ha) than controls. However, in treated households that did otherwise (N=27) we again identified null impacts. The corollary of our findings is that, for reaching self-sustaining REDD+ outcomes for forest conservation, we need to promote the adoption of alternative livelihood activities. Our results also indicate the need to investigate potential heterogeneous outcomes in REDD+ impact assessments since average estimation could hide important variation in treatment effects.

Keywords REDD+, alternative livelihood projects, emission reductions, permanence, climate change mitigation

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The Impact of Land Ownership and Deforestation in the Colombian Amazon from 2010 to 2020 on the Livelihoods of Rural

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Colombia contains 10% of the Amazon forest (Field Museum, 2013) and 14% of the world's biodiversity (Global Forest Atlas, 2020), but it also experienced one of the 20th century's longest-standing civil conflicts. Land management and policy, and particularly the unequal distribution of land in the Colombian Amazon, has been a source of contention for decades and is considered a key factor in much of the violence in Colombia (Nelson, 2019). Furthermore, there is increasing recognition of the importance of secure land tenure for reducing deforestation and addressing forest dependent community wellbeing (Bradley and Fortuna, 2019). Much is still unknown about how communities, and especially women, in this region manage their land and forest resources and how their land use decisions have been impacted by the conflict. I plan to determine how land use and ownership has changed in the wake of the Colombian peace agreement in 2016, and the implications of these changes for the livelihoods of those who live on or have recently returned to this land, particularly women. I will use a mixed-methods approach, utilizing both econometric and survey methods. My research aims to answer the following questions: (1) Has land and forest tenure in the departments of Guaviare and Caqueta changed in the past decade, and if so, what events have caused these changes? (2) How do self-identifying indigenous and non-indigenous women in Colombia rely on land and forest resources for their income and well-being? Has this changed since the passage of the peace accord in 2016? Do any barriers exist for communities to use

their land and forest resources to the extent that they would choose? (3) Through which processes have land use changes, such as deforestation through conversion to pasture or agriculture occurred in communities in Guaviare and Caqueta in the past decade?

Keywords Gender, Conflict, Land tenure, Community Forestry, Deforestation

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Highway BR-319: A New Frontier of Illegal Logging in the Amazon Rainforest Threatens Biodiversity

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Amazonia faces a key conservation issue: the proposed reconstruction of a highway (BR-319: Manaus-Porto Velho) that, together with planned side roads, would give deforesters access to about half of what remains of Brazil's Amazon rainforest. The mere highway "maintenance" program in 2015 is already causing impact on this area, which is one of the Amazon's most conserved forest blocks. Our goal is to highlight how the pressure from illegal logging impacts the composition of forest species in the period after the "maintenance" program began in 2015. Along a 50-km stretch of BR-319 we sampled three 1-ha permanent plots in 2019 where censuses had been conducted in 2010 by the Biodiversity Research Program (PPBio) of the National Institute for Research in Amazonia (INPA). The forest degradation due to illegal logging directly killed 144 trees (either harvested or machinery uprooted) in the three plots. The dead trees were distributed among 20 families, 22 genera and 39 species. Of the trees killed, only 15 individuals (11%) were used for timber as indicated by the trunk having been removed. In other words, 89% of the individuals became coarse woody debris, which is combustible material on the forest floor. The waste this represents reflects the lack of motivation for illegal loggers to use reduced-impact techniques. The trees removed were of species with high commercial value: *Erisma bicolor* (4 individuals), *Goupia glabra* (3), *Peltogyne catingae* (3) *Licania hypoleuca* (1), *Cariniana micantha* (1), *Simarouba amara* (1) and unidentified (2). Current estimates suggest that the Amazon is home to 11,675 tree species and that only 227 of this total are hyperdominant (which represent more than half of all trees present in the forest). Of the timber species harvested, only two are on the list of hyperdominants. One of the main challenges for the sustainability of both the legal and illegal timber sectors in the Amazon is the relatively small percentage of high-value species (which represent less than 1% of the forest's species). Although many species in the Amazon have technical feasibility for timber use (based on wood's physical, chemical and anatomical characteristics), logging depletes the most valuable species and acts as a driver for opening new frontiers for exploitation and degradation. If all of the high-value species (21) and non-commercial potentials (28) were used in logging, the yield could increase up to 3x. The timber sector's current unsustainability is a threat to biodiversity with consequences for the future.

Keywords unsustainable timber, high-value species, sustainable development, amazon, loggers, forest management

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Understanding the Drivers of Forest Loss in Mexico: A Machine Learning Approach

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The loss of forest coverage is one of the most evident processes of human influence on terrestrial ecosystems globally, jeopardizing biodiversity and affecting the delivery of essential ecosystem services such as climate regulation, carbon storage, and water supplies. However, understanding the factors and processes driving large-scale vegetation loss is not an easy task. Firstly, there are multiple biophysical, socio-economic, and political factors that can interact and influence spatially and temporally this phenomenon. Secondly, modeling this type of data often presents several problems for traditional techniques, including unusual frequency distributions, non-linearity, multicollinearity, complex interactions, non-independence of observations, and spatial and temporal autocorrelation. And thirdly, the availability of big data in the current century requires large data cleaning and processing efforts. All these facts raise the need for flexible models that can improve the understanding of how different components or processes interact in social-ecological systems. The framework of Machine Learning (ML) has recently been envisioned as a flexible and powerful tool for analyzing complex systems. The logic behind ML, and particularly for supervised learning, is that through experience, the computer can recognize patterns in the data and predict outputs. Using recent opensource data and Random Forests, a popular ML algorithm, we modeled the spatial patterns of deforestation for Mexico, estimating the probability of forest loss for each squared kilometer in the country. By opening the ML black-box through the use of model-agnostic interpretation techniques, we explored the importance of several factors that promote the occurrence of this process, considering a set of covariates and the relationships and patterns among them. In the presentation, we aim to address the following questions: (i) What regions are experiencing a higher risk of cover loss?; (ii) what are the most important biophysical, socio-ecological, and management factors influencing such risk?; (iii) are there some potential interactions among the factors?; and (iv) is it possible to identify some local clusters with similar influencing variables on the final output?. Predictions show a high risk of loss of vegetation cover in different regions of Mexico, including a "red zone" in the country's southeast. While the obtained predictions can be very informative in showing the areas with the highest pressures, we also discuss the potential of interpretation techniques for exploring the factors that generate such predictions and the general patterns among them towards the design of public policies at local and global levels.

Keywords Machine Learning, drivers, deforestation, socioecosystem, random forests, shap-values.

Agricultural Subsidies Influence Monoculture Cultivar Cashew Expansion in Western Ghats, India

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Agricultural commodity production drives tropical deforestation and biodiversity loss yet is an important source of livelihood for many farmers. While the socioecological effects of agricultural commodities such as palm oil, cocoa and coffee have been well studied, the impacts for other commodities such as cashew are relatively unknown. Global cultivated area for cashew experienced a sharp eleven-fold increase from 526,250 ha in 1980 to 5.9 million ha in 2018. India has the second-largest land area under cashew cultivation globally, often grown adjacent to forests. However, such landscapes have not received much conservation attention. To develop effective conservation strategies, it is crucial to understand how land use policies influence farmers' motivations for growing cashew, and the type of land management practices that characterise present-day farmers. Through semi-structured interviews (n=65) and a literature review on agricultural policies in India, we evaluated the role of state-led policies in cashew expansion and characterised present-day cashew farming systems in the Sawantwadi-Dodamarg landscape in south Maharashtra, India. Agricultural subsidies introduced from 1980 to 1990 encouraged cultivar cashew expansion and influenced land use conversion from rice and privately owned forest to cashew, a trend seen until present-day. Farmers grow a mixture of common and cultivar cashew varieties but the latter is preferred as they produce stable yields faster even though they require agrochemical inputs and are susceptible to pests and wildlife-induced losses. About 80% of farmers had cashew

farms that were planted over forests in the past 30 years and expressed interest to continue forest clearing for cultivar cashew expansion. Although farmers incur high losses from crop depredation on cultivar cashew, they avoid applying for government-sponsored compensation for these losses and choose to expand cultivar cashew cultivation. Our study deepens our understanding of how government-led agricultural subsidies drive farmers' uptake of cashew cultivars, farmers' practices on cashew management, and how these factors at the state and farm level drive deforestation in this landscape. We recommend further socioecological research in cashew farming systems to devise sound conservation planning and sustainability standards for the cashew industry.

Keywords *Anacardium occidentale*, cashew farmers; livelihoods; commodity-driven deforestation; private forests; cultivar-cashew

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How Does Landscape Structure and Configuration Affect Tree Species Diversity: A Case Study of a Dry Forest Landscape in Ecuador

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Introduction/Background/Justification: Land-cover change is estimated to be the largest driver of biodiversity loss worldwide. Therefore, it is necessary to improve our understanding of how species respond to changes in their landscapes, especially changes in forest cover. Because of high rates of diversity and endemism but low native vegetation coverage, studying these processes is particularly critical in tropical biodiversity hotspots. **Objectives/Hypotheses:** Evaluate how landscape structure and configuration affect tree species diversity in a fragmented landscape of tropical dry forest in coastal Ecuador. We hypothesize that higher fragmentation will have a negative impact on tree diversity, but except also to have some species (or group of species) less affected or even benefiting from fragmentation. **Methods:** We use field inventories (i.e. plots) to estimate tree species diversity (i.e. Hills numbers) and Landsat-derived class and landscape metrics to estimate landscape structure and configuration in nested buffers around each sampling plot. The effect of landscapes characteristics on tree diversity was evaluated using generalized linear models and mix models (GLM and GLMMs). **Results:** Results to date suggest that forest (mature and secondary) shape is an important predictor of overall tree diversity. Occurrence of endemic tree species appears also to be associated with forest shape, but also with plot and species characteristics (e.g. aboveground biomass, wood density) and forest type (i.e. old-growth or secondary). These patterns vary across endemic species, with some species even flourishing in secondary forest or positively affected by irregular forest shapes. **Implications/Conclusions:** Results suggest that targeting forest patches of combined secondary and mature forest with more round-like shapes are likely to contribute significantly to overall tree species conservation. For endemic species, conservation should focus on mature forests, although some endemic species thrive in secondary forests. This research improves our understanding of species' responses to forest fragmentation in a highly fragmented tropical dry forest landscape.

Keywords tree diversity, fragmentation, landscape configuration, landscape structure, TDF, Ecuador.

Impacts of Vegetation Quality and Edge Effects on Gastrointestinal Parasite Infections of Small Mammalian Hosts in Madagascar

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Negative impacts of habitat loss, degradation and fragmentation on biodiversity have been demonstrated for numerous taxa. Although parasites constitute a large portion of global biodiversity and provide important ecological services, e.g., by affecting trophic interactions, controlling population dynamics of their hosts and thereby enabling the coexistence of species, the effects of habitat alterations on parasites have been largely neglected. This study aims to investigate if habitat alterations affect the composition of gastrointestinal communities in small mammalian hosts in networks of fragmented tropical dry forest in northwestern Madagascar and to identify ecological key factors that impact the relationship between parasite, habitat and host. Fecal samples from 903 individuals of two mouse lemur species, *Microcebus murinu*s (n = 199) and *M. ravelobensis* (n = 421), and two rodent species, *Eliurus myoxinus* (n = 102) and *Rattus rattus* (n = 181), inhabiting forty forest fragments differing in host population density, size, shape and vegetation structure and four neighbouring continuous forest sites in the Ankarafantsika National Park and the Mariarano region were examined for gastrointestinal parasite infections by coproscopy. Ten host- and habitat-related ecological variables were evaluated by generalized linear mixed modeling for significant impacts on the prevalence of the most abundant gastrointestinal parasite types and on gastrointestinal parasite species richness (GPSR). The modeling showed a negative relationship between fragmentation- and edge-associated vegetation changes and prevalences of heteroxenous parasites (Subuluroidea fam. gen. spp., spirurid egg 1) and species with heterogonic free-living generations (*Strongyloides* spp.). Prevalence dynamics of directly transmitted and homoxenous parasitic nematodes (Enterobiinae gen. sp., *Lemuricola* sp.) were mostly not affected by habitat-related variables, but were affected by host-related factors like host species and sex. Soil-transmitted helminths and intermediate hosts require certain abiotic conditions, which are likely influenced by differences in vegetation structure at the forest edge and in highly fragmented and degraded habitats. The results of our study provide evidence of serious threats to parasite diversity, as it was shown that specialized species with complex life cycles are particularly vulnerable to changes of habitat quality. Since parasites can provide vital ecological services and ensure ecosystem stability, these results encourage greater consideration of parasites in the context of biodiversity research and conservation application in view of ubiquitous ecosystem alterations.

Keywords habitat fragmentation; edge effects; Madagascar; parasite communities; Microcebus; Eliurus; Rattus

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Does Patch Quality Drive Arboreal Mammal Assemblages in Fragmented Rainforests?

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Patch size is considered a major driver of species diversity in fragmented landscapes. Yet, assemblages of forest-dependent species, such as tropical arboreal mammals, can also depend on vegetation characteristics within the patch, i.e. patch quality. To test this, we assessed the influence of patch size and quality (measured through six attributes of vegetation structure) on arboreal mammals in 20 forest patches in the Lacandona rainforest – a biodiversity hotspot in the Mesoamerican Biological Corridor. We placed camera traps in 100 trees and registered arboreal mammals for one year. We used generalized linear models with a multimodel averaging approach and a distance-based redundancy analysis to identify the relative importance of patch size and quality on arboreal mammal diversity and composition. Species diversity was mainly and positively influenced by tree basal area – a vegetation attribute indicative of older and better-preserved forests – while species composition was driven by both patch size and quality. Patch size was negatively related to the abundance of kinkajous and Deppe's squirrels, likely due to a higher density (and detectability) of individuals in small patches. The abundance of kinkajous and Deppe's squirrels were lower in patches with higher tree density – an attribute

typically related to forest disturbance. Therefore, to effectively preserve this highly endangered and ecologically relevant group of mammals, both patch size and quality should be considered, paying special attention to the conservation of large trees.

Keywords Epiphyte cover, Fragmentation, Habitat quality, Large trees, Lianas, Tree basal area

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Protecting Large Forest Fragments within Oil Palm in the Eastern Amazon Is Crucial for Preserving Bird Diversity

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The expansion of agricultural activities is one of the main drivers of the biodiversity extinction crisis. One mechanism to reduce the negative impacts of agriculture expansion on biodiversity is the land-sharing approach that suggests the integration of production and conservation goals. The oil palm plantation is one of the main threats to tropical biodiversity, but so far, few studies have addressed the impact of this activity on the Amazonian birds. To understand whether the retention of forest fragments within oil palm plantations enhances the bird phylogenetic and functional diversity in production sites and which landscape factors are influencing these responses, we sampled birds in eleven transects in large forest fragments and eleven in oil palm plantations located in Eastern Amazon. We also collected the distance from each oil palm point to the nearest forest fragment and the percentage of forest cover in a buffer of 1km. Large forest fragments (>1000 ha) retained significantly higher Functional Richness (FRic) and Functional Divergence (FDiv) than oil palm points. Forest fragments also showed higher Phylogenetic Diversity (PD), Mean Pairwise Distance (MPD) and Mean Nearest Taxon Distance (MNTD), but the standardized metrics (ses) was not affected. Oil palm plantations presented impoverished phylogenetic diversity and fewer functional traits more evenly distributed (FEve). The proximity to forest fragments did not improve functional diversity in oil palm plantations. We observed that the bird community in oil palm points nearer forest fragments presented higher values of MNTD. Our results show that large forest fragments within oil palm-dominated landscapes protect important levels of forest phylogenetic and functional diversity, this is even more important given the high levels of deforestation and the number of endemic bird species endangered in the area. Despite the retention of forest fragments did not improve the functional diversity and most of the phylogenetic diversity metrics within the production areas, we found that species with close phylogenetic relations became more prevalent further from the forest. Thus, there is some evidence of spillover of species with more diverse evolutionary histories into oil palm close to large forest fragments. Our study shows that the retention of forest fragments near production areas may benefit oil palm plantations through spillover of some phylogenetic diversity and balancing the occurrence of the few remaining functional traits. We suggest the conservation of the large forest fragments is urgent and ensure that the proportion of natural remnants in land-sharing crops exceeds 40% of the landscape.

Keywords functional diversity, phylogenetic diversity, spillover, landscape ecology

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Forest Fragmentation in the Amazon Reduces Ant-following Bird Attendance at Army Ant-swarms

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Despite concerted efforts to understand how forest fragmentation impacts individual avian species or guilds, very little is known about its effects on networks of interspecific interactions. Understanding these effects is particularly important in rapidly deteriorating tropical forests, where a large proportion of species participate in mixed-species flocks or aggregations. In the Neotropics, ant-following birds that forage on fleeing arthropods at army ant swarms are consistently identified as one of the most vulnerable avian guilds to anthropogenic disturbance. At the Biological Dynamics of Forest Fragments Project (BDFFP) in central Amazonia, obligate ant-following birds disappeared completely from fragments for up to 5 years following isolation. To examine the long-term effects of fragmentation on networks of ant-following birds, we used 40 years of capture data from the BDFFP to retroactively assemble virtual ant-following bird flocks. We then calculated the frequency of attendance at swarms and the proportion of attending to non-attending birds in fragments before and after isolation. Attendance rates of ant-following birds declined by 45% and 54% in 1ha and 10ha fragments, respectively. Ant-followers did not resume attending swarms until 8-11 years following isolation, with attendance rates in 10ha fragments returning to pre-isolation rates only after 23 years. Furthermore, increases in species abundance over time did not correspond to comparable increases in swarm attendance rates. Additional network analysis will reveal how fragmentation affects species composition and relationships between ant-following birds at swarms. These results suggest that despite species abundance in fragments increasing as the surrounding forest regenerate, birds may take decades to return to their respective functional roles following disturbance. When measuring the impact of forest fragmentation on birds, researchers should be cautious when using species abundance alone as a metric. Considering networks of interspecific interactions will be crucial for the future conservation of tropical biodiversity

Keywords Fragmentation, ant-following birds, ecological networks, interspecific interactions, biotic interactions

Optimizing Educational Strategies and Public Policies for Conservation

Session Recording: https://youtu.be/UIo5dbUUipg

Charting Career Trajectories following an Exceptional Training Opportunity in Manu National Park, Peru

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There is no better way to teach and learn about the richness, exuberance, complexity, integrity and fragility of tropical forests than by living in one of them. To provide such an opportunity, we created an intensive course in Field Techniques and Tropical Ecology Course, immersing 10-12 promising young scientists for 3 months each year in the rainforest experience at the Cocha Cashu Biological Station in the heart of Manu National Park. "Cashu" is defined by its remoteness, and students enjoyed "nature as it should be" in a biodiversity hotspot, while learning all the tools needed for tropical research. This course is designed to fuel student's inquisitive minds, strengthen their academic background, provide them with communication and art tools, and with challenging projects that challenge them with the reality of investigating in a tropical forest. Three months spent in coexistence with the forest invariably results in the realization that they are themselves an integral part of the ecosystem, a somewhat intangible outcome that nonetheless supports future decisions that recognize the inextricable interconnectedness of nature and people. The course's success may be measured by the students' trajectories. Feedback we received, including surveys, indicates that 90% remain active in research and conservation, either independently or associated with national or international institutions; $>$ 50% have gone on to pursue postgraduate studies and additional coursework; several have earned international awards; five are pursuing a PhD; eleven completed an honors thesis; three have started their own NGOs; and two became renowned artists. Although we have no control group, we can safely conclude that students of this course were galvanized into pursuit of activities supporting a career in ecology and conservation. Cashu alumni appear to be positioning themselves in Peru and abroad to be the agents of change. Continued support from Cashu, in the form of advice and encouragement, is vital to keep these promising young scientists on this path. We have ourselves learned many lessons along the way, and continue to seek feedback that can further improve outcomes.

Keywords Tropical-Ecology Amazon-Andes Manu-National-Park Interconnectedness Coexistence Nature-and-People Decision-makers Career-paths Cocha-Cashu

Typifying Conservation Organizations' Views on the Role of Education

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Our present biodiversity crisis can only be solved with transformative change. Education is one of the key paths towards a sustainable future and is used as a biodiversity conservation strategy to enhance human-environment relationships. Most conservation education practitioners believe that education positively impacts conservation efforts, yet there is limited empirical evidence supporting this claim. The aim of this study is to unpack practitioners' perspectives on the role of education in conservation by a) typifying the paths that connect education interventions with a change in the health of the environment, the local communities and the individuals (i.e., pathways of change) and b) assessing whether these emerging pathways align with current theoretical discourses on the factors influencing human behavior. We addressed these questions in Madagascar, a top global conservation priority, where concerns about biodiversity loss have motivated conservation organizations to include education as an important component of their interventions. We used a theory of change approach to interview 15 conservation non-governmental organizations in Madagascar to understand how education initiatives generate a particular change in conservation. We found that practitioners focused on five pathways of change: i. increasing knowledge, ii. changing emotions and traditional cultural practices, iii. fostering leaders, iv. diversifying outcomes, and iv. influencing the community and society. These emerging pathways resonate with existing theoretical discourses. Whereas most of the individual organizations had a dominant pathway, others supported different interacting pathways. Noteworthy, most pathways lacked culturally-grounded approaches. Our findings illustrate that organizations sharing the common goal of biodiversity conservation have different rationales on how change happens, reflecting the complexity of factors that influence behavior. Yet, it remains a question whether this diversity is driven by the local sociocultural contexts in which organizations operate, or the interactions with other conservation approaches or structural solutions. Our research contributes to our understanding of the role of education in conservation, which can foster diversification and complementarity of educational practices, and provides the foundation for more comprehensive evaluation.

Keywords environmental education, Madagascar, theory of change, conservation educators, practitioners, outcomes

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Priority Areas and Actions to Conserve Globally Significant Ecosystems in Sulawesi

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Protected areas (PAs) are a mainstay approach to achieve biodiversity conservation goals. Furthermore, making priority amidst limited resources is the central tenet of conservation biodiversity strategy. In this study, we do a conservation prioritization using Marxan to achieve protection targets of an increasing proportion of forest cover, carbon stock, karst ecosystem, and degraded areas in Sulawesi's protected areas. The targets are set in a trade-off with the cost of conserving an area with low integrated forest, highly modified land-use type, high population density area, and high deforestation risk area. The Sulawesi's PA network currently only covers 10% of Sulawesi. Hence, the representativeness of conservation targets within the PA is limited. As much as 80% of the top quartile of the carbon storage area is not protected, only less than 10% of the karst ecosystem, degraded lands, and forest covers are protected. The current PAs are also ineffective, as shown by prioritizations that tend to choose areas outside those current PAs. Aside from this, all scenarios run consistently chooses the vast landscape of Mekongga (2,986 km^2) as one intact landscape to be protected outside the PA network. Our results suggest that, at minimum, an additional 5,581 km^2 of the first-tier high priority area must be included in the current PA network to increase target coverage and representative of Sulawesi's PAs. The work laid out here can be an excellent example to be replicated elsewhere in Indonesia's PA for helping the government in achieving the post-2020 global biodiversity framework, which most likely will adopt the 30x30 initiative, protection of 30% land, and sea by 2030. Coverage and representative in itself will not do much good without effective and equitable management of the PAs. We suggested approaches to effective management by adding priority areas to the existing PAs network as part of the Essential Ecosystem. Alternatively, the private involvement in the Ecosystem Restoration Concession scheme or community-based conservation area with equity in mind can be considered and have these recognized as OECMs.

Keywords Aichi Target 11, Marxan, OECMs, Post-2020, Prioritisation, Systematic conservation planning

The Role of Protected and Unprotected Forest Remnants for Mammal Conservation in a Megadiverse Neotropical Hotspot

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The Brazilian Atlantic Forest of Southern Bahia is a megadiverse region given its remarkable number of species and endemism. Despite being a priority region for biodiversity conservation, the role of protected and unprotected forest remnants for long-term species conservation is unknown. Here, we unveil the main patterns of occurrence and distribution of medium- and large-sized mammals in remnants of the Atlantic Forest of Southern Bahia, to generate subsidies for applied conservation strategies. We recorded mammals using camera traps, active search, and/or line-transect surveys and complemented our species list with literature data. We thus obtained information on richness attributes, relative abundance, and biomass of mammal species per forest remnant, compared assemblages in protected and unprotected areas, and finally investigated both species-area and biomass-area relationships. From 72 forest remnants assessed, we recorded 45 mammal species, including 19 threatened locally. Protected areas were richer in species, especially concerning threatened ones, and concentrated most of the mammal biomass, which presented consistently low values for most areas. The positive and significant species-area and biomass-area relationships further corroborate these patterns since protected areas are larger in size. Despite the historic anthropogenic pressures, we conclude that Southern Bahia still harbors an expressive mammal diversity, with protected areas being critical to maintain most of the species' richness and biomass across the entire region. Nevertheless, small unprotected remnants ($<$100 ha) safeguard mammal species, including threatened ones, stressing their importance to maintain mammal assemblages in one of the most important hotpoints of the entire biome.

Keywords Assemblage composition, Biomass, Patch size, Relative abundance, Species-area relationship

Reduction on Effectiveness of Amazon Protected Areas under Climate Change Threatens Plant-animal Interactions

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Introduction: Protected areas are an essential strategy to conserve biodiversity and ecosystem services throughout generations. However, the accelerated pace of climate change due to human actions may reduce the long-term effectiveness of protected areas in safeguard species and their biotic interactions. **Objective:** We used Ecological Niche Modeling to evaluate the long-term effectiveness of Amazon-protected areas focusing on plant-animal interactions, with emphasis on pollination and seed dispersal in the emergent tree *Dipteryx micrantha*. **Methods:** The algorithms BIOCLIM, Domain, Mahalanobis, SVM, and GLM were used to forecast

the current and the future (RCP 4.5 for 2061-2080, derived from CESM1-BGC, CMCC-CMS, and MIROC5) habitat suitability areas for D. micrantha and its associated bee pollinators (e.g., *Euglossa mourei*, *Eulaema mocsaryi*, *Melipona grandis*, *Tetragona clavipes*, and *Trigona pallens*), and bat dispersers (e.g., *Artibeus concolor*, *A. jamaicensis*, *A. literatus*, *A. obscurus*, *A. planirostris*, and *Carollia brevicauda*). Shapefile layers were georeferenced in Universe Transverse Mercator and the World Geodetic System 1984 (WGS-84) Zone 19S, and borders of the distribution areas were smoothed for each animal species and D. micrantha. Then the intersected area between *D. micrantha* and each of the bees and bats was used to estimate the reduction or increase of the species distribution within the protected areas. **Results:** Considering the interactions among *D. micrantha* and its pollinators and seed dispersers, the highest reductions of habitat suitability were observed between *D. micrantha* and *E. mocsaryi*, and between *D. micrantha* and *A. obscurus*/*A. planirostris*, (in 221 of 333 protected areas). For only one animal species (e.g. the bat species *A. concolor*), we observed an expansion of habitat suitability areas. Furthermore, we also observed two largest climatically suitable areas for the species' intersections separated by several disconnected ones: the Southeast Peru/North Bolivia/Northwest Brazil, and the Northwest Peru/Southeast Colombia/Northwest Brazil. **Conclusion:** Our results indicate a reduction of effectiveness of the most Amazon protected areas under a future climate change scenario, suggesting disruptions in important biotic interactions (e.g. pollination and seed dispersal) and evolutionary processes in the Amazon Rainforest

Keywords Ecological Niche Modeling, pollinators, seed dispersal, biotic interactions, Dipteryx

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Three-years Monitoring of Roadkill Trend in a Road near a National Park in Panama

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Roadkill monitoring can provide important information about spatial and temporal trends, including influential factors on the probability of wildlife – collisions. Such data are important for applying mitigation measures that reduce the mortality of species of conservation concern. Unfortunately, road ecology is not a mainstream discipline in some regions of the world and Central America represents one of those cases. I aimed to monitor roadkills in a road next to a national Park in Panama for three years. I examined whether there was variation in the number of roadkills across taxa (birds, mammals and reptiles), year (2017 – 2020), season (dry vs rainy) and whether monthly average precipitation and temperature influenced the probability of roadkill occurrence. Additionally, I performed a spatial analysis to identify roadkill hotspots. Mammals and reptiles were the most common roadkills. Roadkills tended to decrease with increases in temperature and precipitation. A separate analysis of the two most commons roadkills (green iguanas and tamanduas) provided similar trends. The spatial analysis helped to identify a hotspot located in a curved section of the road and surrounded by water. This is the first study to examine for any road in Panama - through statistical modeling – factors that may influence the occurrence of roadkill events. The results suggest that vehicle collisions exert a similar pressure on all taxa and the geometry of the road or distance to the water are also influential. Finally, I also propose mitigation measures and report anecdotal roadkill data from other sites in the country.

Keywords Human-wildlife conflict, mitigation measures, road mortality, wildlife – vehicle collision

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Applying the Tropical Important Plant Areas Approach to Conserve Useful Plant Species in Colombia

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Colombia ranks second in the world for the number of plant species it supports. However, large gaps remain in understanding the country's biodiversity and its role in human welfare. Simultaneously, few protected areas address the conservation and management of useful plants – species known to fulfil a need for humans, including medicine, materials, food, and fuel. We applied the Important Plant Area (IPA) approach to identify key sites for the conservation of useful plant species in Colombia, contributing to the Tropical IPA programme. In particular, we asked: (1) Which useful plant species in Colombia are conservation priorities? (2) What is the known geographic distribution of priority useful plant species? (3) Where are potential TIPAs for useful plant species in Colombia? (4) How are potential TIPAs represented in the current national protected area network? Principles of Strategic Conservation Planning (SCP) and a proposed national methodology for IPA identification in Colombia were applied, allowing the latter to be tested for the first time. Drawing on a checklist of useful plants of Colombia (>6,000 species), compiled as part of the "Useful Plants and Fungi of Colombia" project, over 180 priority species for conservation were identified. Through a regionalized, unweighted approach, existing georeferenced records of priority species were combined with a national habitat map to identify areas meeting IPA criteria. Initial prioritization of these potential TIPAs was undertaken using the conservation planning tool Marxan, including assessment of representation in existing protected areas. This indicated that the existing protected area network in Colombia does not sufficiently protect priority useful plant species. This presentation will summarise the methodologies used, and results gained. Additionally, we will outline planned next steps to compare local knowledge and use of plants with IPA conservation prioritisation using social science methods in three case study areas. Multiple studies show that SCP approaches require practical validation to achieve conservation and local development. A socio-ecological approach is therefore fundamental, enabling evaluation of the relevance of standard conservation planning practices to local people. Project outcomes will be important at a range of scales through conserving plants locally, identifying a conservation network nationally, and contributing to global understanding of the application of IPA criteria to useful plants.

Keywords Important plant areas; ethnobotany; plant conservation; Colombia; socio-ecological system

Biology and Conservation of Tropical Birds

Session Recording: https://youtu.be/FZPUVG7m3E8

Light and Temperature Niches of Ground-foraging Amazonian Insectivorous Birds

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Introduction / Background / Justification: Insectivores of the tropical rainforest floor are consistently among the most sensitive birds to forest clearing and fragmentation. Several hypotheses address this pattern, including sensitivity to novel microclimates manifested near forest borders—particularly brighter and warmer conditions. Importantly, this "microclimate hypothesis" has additional implications for undisturbed forest under global climate change and may be the mechanism behind enigmatic bird declines reported across undisturbed Amazonian forest. Yet, empirical assessment of the light and temperature environment occupied by terrestrial insectivores is largely limited to indirect observations and equivocal results. **Objective(s)/Hypothesis(es):** In this study, our objectives were to (a) directly quantify the light and thermal niches of nine species of terrestrial insectivores, and (b) compare microclimate use to published abundance trends from primary forest to test whether declining species used darker and cooler microclimate. **Methods:** Loggers placed on birds (N = 33) and their environment (N = 9) recorded nearly continuous microclimate data from 2017–2019, amassing >5 million measurements. Results: We found that midday light intensity in treefall gaps (39,000 lux) was >40 times higher than at the ground level of forest interior (950 lux). Birds used even darker microhabitats. Light intensity registered by sensors on birds averaged 17.4 (range 3.9–41.5) lux, with species using only 4.3 (0.9–10.4) % of available light on the forest floor. The thermal environment occupied by birds was a function of ambient as well as body temperature, which averaged >40.5 °C but varied among species. Forest floor temperature peaked daily at 27.0 °C, while bird loggers averaged 35.1 (34.5–35.7) °C at midday. The antpitta *Myrmothera campanisona* and the antthrush *Formicarius colma* used thermal conditions closest to their body temperatures, while leaftossers (*Sclerurus* spp.) and *Myrmornis torquata* occupied relatively cool microclimates. We found no general link between abundance trends and variation in species-specific light and thermal niches. Rather, all species occupied remarkably dim and cool microclimates. **Implications/Conclusions:** Because such conditions are rare outside the interior of primary forest, we consider these results as support for the microclimate hypothesis in disturbed landscapes. However, the strong association with conditions that are shifting towards the contrary under climate change highlights the vulnerability of terrestrial insectivores even in the absence of disturbance and may be the reason for declines in Amazonia and elsewhere.

Keywords bird declines, climate change, forest interior, microclimate, rainforest, terrestrial insectivores

Bird Community Dynamics in Forest Fragments: Insights from Two-decades of Bird Surveys in Rainforests of Southern India

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As rainforest fragments become increasingly common, there is an urgent need to understand what limits their viability for bird conservation in the long term. However, longitudinal studies are rare, primarily picking up transient dynamics in the decades immediately following fragmentation. Moreover, studies often rely on fragment characteristics as drivers of bird community change and ignore habitat quality, despite evidence for strong bird-habitat coupling. Our study examined bird community dynamics over 19 years in variously-shaped forest fragments of differing sizes and habitat quality in the Anamalai hills, Western Ghats, India; these fragments are conducive to study steady-state dynamics because habitat-matrix boundaries have remained stable for at least 70 years. Using information from fixed-radius point counts across 19 forest fragments sampled in 2000, 2002-2005 and 2019, we computed rarefied species richness, estimated bird density by accounting for incomplete detection and measured temporal stability in community composition for each fragment. We modelled their relationship with fragment size, fragment shape, time and habitat quality using linear models, separately for rainforest and open-country bird species; we used six complementary habitat variables collapsed into principal components as measures of habitat quality and fractal dimension of fragments as a shape-index that is independent of area. We found that species richness was surprisingly resilient over space and time, and independent of habitat quality. The density of rainforest birds declined over time, and was higher in more compact forest fragments but agnostic to fragment size. On the other hand, the density of open-country birds was constant over time but higher in smaller and less evenly-shaped fragments. In addition, the community of rainforest birds were more stable in larger, more evenly-shaped fragments. All relationships were qualitatively similar when habitat variables were added, but effect sizes declined and estimate uncertainty increased: the one exception was lower compositional stability of open-country birds in more compact fragments. Our results indicate that in order to maintain high densities of rainforest birds, minimizing edge effects is more important than maximizing fragment size, even though community stability increases with fragment size. Good habitat quality is likely important in mitigating the limitations imposed by fragment size and shape on bird communities. While stability of richness over time bodes well for long-term viability of forest fragments, the decline in rainforest birds over time (likely due to regional and global drivers) may have serious negative implications for ecosystem functioning in the future.

Keywords forest fragmentation, bird communities, rainforest, open-country, richness, density, composition, dynamics

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Genetic Structure in Birds with Different Tolerance to Urbanization: The Case of White-eared Ground-sparrow and House Wren

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The proportion of land covered by urban settlements has steadily increased during the past 50 years, diminishing surrounding forests and semi-natural areas. This phenomenon can directly decrease a species genetic diversity and gene flow, increasing inbreeding and genetic structure. However, contrasting results can be expected for species whose populations and connectivity increase in urban areas. This species can exploit urban resources and flourish in the city. Here, we investigated the effect of urbanization on the genetic structure of two bird species with different tolerance to urbanization: White-eared Ground-sparrow (*Melozone leucotis*) and House Wren (*Troglodytes aedon*). We genotyped individuals of both species in 5 locations across an urban gradient in Costa Rica using eight microsatellite loci. We estimated genetic structure for each species and generated resistance matrixes based on land cover and habitat suitability for each sampling location and analyzed connectivity using circuit theory. We found substantial genetic structure in White-eared Ground-sparrow and lower structure for *T. aedon*. For House Wren, we found that all individuals were assigned to one genetic cluster and two clusters for White-eared Ground-sparrow. Genetic differentiation for White-eared Ground-sparrow was related

to geographic distance, land cover resistance, and habitat suitability. For House Wren, we found no relationship between genetic differentiation and any of the predictors. Genetic differentiation and structure in White-eared Ground-sparrow can be related to its habitat loss (thickets and coffee plantations) and fragmentation since it has been replaced by urban settlements in the study area. These habitats have been gradually lost during recent years, in part because these are not included in any conservation category. However, House Wrens are more adapted to urban environments, showing no detrimental effects of urbanization on genetic diversity or structure. We conclude that urbanization has a different impact on gene flow depending on species tolerance to urbanization, adaptability, and its ability to exploit available resources of urban areas. These results support the need for conservation strategies towards White-eared Ground-sparrow and other animals whose habitat and connectivity have been reduced due to recent urban expansion.

Keywords Urban ecology, landscape genetics, avian population biology, population genetics, urbanization.

Is Urban Avian Biodiversity Representative of the Regional Avifauna in Brasilia, Brazil?

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Urban areas in tropical regions often have unexpectedly high levels of biodiversity, including the occasional species usually found in pristine habitats. The purpose of this study was to compare the avian species composition of urban fragments and of protected areas in the city of Brasília and surrounding Federal District, Brazil, to determine whether urban areas are representative of the general avian diversity of the region. An additional objective was to test the use of a rapid assessment method, the Mackinnon list, that is suitable for use by citizen scientists and has a well developed analytical framework. We sampled 4 natural and 7 urban sites using 10-species mackinnon lists, compiling 23 surveys in natural areas and 44 in urban areas between may 2016 and february 2021. We recorded 153 species, and the rarefaction-based estimate is 175 species for the natural areas and 150 for the urban area. The natural areas also had higher Simpson diversity (62.7 vs 48.9) Although species richness is similar between urban and natural point sites, there is a major difference in species composition when we examine the most common species in each habitat. The Jaccard Similarity Index of the 51 most abundant species was 0.17 between urban and natural areas, with only 9 species on both lists. Only one species, the Southern caracara, was in the top 10 in both lists. We conclude that although there may be similar species richness in natural and urban habitat sites, the differences in dominance and species composition confirms the need to maintain natural habitats and provides guidelines to manage urban areas to enhance biodiversity.

Keywords biodiversity, Brazil, MacKinnon lists, rapid assessment, urban, species richness, birds

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Models of Human Transportation Systems Show No Dispersal Limitation in Flower Mites Hitchhiking on Hummingbirds

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Limitations to dispersal can affect the ability of an organism to interact with other species within a community, ultimately affecting the structure and composition of communities. This is especially true for species that have intrinsic dispersal limitations, such as small body size, and those who rely on other organisms for long distance dispersal, as is the case for phoretic organisms. Phoresy is the use of another organism for dispersal. Models developed to determine the connectivity associated with routes in human transportation systems (The Geography of Transport Systems), can be adapted to investigate how phoresy affects species interactions and species' niches. In this study, we adapted the measures developed to determine the accessibility of hubs for human transportation networks, such as airports or subway stations, to interactions among phoretic flower mites, their host plants and their hummingbird dispersal hosts. Combining DNA barcoding and traditional taxonomy to identify flower mite species, with video recordings of hummingbird species visiting host plant species in a lowland tropical rainforest site in Costa Rica, to (1) map flower mite dispersal routes among host plant species; (2) determine the accessibility of host plants for each flower mite species; and (3) assess whether each flower mite species currently uses all host plants it can access via hummingbird transportation. Sixteen out of the 18 flower mite species included in this study can directly access all the host plants that they are found on, via hummingbird visits to the plants. Additionally, we found that 60% of all flower mite species only use a subset of the host plant species that they have access to via hummingbirds. These results suggest that phoresy is a fundamental part of flower mites' life as a dispersal mechanism, but it might not determine host plant resource use by mites. Flower mites, rather than visiting any flower that their hummingbird carriers take them to, select a subset of the plant species that hummingbirds visit as their preferred host plants. The mechanisms of flower mite host plant choice remain understudied, but flower scent is likely the cue mites use to recognize their host plants on the fly.

Keywords dispersal, interactions, tropics, phoresy, flower mites

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Climatic Drivers of Avian Species Richness across the Andes and Implications under Climate Change

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As the Earth's climate continues to change, scientist and decision-makers are challenged to predict and mitigate risks to biodiversity. Whereas rising temperatures are expected to shift species distributions poleward and uphill, much less is understood about the effects of changes in precipitation patterns. We studied 16 elevational gradients across the Andes of Colombia, Ecuador, Peru, Bolivia, Argentina and Chile to (1) evaluate the extent to which current relationships between elevation and avian diversity were explained by interactions between temperature and precipitation, and (2) predict responses to future climatic conditions. Two key patterns emerged, even amid regional variation. In mesic regions, like the Amazonian slopes of the Andes, avian species richness generally declined with elevation and latitude and was best explained by temperature. On the other hand, along xeric slopes (e.g., central-western slopes of the Andes) where precipitation is more limiting, avian richness peaked at mid-elevations and was most closely associated with an interaction between temperature and precipitation. Specifically, the warmer and wetter conditions at mid-elevations seemed to promote species richness in contrast to the warm-but-dry lowlands and wet-but-cold highlands. Based upon four climatic scenarios, mesic slopes are predicted to gain species by 2070, whereas xeric slopes, especially at low elevations that are expected to be both warmer and drier, are expected to lose species. Our findings highlight that efforts to forecast the consequences of climate change using temperature alone can produce misleading results, especially in xeric regions that also seem to be the most vulnerable.

Keywords Mountains, Birds, Tropical Andes, elevational gradients, mid-elevations, biodiversity, amazon, Peru, Colombia.

Flight Efficiency Predicts Probability of Road Crossing in Amazonian Forest Birds

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Dispersal is a fundamental process in ecology that affects species distribution, population connectivity, migration, and metapopulation and metacommunity dynamics. In particular, a species dispersal ability can determine its chances of persistence in fragmented landscapes and its ability to track changing environmental conditions. Despite its importance, there is little empirical evidence showing the effect of dispersal ability on patterns of movement across fragmented landscapes. In this study we investigated the role of flight performance on the capacity of birds to cross a road that dissected an otherwise continuous Amazonian terra-firme forest. We used published data from the Biological Dynamics of Forest Fragments Projects on recapture of forty-five species of forest birds to estimate the probability of crossing and estimated flight performance using the hand-wing index (a proxy for the aspect ratio of the wing). We analyzed the relationship between the probability of road crossing, flight performance, microhabitat and feeding guild using phylogenetic logistic regression models. Values of hand-wing index varied between 6.6 (Winged-banded Wren *Microcerculus bambla*) and 30 (Rudy-quail Dove *Geotrygon montana*). We found that the hand-winged index is a strong predictor of the probability of crossing the road. Species with high flight performance had higher probabilities of crossing the road than those with low flight performance. Our results suggest that flight performance can be used as a powerful predictor of the vulnerability of bird species to forest fragmentation and habitat disturbance.

Keywords Amazonia, birds, conservation, dispersal, flight-efficiency, fragmentation, hand-wing index, roads

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Farm Structural Heterogeneity Best Supports Insectivorous Birds' Contribution to Arthropod Herbivore Regulation under Organic Systems

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Background: Despite their role as cropland arthropod predators, insectivorous birds' ecological service role in reducing crop damage through arthropod consumption is still underappreciated compared to predacious arthropods. This is despite insectivorous birds consuming an estimated 100 mil metric tonnes per year of cropland arthropod herbivores, majority of which constitute crop pests. **Objectives:** We examined roles of farming system, crop cover pattern and structural configurations in influencing assemblage composition of insectivorous birds and their herbivorous arthropod prey across non *Bt*-maize fields. We also determined how avian insectivory impacted crop herbivory levels. **Methods:** Sampling was conducted comparing nine organic and seven conventional small-scale maize farms in western Kenya. We assessed variations in abundance, diversity and richness of insectivorous birds and arthropod prey between mono-cropped and inter-cropped maize. To determine impact of insectivorous birds on arthropod herbivores, we set up a bird exclusion experiment in six plots, three each in two farms. This was to assess birds' predation impact on herbivorous arthropods across three exclusion treatments per plot. **Results:** Higher structural heterogeneity supported higher insectivorous bird richness, particularly under organic systems and structurally complex landscapes. Bird abundance further increased with crop diversity but not cropping method, nor percent maize cover per se. Conversely, indicators of crop herbivory were enhanced on conventional farming systems, but were largely unaffected by key structural complexity features. From exclusion experiment, arthropod herbivory indicators confirmed impactful linkage of birds to arthropod herbivore suppression. **Conclusions and implications:** Importance of organic farming and conservation agriculture incorporating structural heterogeneity, diverse croplands and on-farm trees was demonstrated as a strategy for potentially supporting insectivorous birds' contribution to arthropod herbivore

suppression. This is among only a handful of studies undertaken in tropical Africa to examine top-down regulation of arthropod crop herbivores by predacious vertebrates in agricultural systems. The results are significant in highlighting potential for application of low-cost on-farm habitat management measures for boosting integrated pest management in non *Bt*-maize farming.

Keywords Non-*Bt*-maize; structural heterogeneity; herbivorous arthropods; birds; top-down suppression; Kenya

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Using Acoustic Indices to Monitor Bird Communities in Tropical and Subtropical Regions

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Intense anthropogenic activities pose a considerable threat to the faunal communities worldwide and call for efficient biodiversity monitoring methods. Acoustic indices have been recognized as a promising rapid biodiversity survey approach, which incorporates passive acoustic methods to estimate vocalizing animal communities. Multiple studies have suggested that several acoustic indices reflect well the bird communities in temperate forests. However, the performance of these indices in tropical ecosystems, where biodiversity is higher, needs to be explored further. Here, we assessed the accuracy of seven commonly used acoustic indices to monitor the bird communities in three subtropical and tropical areas in Guangxi Province, south China. At each area, we selected 20 forest sites inside a nature reserve and 40 sites in nearby agricultural land capturing different levels of agricultural intensity. We conducted acoustic and bird surveys simultaneously, using the point-count method, repeating each survey three times. First, we evaluated the efficacy of the acoustic indices based on two important aspects: (a) the strength of their relationship with bird species richness and (b) the consistency of that relationship across sites and land-use types. Second, we examined how sounds other than bird vocalizations, which are frequently present in working landscapes, may influence the performance of the indices. We grouped those sounds into multiple categories belonging to biophonies (e.g., insect calls), anthrophonies (e.g., traffic noises), and geophonies (e.g., wind). We found that the indices did not always correlate strongly or consistently with bird species richness across forest and agricultural sites. The only exception was the Bioacoustic Index, which showed a consistently positive and relatively strong relationship with bird species richness in all habitats. Our second analysis revealed that anthrophonies and geophonies influenced considerably the efficacy of the indices, as they correlated strongly with the unexplained variation of the relationship between bird species richness and acoustic indices. This was also true for biophonies produced by birds, as well as other animals, such as insects and domestic animals. In conclusion, the various other acoustic cues, which are often present in soundscapes, influence the predictions made by the indices on the focal animal community. We suggest that acoustic indices are refined further to improve their performance in working landscapes. Moreover, species richness may not be the most suitable estimator when evaluating the acoustic indices in diverse tropical bird communities, as it does not reflect all the bird vocalizations, many of which remain unexplained.

Keywords Bioacoustics, Biodiversity monitoring, Bird diversity, Bird vocalizations, Ecoacoustics, Soundscapes, Tropics

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Using Automatic Sound Recording to Monitor Avian Diversity and Guide Conservation in an Urban-natural Landscape in a Biodiversity Hotspot

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Many tropical cities are situated in global biodiversity hotspots, and their growing human populations and land use are negatively impacting endemic and/or threatened native species and communities. The city of Brasília, Brazil is surrounded by Cerrado, the most species-rich tropical savanna on the planet, of which over 50% of its original extent has been converted to human use in recent decades. However, in the Federal District around Brasília there are significant protected areas covering a total area of approximately 70,000 ha, as well as numerous urban parks and reserves with fragments of native Cerrado. There is a significant community of environmentalists, nature and outdoors lovers, and several universities, governmental agencies, and scientific institutions with strong programs in conservation. The purpose of this project is to use automatic recording of bird sounds to generate biotic diversity indices for various urban and natural environments, and to use these indices to direct landscape restoration and management to increase diversity and representativeness of cerrado fragments in urban parks. Automatic recordings can be made by non-experts and the continuous sampling is helpful in confirming the presence of rare and hard to identify species. We placed cost-effective Audiomoth recorders from April 2019 to May 2021 in 12 points in 3 protected areas (572 hours), 4 points in 1 urban ecological park (592 hours), and 7 points in urban residential areas and gardens (886 hours). Results show that the automatic recordings are extremely useful to measure biotic acoustic diversity as well as provide an index of sound disturbance from urban and human sources. The next steps will be to share results with park managers and local communities to demonstrate how non-invasive monitoring can generate data on ecosystem conditions and guide conservation plans.

Keywords ornithology; bioacoustics; conservation; urban-natural landscape; cities; biodiversity

Human Dimensions to Biodiversity Science

Session Recording: https://youtu.be/OU9aFNXeKS4

Environmental, Social and Economic Dimensions of Dam Development in Brazil: A Review

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Dams can provide several benefits including hydropower generation; yet can cause direct and indirect negative impacts on the environment, people and their livelihoods, especially in developing countries. Brazil has 1,374 hydroelectric dams (generating 61.73% of energy requirements). Numerous studies on the impacts of dams have been conducted, however, most tend to focus on single aspects, such as ecological or social impacts, making it challenging to understand how multiple impacts of dams may synergise, and how development and conservation policies could better address multiple socio-ecological dimensions through space and time. Here, we conduct a quantitative review of the ecological, social and economic implications of Brazilian dams. We synthesise current knowledge and highlight where further research is needed, to better understand potential trade-offs between dam development, people and environment. We expected that most studies focused on large hydroelectric dams; were concentrated in the Amazon region; centred on ecological impacts; and that the magnitude of impacts would increase with dam size. We performed a peer-reviewed literature search in English and Portuguese, compiling a dataset of 145 studies, some assessing multiple dams, totalling 180 investigations across 68 dams. We find that hydroelectric dams are the most evaluated type (50 dams; 74.4% of investigations) with a focus on large dams (94.8%; >30MW installed capacity); and 42.8% of investigations (20 dams) originate from Brazil's Amazon Legal region. Across all studies, 42.1% focused on ecological (i.e. biodiversity alterations), 17.9% on environmental (i.e. physical-chemical alterations), and 7.6 % on health, social and economic effects of dams. The remaining studies assessed compensation and mitigation measures (12.4%) or covered multiple themes (20%). Given the relative paucity of studies on socio-economic and health impacts, as well as effects of small hydropower schemes, we emphasise the need to further investigate these areas to better understand the possible connections and synergies between the different impacts of dams. Additionally, more information is needed from other regions of socio-ecological importance, such as the Cerrado, currently under increasing pressure from dam expansion. Development and conservation policies must address all actors involved, the whole area impacted and over the complete timeline of dam implementation and operation. We indicate underestimated aspects that are essential to achieve a complete overview of dam development in Brazil. Only by accounting for and better understanding all aspects and their interactions, will it be possible to effectively predict, manage, and mitigate dam effects, and consequently better balance the multiple trade-offs of dam development.

Keywords dams, hydropower development, conservation, social, ecological, economic, Brazil, trade-offs, policy

Building a Participatory Socio-ecological Model to Understand Natural Resource Management around Ranomafana National Park Madagascar

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Conservation has conventionally relied on biodiversity science focusing on ecological systems. However, the rise of many conflicts between protected areas and local communities around the world has triggered calls to understand human dimensions of biodiversity conservation as well as to include local voices in conservation practice. For this reason, we chose to study the perspective of socio-ecological systems to understand the complexities of natural resource use around Ranomafana National Park in Madagascar, a global biodiversity hotspot. Ranomafana National Park is the flagship national park of Madagascar and a UNESCO world heritage site, located in the South-East of the island, and it is surrounded by more than 150 villages. Our objective was to follow the participatory ARDI methodology created by Etienne *et al.* (2011) to construct a qualitative model of the socio-ecological issues around Ranomafana National Park. This was done in eleven workshops with local communities as well as other stakeholders of conservation. We built the model in three consecutive phases: identification of the problem, creation of the model and validation. Our first research question was: What is the most important problem related to natural resource use? The main problem identified was: "The land doesn't produce enough to provide for the families." The second research question was: What are the actors, resources, drivers and interactions that affect the problem? The work resulted in a model showing the perception of local actors about interactions between actors as well as economic interlinkages at different scales from local to global that influence natural resource use in Ranomafana. At the same time, there were differences in the challenges across villages. Using the model, local actors expressed their recommendations to improve the conservation practice. The method brought forth results that would not have been reached with more conventional, less participatory methods. This method could be used as a holistic alternative to the surveys that many conservation organisations conduct in communities around protected areas. The model can improve conservation actors' understanding of the main issues in order to better target their limited funding. For local people involved the process was a chance to express concerns and views to conservation organisations and representatives of authorities as well as to interact and learn from each other's experiences.

Keywords participatory modeling, biodiversity conservation, protected areas, natural resources management, Madagascar

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Is Timber Management a Realistic Conservation Alternative for Indigenous Amazonian Communities?

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Indigenous people, who are often economically, socially, and culturally dependent on forests, represent important stakeholders in forest management. Due to high costs, indigenous communities partner with external institutions to harvest timber, often resulting in forest degradation within their territories, internal and external conflicts, and disinterest in starting new timber management projects. Using a standardized methodology to investigate the outcomes of previous community forestry projects presents an opportunity to better understand and potentially resolve further issues. To investigate this issue, we conducted research in the Sinchi Roca I native community in Peru. Our objectives were: (1) to describe the process of timber harvest (2) to analyze gender differences in local perception of timber management and (3) to evaluate the outcomes of the timber activity, applying socioeconomic criteria and indicators. Data collection included in-depth interviews, focus group discussions, and intra-household surveys. We found that locals partnered with a company for timber harvesting, which led to a sanction from the Peruvian government. Timber harvesting was negatively perceived

in the community, with 83.75% of survey respondents dissatisfied with the activity and 88.75% reporting internal and external conflicts due to the presence of the company. Moreover, women did not have a major role in timber harvesting, nor did they actively participate in planning meetings. Results suggest that improving future timber management projects in indigenous communities requires that projects be adapted to local realities and encourage local participation, including training for locals in governance, administration of documents, and negotiations with external stakeholders.

Keywords Community forest management, gender participation, Kakataibo, local perception, multivariate analysis

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Conservation Status Revision and Communities' Perceptions of 22 *Aloe* Species in Tanzania

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Background and aims: Many *Aloe* species are globally threatened due to overharvesting for trade and habitat destruction. CITES regulates their international trade. In Tanzania, 50% of all existing *Aloe* species had previously been assessed, though some of these assessments were Data Deficient. For those with sufficient data, an update is required as the rate of decline has rapidly increased over the last few years. **Methods:** We estimated Area of Occupancy (AOO) and Extent of Occurrence (EOO) for *Aloe* species using the Geospatial Conservation Assessment software (GeoCAT). We assessed the reasons leading to their decline based on direct field assessments and community perceptions. **Key results:** We revised the conservation status of 22 *Aloe* species; two of those we assessed as Critically Endangered, ten as Endangered, five as Vulnerable, one as Near Threatened, and five as Least Concern. We further re-discovered the Critically Endangered *Aloe boscawenii*, which had not been seen in Tanzania for more than six decades. We propose to downgrade the endemic *Aloe dorotheae*, *Aloe leptosiphon* and *Aloe flexilifolia* from Critically Endangered to a lower threat level. The community perception of Aloe species availability did not accurately reflect their categorization based on the IUCN criteria B. We identified agricultural activities and climate change effects as the two main threats to Tanzanian *Aloe* species. **Conclusion:** We conclude that overall numbers are declining for 22 *Aloe* species in Tanzania, mainly due to human activities. We recommend the implementation of laws and policies to protect their natural habitats.

Keywords Area of Occupancy, Distribution, Eastern Africa, Extent of Occurrence, IUCN

Started from the Bottom Now We're Here: From Grassroots Participatory Research to Informing Wildlife Policy in Guyana

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Introduction: Indigenous Makushi and Wapichan communities of the Rupununi region of SW Guyana have employed traditional management strategies in the stewardship of their resources for millennia. Recently, these communities have experienced rapid economic, social, and environmental change driven by improved infrastructure, increased access to technology, and a changing climate, prompting the need to adapt traditional approaches for an increasingly globalized reality. The Rupununi Wildlife Research Unit was formed to develop participatory wildlife research projects that build local capacity and increase understanding of the scope and implications of changes to socio-ecological systems on the biodiversity that many of the region's residents continue to depend on for their livelihoods. **Methods:** We focus our projects on species (large carnivores, game species) and issues (overhunting, human-wildlife conflict) that are of local priority in an effort to produced data that is relevant and readily integrated into local and regional conservation and management strategies. We build local capacity for implementation using a scaffolded approach that helps local researchers build skills that

are transferrable to other employment sectors, consistently provides new challenges, and creates opportunities to learn, grow, and increase ownership, independence, and leadership. We support well-trained and highly motivated local scientists, maintain a transparent approach, and share data willingly in an effort to establish a positive reputation and open opportunities to partner with industry, NGOs, and government agencies on projects at the regional and national levels. **Results:** The Rupununi Wildlife Research Unit has provided training and part-time employment for >150 local researchers, supporting regional development and the management of protected areas. We have produced three recent publications in peer-reviewed literature, with another five currently currently under revision. These publications have expanded knowledge of a number of species of conservation interest in Guyana, contributed to range-wide evaluations of species of international concern, and expanded our understanding of the impact of low-intensity harvest regimes on Neotropical game species. Highly experienced local scientists have secured contracts as consultants that have further increased their economic stability and increased scrutiny in the evaluation of development projects. Based on our track record, our team has been selected to conduct national population assessments and produce national management plans for six species (lowland tapir, tortoises, caimans) of conservation concern. **Conclusions:** By placing an emphasis on building local capacity and maintaining a transparent process that shares data freely with partners, indigenous scientists from the Rupununi Region have moved from grassroots research in their community to consulting on regional and national infrastructure projects, and directly informing the development of national wildlife policies in Guyana.

Keywords Participatory research, large mammals, indigenous communities, wildlife policy, Guyana

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Rural-urban Mobility Influences Wildmeat Access and Consumption in the Brazilian Amazon

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Urbanization can increase natural resource use, contradicting previous assumptions that rural depopulation would result in net conservation benefits. Worldwide evidence shows urban consumption of wildmeat can indeed endanger wildlife populations. Recent studies identify substantial wildmeat consumption in Amazonian towns and highlight the role of trade networks. Yet, social research in the region demonstrates that despite urbanization, rural-urban mobility persists – that is, the circulation of people, ideas, and products between rural and urban areas - blurring the frontiers between rural and urban lives, and maintaining products' flows outside of market exchanges. Understanding rural-urban wildmeat flows in the forested tropics and the scale of wildmeat consumption in those areas is paramount to developing appropriate management plans for wildlife use. To understand the conservation implications of rural-urban mobility, we investigated its relationships with wildlife consumption in central Brazilian Amazonia. Specifically, we examined (i) the association between rural-urban mobility and wildmeat consumption in urban and rural areas, (ii) differences in patterns of wildmeat consumption (i.e. species consumed, ways of obtaining wildmeat, consumption frequency) between urban and rural areas, and (iii) total wildmeat demand in geographically isolated towns and surrounding rural areas of western Brazilian Amazonia. We surveyed households in four towns (n=798), and rural households in 64 riverine communities (n=311). Rural-urban mobility prevailed even in larger and less remote towns: most urban households maintained rural livelihoods and were headed by rural in-migrants. Still, wildlife was eaten more often in rural areas. In towns, consumers depended equally on trade and social networks (gifts) to access wildmeat. Urban households with greater rural-urban mobility consumed wildmeat more often but were less likely to purchase it. Urban consumption was centred on highly-preferred species, compared to more diverse consumption in rural areas. Although per capita and total consumption of wildmeat were higher in rural areas, urban populations place intensive pressure on selected vulnerable species. However, given multi-dimensional poverty in these towns and the role of social relations in shaping access to wildmeat, it is debatable whether urban Amazonians should be denied wildmeat access entirely. Nonetheless, actions to curb the trade of vulnerable species, careful monitoring, and management of hunting, though challenging, is required to achieve sustainable hunting and wildmeat access to rural and vulnerable urban populations.

Keywords Bushmeat, sharing, sustainability, tropical forests, wildlife conservation

Human-elephant Conflict Mitigation as a Public Good: What Determines Fence Maintenance?

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Negative interactions between humans and elephants are known to have serious consequences, resulting in loss of life and deterioration in the quality of life for both species. Reducing human-elephant conflicts (HEC) is essential for elephant conservation as well as social justice. Non-lethal electric fences placed around villages or communities are a widely used intervention to mitigate HEC. In order for such barriers to work, beneficiaries have to act collectively to maintain the fence, making it a 'public good'. Despite being fairly effective when well-maintained, a majority of such fences in northeast India are poorly-maintained. This leads to our central question: why are some fences well-maintained and others poorly-maintained? We studied 19 such fences using a trans-disciplinary approach, combining qualitative comparative analysis, Ostrom's social-ecological systems (SES) framework, and a grounded theory approach incorporating ecological and qualitative social science tools. We found that, contrary to our hypothesis, the functionality of fences cannot be predicted based on the design of the fence, whether or not the community made cash payments, or ethnic homogeneity or leadership in the village. Instead, we found there are three potential pathways of maintenance; (1) a community maintainer, (2) the community self-organizes, and (3) the forest department. Maintenance occurs when there is a congruence between perceived costs and benefits for any one of these entities. These costs and benefits are diverse, including not just material benefits but intangibles like goodwill, a sense of safety, social standing, and a feeling of fairness. We highlight these factors and provide recommendations for practitioners and policy.

Keywords collective action problem, human-elephant conflict, India, Ostrom SES

Ecology and Conservation of Primates

Session Recording: https://youtu.be/jH3bg3fiZ1U

Structure of Microhabitats Used by Microcebus Rufus across a Heterogeneous Landscape

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Microhabitat preference among primates, which provides them with the niche they need to survive, often conditions primate diversity, abundance, and coexistence. Vegetation alteration and recovery have built heterogeneous forest landscapes that may influence primates' microhabitat preference. We compared the diversity and size of trees/shrubs and the presence of lianas in 132 sites where we captured the rufous mouse lemur (*Microcebus rufus*), with that of 240 sites where we did not capture this species, to investigate the aspects of microhabitat structure they prefer. We then examined how this structural preference varies across a heterogeneous landscape of forests with different disturbance levels. Overall, microhabitats used by *M. rufus* differed significantly from unused ones in densities of small size, understory, and midstory plants. *Microcebus rufus* frequented microhabitats with significantly denser small- and medium-size (DBH 2.5-10 cm) trees/shrubs without lianas in the primary forest and small-size plants (DBH 2.5-4.9 cm) with one liana in other forest types. Compared to the microhabitats they used in the primary forest, the microhabitats in other forest types had lower densities of trees/shrubs with lianas. Additionally, the secondary forests and forest fragments also had significantly lower DBH. Although this variation in microhabitat use may represent an opportunity for *M. rufus* to live in disturbed habitats, it may expose them to additional threats, affecting their long-term survival. These findings emphasize the need to examine potential changes in microhabitat use among primates living in anthropogenic landscapes, which could help optimize long-term conservation and management of threatened primate species in heterogeneous landscapes.

Keywords Conservation, Habitat, Madagascar, Mouse lemurs, Primates, Tropical forests, Vegetation analysis

Home Range Study of Greater Bamboo Lemur (Prolemur Simus): A Comparison between the Wet and Dry Season in Sahavola Sites-Madagascar

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The greater bamboo lemur (*Prolemur simus*) is a critically endangered primate endemic to Madagascar. The greater bamboo lemur's preferred habitat is humid primary forest however, deforestation and habitat degradation has led to their persistence in marginalized habitat and their present population size is estimated to be less than 600. A better understanding of their behavior and variation in home range across populations and seasons is needed to develop effective conservation strategies to protect them. To determine home range seasonal variation of two groups of greater bamboo lemur inhabiting a highly disturbed habitat, we used Altmann scan sampling to monitor group behavior and a Minimum Convex Polygon (MCP) to delimit home range size in 2013 – 2015 in Sahavola site, a highly degraded forest in Madagascar. We found a significant difference in the population size of the two groups independently of the season (Spearman coefficient r=-0.2; P=0.8) and their range size is decreasing during the dry season. We found that many factors including intergroup competition for food were responsible for the variation in home range size in greater bamboo lemur. It is therefore crucial to understand the use of home range to develop strategy to monitor and protect populations of greater bamboo lemur in order to ensure both their conservations and long-term survival.

Keywords Behavior; home range; seasonality; greater bamboo lemur; Sahavola; Madagascar

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The Contribution of an Endangered Small-bodied Primate Species to the Seed Dispersal Network in the Atlantic Rainforest

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Many tropical communities are currently composed by small and medium sized frugivores due to depletion of larger vertebrates occurring in anthropized landscapes. However, some of those frugivores are also endangered and their contribution to seed dispersal networks is largely unknown. Here, we evaluated the role of an endangered small-bodied primate species, the black-lion-tamarin (BLT), within the seed dispersal network of its distribution area, the Brazilian Atlantic Rainforest in the São Paulo State. Firstly, we determined the list of dispersed plant species, by monitoring three BLT groups, in two Atlantic Rainforest areas: the Morro do Diabo State Park (MDSP) and the Rio Claro Farm riparian forest. We followed the groups (min: 21 days; max: 35 days), from January 2018 to April 2019, totalizing 1056 hours of sampling effort. We combined the data we collected in the field with all studies of frugivory and/or seed dispersal by BLT available in the literature so far. We created a binary qualitative matrix of plant-disperser interactions where the sympatric mammal and bird species interact with the plant species dispersed by BLT. We considered the MDSP species list as equivalent to the expected fauna of the Atlantic Rainforest domain as it maintains its fauna and is one of the few forest remnants that are still environmentally suitable for large vertebrates. We extracted frugivory data of the other animal species from the data paper "Atlantic frugivory: a plant-frugivore interaction data set for the Atlantic Forest". This resulted in a matrix of 103 animal species, 64 plant species and 571 potential seed dispersal interactions. We evaluated the community structure through six parameters: nestedness, modularity, robustness, connectance, dependence and species strength. The network showed medium levels of nestedness, modularity and robustness, but low connectance (NODF=39.68; Q=0.33; R=0.46; C=0.08). We obtained that 23.44% (n=15) of plant species showed maximum dependence on the interaction with BLT, especially from Bromeliaceae and Cactaceae families. The capuchin monkey *Sapajus nigritus*, the red howler monkey *Alouatta guariba clamitans*, and the jacupemba *Penelope superciliaris* were the species functionally more similar to the BLT while the tapir *Tapirus terrestris* was the species that most contributed to the network maintenance. Our results suggest that the BLT can exert an especially important role as disperser, mainly by dispersing medium-sized seeds (0.3 to 1.2 cm width) like larger frugivores that are already extinct in many fragments of the Atlantic Rainforest.

Keywords Black-lion-tamarin, Defaunation, Ecosystem services, Frugivory, Network analysis

Feeding and Reproduction Patterns in Golden Monkeys *Cercopithecus mitis kandti* in Rwanda

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Many primate species exhibit great flexibility to adapt to habitat change through alterations in multiple aspects of their daily life. The Endangered golden monkey (*Cercopithecus mitis kandti*), a subspecies of the primarily frugivorous blue monkey, suffered a series of major habitat loss events. Consequently, golden monkeys only remain in two fruit-poor forest fragments in the Albertine Rift region; the Virunga massif and Gishwati forest (Uganda, Rwanda, and DRC) where they inhabit the bamboo zone and tropical montane forest, respectively. Using scan and ad libitum sampling, we recorded feeding and birthing events in two social groups (K: 150 individuals, M: 60 individuals) living in the Volcanoes National Park (VNP), the Rwandan part of the Virunga massif between 2004 and 2018, and in one group (G: 30 individuals) found in the Gishwati forest in 2017 and 2018. We also monitored the availability of key food resources (bamboo shoots in VNP and fruit in Gishwati) every two weeks. VNP groups were mostly folivorous (leaves made up between 72.8% and 87.16% of the diet) and fed mostly on young bamboo leaves and bamboo shoots, while 48.69% of the diet of the Gishwati group consisted of fruit from 22 different tree and shrub species. Bamboo shoots and fruit are seasonally available food and were consumed regularly throughout the period when they were available in their respective habitats. Spatiotemporal variation in high availability and consumption of these preferred foods strongly determined the birthing season of golden monkeys and explained intra- and inter-populational differences. Births in K, ranging at low altitude, were observed from September to December, whereas births in M, located at high altitude, occurred from February to April. In Gishwati, births occurred from March to April when fruit availability and consumption peaked. Currently detectable changes in key food regeneration, possibly driven in parts by climate change, across golden monkey habitats need to be closely monitored to understand the impact on golden monkey reproduction and long-term survival.

Keywords dietary flexibility, food availability, birthing season, bamboo, tropical montane forest

Rapid Transmission of Respiratory Infections within but Not between Mountain Gorilla Groups

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The catastrophic effects of infectious diseases in wild ape populations have been well documented over the past two decades. Despite this, little is known about how diseases transmit within these wild populations and how this is influenced by their social structure. This information is crucial for developing conservation strategies for mitigating disease transmission in these critically endangered species. We aimed to use fine-scale social and health data collected on 166 mountain gorillas from 12 social groups in the Volcanoes National Park to model how respiratory infections spread both within and between groups. We analysed 15 respiratory outbreaks that took place in the study population between 2005 and 2020. We investigated transmission within groups using social network analysis based on physical contact and proximity within 5 meters, and transmission between neighbouring groups using observations of inter-group encounters, transfers and home range overlap. Respiratory infections transmitted rapidly within mountain gorilla groups and the spread of symptoms was not consistent with transmission through the social network. Gorillas that were more central in their group's social network were also not more likely to show symptoms. Between groups, encounters with infected groups and transfers from infected groups did not appear to have resulted in disease transmission and the geographic overlap of groups did not predict the spread of infections. The high rates of social interaction within groups and limited

interaction between groups in mountain gorillas appears to enable rapid transmission within groups but limits transmission between groups. This means that conservation strategies targeted at preventing transmission into new groups are likely to be more effective than those aimed at reducing transmission within groups, where all individuals are rapidly exposed to an infection. Genetic analysis has confirmed a number of respiratory infections in gorillas as human in origin, so the source of the outbreaks studied here is likely to be multiple transmission events from humans rather than transmission between neighbouring gorilla groups. Considering the emergence of novel pathogens such as COVID-19, it is vital we strengthen methods for limiting human-ape disease transmission. Continuing the ongoing efforts to protect gorillas through extensive testing, vaccination and mask-wearing for all those that come in close proximity with gorillas will be vital.

Keywords Disease transmission, respiratory infection, gorilla conservation, zoonotic disease, social structure

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Route Planning Process by the Endangered Black Lion Tamarin (*Leontopithecus chrysopygus*) Is Influenced by Resource Distribution and Spatial Limitations

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On a daily basis, primates execute a wide variety of decisions on when and where to move. However, current knowledge regarding the primary factors shaping daily routes and influencing primate decision making is still insufficient, particularly in forest fragments. Here we investigated what social and environmental factors influenced the daily route planning process of black lion tamarins' (BLT), a frugivorous-insectivorous primate, in a 100-ha Atlantic Forest remnant. We predicted that fruit sites would be the main factor driving daily routes. Also, we expected physical limits of the area to be important factors influencing routes. We followed a group of BLT for 42 full days between March and August 2019, recording GPS locations and group behaviors through scan sampling every five minutes as well as all observed feeding events and intergroup encounters. We used the Chang Point Test to identify locations of significant direction change (change points-CPs) on each daily route, and assessed the group behavior associated to each CP. We divided the home range into territory border, central area and fragment edge to investigate zone-use patterns. Finally, we estimated mean distances between monthly fruit sites, as well as the mean distances that BLT should travel from random locations within the home range to reach a fruit site each month. Frugivory, locomotion and foraging were the most frequent behaviors (29.9%, 29.8%, and 25.3% of the scans, respectively). CPs were mostly associated with locomotion (34.54%), foraging (25.45%) and frugivory (12.7%). On average, intergroup encounters occurred every 4 days and, although not significant ($p=0.756$), daily CP proportions were higher at the territory border, followed by fragment edge and central area. Fruit sites were located, on average, every 33.4m throughout the study area, with most frequently consumed fruiting plants in high density in the area. Although fruits represented an important item for BLTs, our results show that daily routes were not driven by them, possibly due to their high density throughout the area. Atlantic Forest remnants impose structural limits and a possibly higher intra-specific competition. When arriving to these limits, there are no other options than to change directions, which can explain the higher density of CPs close to borders (fragment edge and frontier with other group´s home range). In conclusion, while previous studies in larger areas usually point fixed feeding sites as the main factor shaping primates' trajectories, we suggest that route planning processes might be context-dependent.

Keywords Route planning process, resource distribution, black lion tamarin

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Black Lion Tamarins' Movement Patterns in Distinct Environmental Contexts

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Black lion tamarins (*Leontopithecus chrysopygus*, hereafter "BLT") are territorial frugivorous-insectivorous primates. They inhabit the highly fragmented Atlantic Forest and are classified as endangered by the IUCN. Despite their small size, BLTs can have large home ranges and travel more than 2 km a day, enabling the dispersal of intact seeds at relatively long distances. However, while their home range size varies largely throughout their distribution area (from 35 to 400 ha), it is still unknown how much the environmental context, for instance patch size and shape, affects their movement patterns and consequently their effectiveness as seed dispersers. In this study, we aimed at comparing BLT movement patterns in four distinct contexts: continuous primary forest, 500-ha fragment, 100-ha fragment, and narrow riparian forest. We registered group locations with GPS every 5 min for 4 to 12 months. Using complete trajectories, we calculated the step lengths and turning angles for each group. Then, we filtered the movement patterns by behavior, selecting foraging, three and six steps before feeding and three and six steps before going to sleeping sites. Overall, step length (Pairwise Wilcox with Bonferroni correction, $p \leq 0.03$) and turning angles (Watson-Wheeler test, $p < 0.0001$) differed between all four areas. The BLT group living in continuous forest presented longer step lengths (23.9 m) and more directed routes, while the one living in the smallest fragment presented less directed routes. Step lengths were the smallest in the riparian forest (8.9 m). All behaviors were directional in the continuous forest, with step length frequently two-fold longer (around 45 m) than in the other groups. Directionality of behaviors varied in the other areas but was usually less directed in the smallest fragment and riparian forest. Overall, as expected, BLTs moved faster and with higher directionality to sleeping sites and with high directionality to feeding trees, except in the smaller fragment. Foraging also showed some directionality in all areas, except in the smallest fragment. We concluded that BLTs moved faster and with more directed trajectories in larger areas. However, the movement patterns of BLTs according to their behavior is quite consistent across the distinct environmental context except for the smallest fragment where lower directionality was observed. These results are a first step towards a better understanding of how the environmental context, such as patch size and shape, can affect the movement patterns and consequently the effect of BLTs in the seed dispersal process.

Keywords Movement ecology; Movement patterns; Turning angles; Travel speed; Route direction

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Black Lion Tamarins Do Not Change Daily Distance in Small Forest Fragments but Reduce and Share Their Home Ranges

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The movements and space use of forest-dependent arboreal species are fundamentally driven by forest structure. Thus, quantifying the patterns and drivers of species movements in degraded landscapes, such as through forest degradation or fragmentation, can inform guidelines for better habitat management and increased population viability. Black lion tamarins (Leontopithecus chrysopygus) are an arboreal primate endemic to the Brazilian Atlantic Forest of São Paulo state, threatened by forest fragmentation. We aimed to characterize and compare the space use and movement patterns of populations living in forest patches with contrasting forest structure. We monitored four groups using animal-attached GPS devices on one tamarin per group - two groups from a large fragment (PBC=1303ha) and two from a small one (GUA=105ha). We characterized vegetation structure by measuring height and DBH of all trees with DBH>4.5 cm in 22 systematically distributed 10x10 m-plots in each fragment. Group movements were monitored over a month with GPS locations recorded every 10 minutes during their activity period (06:00 to 18:59 BRT). We estimated mean daily path (±SD), distance from forest edge (compared against random locations), and monthly home range size (95% and 50%

fixed kernel UDs). Differences between fragments and groups were tested using non-parametric tests and ANOVA. Both mean tree height and DBH were higher in the smaller fragment (P=0.0001). We collected an average of 1152(±519) locations per group, over 10 to 23 monitoring days (72±4 locations per day). Mean daily path lengths were similar between the groups (PBC01=2753.7±434.5m, PBC02=2461.2±520.1m, GUA01=2615.6±310.8m, GUA02=2651.7±387.2m; P>0.05), whereas there was an up to 5-fold difference in home range size between the groups (95 and 50% Kernel: PBC01=128.2/39.8 ha, PBC02=211.8/61.4 ha, GUA01=44.2/10.4 ha, GUA02=55.1/16.4 ha), with a high home range overlap between the groups in GUA (16.3/2.1 ha; 37%), but not in PBC. The distance to the forest edge was different from random in the smaller patch, being longer than expected for GUA01 (P<0.0001) and shorter for GUA02 (P<0.0001), but did not differed in the large patch for both groups (P>0.05). The estimated home ranges for the groups in the small fragment are among the smallest ever recorded for the species, suggesting a strong effect of patch size, with also a high overlapping between neighboring group home ranges. Quantifying the relative effects of competition, edge effect or resource availability driving these differences between forest patches is an important next step.

Keywords *Leontopithecus chrysopygus*; movement ecology; daily path; use of space

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Insect-infested Fruit: Preference and Detection by the Golden-backed Uacari Monkey (*Cacajao ouakary*)

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Current studies in behavioral ecology often disregard insect-infested fruit consumption as a significant food source, especially in vertebrate frugivores, including non-human primates. In this study, we used generalized linear mixed-effects models to estimate the likely mechanisms used by the golden backed uacari monkey (*C.ouakary*) to choose or avoid infested fruits. We also aimed to identify and describe the relationships between tree and fruit-specific traits, including infestation rates of trees and fruits. Our results do not support the hypothesis that infested fruit preference by *C.ouakary* is related to specific traits of the visited trees or their predated fruits. However, we demonstrated that infested fruit detection may be facilitated by both tree- and fruit-specific cues.

Keywords Pitheciidae, foraging, dietary preference, frugivore, infested fruit, insectivory, grubivory, Ivlev

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Human-wildlife Conflict in Golden Monkeys (*Cercopithecus mitis kandti*) of the Volcanoes National Park, Rwanda

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Crop-raiding is one of the main causes of human-wildlife conflict (HWC) challenging conservationists worldwide and primates are frequent raiders in many protected areas. Crop-raiding negatively affects not only farmers' livelihoods but also the conservation of the primate species concerned. Golden monkeys (*Cercopithecus mitis kandti*) in Volcanoes National Park (VNP), Rwanda, predominantly inhabit the bamboo vegetation zone. This zone is found near the park boundary and adjacent to farmlands. Recent studies indicate that golden monkeys are now the second most frequent crop-raiders near VNP and the frequency with which they leave the park and raid on crops is increasing over time. We used an integrated and participatory approach to identify effective interventions that might mitigate the conflict between humans and golden monkeys. Firstly, we organised a workshop with a wide range of local and regional stakeholders to discuss possible mitigation measures. Secondly, using a structured questionnaire, we interviewed 45 farmers near VNP to evaluate the impact of the conflict for monkeys and farmers. Thirdly, we collected ad libitum behavioural data in one habituated golden monkey group for 11 weeks to document differences in monkey behaviour when foraging inside versus outside the park. Fourthly, using chilli-laced potatoes, we also tested the feasibility of a taste-aversion mitigation

technique to discourage monkeys from crop-raiding. Improving existing crop-guarding through increased co-operation and government financial support was thought by farmers and workshop participants to be the most effective mitigation approach. Survey outcomes revealed that 95% of participants had experienced potato loss to golden monkeys and 36% had used potentially harmful methods to stop raiding, with a few cases of adverse impact on monkeys described. Behavioural observations showed an increase of vigilance-related behaviour and a decrease in social behaviour when foraging on farmland, reflecting a higher level of perceived risk by monkeys when outside the park. The taste aversion experiment was challenging, and although the nine monkeys who visited the experimental area avoided potatoes smeared with chilli oil, they ate other potatoes instead. Behavioural change shown by monkeys in farmlands along with survey outcomes indicated that crop-raiding by monkeys around the VNP can negatively affect both monkey conservation and farmers' livelihoods. Overall, our multifaceted approach showed that existing mitigation measures need to be improved, while alternative measures should be further explored and tested to facilitate a positive coexistence between golden monkeys and farmers through reduced crop-raiding, which will ultimately improve their conservation.

Keywords taste-aversion, mitigation measures, integrated and participatory approach, survey, behaviour

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Effect of the Habitat Quality on the Sleeping Site Selection by the Black Lion Tamarin (*Leontopithecus chrysopygus*)

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Information about the impact of habitat degradation on the availability of sleeping sites and their selection process is scarce. The sleeping site selection process can be influenced by the level of intra and interspecific competition, the presence of predators and parasites, and the proximity and availability of food sources. The black lion tamarin (BLT), *Leontopithecus chrysopygus*, is an endemic and endangered primate of the state of São Paulo, Brazil, occurring in a highly anthropized landscape. We tested whether and how the sleeping site selection process was altered by habitat quality. We compared the sleeping site characteristics selected by two groups of BLTs and the availability of sleeping sites in a continuous forest (33.000 ha) and in a 100-ha fragment. The sleeping site availability was provided through the implementation of 20 plots in each area measuring 10x10m and the characterization of trees with a diameter at breast height (DBH) 10 cm with the following data, also measured in each sleeping site: species, total height, DBH, canopy diameter; canopy cover, the height of the first branch and the number of connection with other canopies. The animals were followed for 43 nights in the continuous forest and 63 in the fragment using radio telemetry techniques. They used one new sleeping site every two days in both areas. In the continuous forest, BLTs mostly used tree hollows (56% of the nights), while in the fragment, they mostly used lianas (77.7% of the nights). The forest structure was similar between the two areas and the BLTs chose sleeping sites with similar characteristics: trees taller than those available in the environment and with fewer connections between the canopies, evidencing the selection of characteristics that provide protection against predators. The similar sleeping site selection process in both areas suggests that the fragment still presents a forest structure allowing the selection of sleeping sites with preferred characteristics. However, the lower number of tree holes in the fragment, usually considered as preferred sleeping sites by BLTs, indicates a possible paucity of this resource, with unknown consequences on the BLT population. The study of sleeping site selection enables a better understanding of the ecological plasticity of the species and its requirement in terms of resources. The planting of trees chosen as sleeping sites and the identification of specific areas fulfilling their requirements are tools that can be used for future BLT translocation and reintroduction programs.

Keywords Ecological plasticity, anthropized landscape, resource selection, Atlantic forest.

Biology and Management of Fishes and Herpetofauna

Session Recording: https://youtu.be/BBvkIsyQ_fU

An Analysis of Climate Change Vulnerability in Artisanal Fishing Communities, Policy Challenges to Ensure Long-term Food Security in Mozambique

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Mozambique is projected to become one of the World's most vulnerable countries to resource scarcity and climate-related disasters by 2050 and is presently one of the highest-ranking countries in the Global Hunger Index (GHI). This chapter analyzes climate change impacts and future food security in the rural coastal communities in Sofala Bank, Mozambique, where the primary food sources are fishery and agriculture. Twenty percent of the coastal population depends on artisanal fishing, in which tropical Penaeid shrimps are the most valuable resource. The effectiveness of existing fishing management policies is assessed. To test our hypothesis, we first address climate change impacts and key food security challenges in coastal Mozambique and then consider a fishing community's daily lives and practices via a case study in one of the 200 fishing centers in the Sofala Bank Delta We find that coastal flooding resulting on coastal erosion is the phenomenon with most persistent negative impacts. Policies can address and avoid urgent ecological crises of overexploitation, both in the industrial open sea and in artisanal river fishing, when implemented adequately. However, it is shown that policies are not effective because they don't take into account the rural fishing communities' life practices, and they don't address their daily need for food and subsistence income. A policy change is proposed, addressing the interconnectedness between the fishing sectors, e.g., compensating for the benefits in open sea fishing provided by a prohibition period for artisanal river fishing. It implies strengthening the responsibilities of NGOs and donors. Additionally, we suggest improve the efficiency of production by focusing on sustainable and complementary fishery and agricultural practices, including cultivating a climate change-resilient crop traditionally (and still) used in Mozambique and South-Eastern Africa - the sisal plant, to provide untapped alternatives sources of income.

Keywords Artisanal shrimp fishery, food security (SGD 2), fishery management policies (SGD 14, SDG 8); climate change (SDG 13); sustainable fishing and agricultural practices (SDG 1, SDG 3); Mozambique; Sofala Bank

Local Communities Bring an Amazonian Giant Fish Back from the Brink

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The dramatic decline of freshwater megafauna has been reported worldwide. Arapaima (*Arapaima gigas*) is the world's largest scaled freshwater fish, reaching three meters in length and more than 200 kg in weight. Historical overfishing decimated populations of this remarkable fish across Amazonian floodplains, which was almost extinct in many localities. In an attempt to reverse this trend, local communities in partnership with NGO and researchers developed a community-based management (CBM) model, based on local protection of floodplains lakes. Now, CBM arrangements are stimulating the recovery of wild populations and the arapaima have become one of the most promising species for sustainable use in Amazonia. Here, we conducted a comprehensive evaluation on success of this community-based arrangement analyzing 20 years of population monitoring data from more than 700 floodplains lakes across the entire Amazon floodplains. Our results shows that population recovery of arapaima has been achieved in large scale, reaching over 420% in some locations. Even outside formal protected areas, wild populations have recovered following the establishment of no-take areas fully protected by indigenous peoples and traditional communities, reinforcing the suitability of arapaima management as a powerful tool for both biodiversity conservation and the improvement of local livelihoods. In addition to arapaima, other species including black caiman (*Melanoshuchus niger*) and freshwater turtles (*Podocnemis* sp.) also benefit from habitat protection by local communities and are more abundant in managed areas relative to open-access lakes. Besides biodiversity conservation outcomes, arapaima management induces significant social transformation in the Amazon, substantially improving local quality of life through income generation, reduction of gender inequality, cultural maintenance, and other benefits. The community-based management of arapaima brings a message of hope for the conservation of megafauna, showing that is still possible to align biodiversity conservation and local needs, bringing large species back from the brink.

Keywords positive conservation, community-based conservation, fisheries, arapaima, pirarucu

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Feeding Traits Shaping the Spatial Distribution of the Fish Family Serrasalmidae in the Amazon Drainage Basin

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Resource availability and niche breadth are important factors that can influence the spatial distribution and local abundance of a species. The fish family Serrasalmidae exhibit a highly variable dietary composition and level of specialization within clades, being an ideal model to study the influence of feeding specialization on the spatial distribution of species. The aim of this work is to explore the spatial distribution of the Serrasalmidae family clades across the Amazon region based on their feeding habits. We hypothesize that the differences in specialization level and feeding guilds will drive the distribution patterns of the species. Using stomach content data from literature, we classified the species in levels of specialization and feeding guilds. We used a satellite-derived landcover image to estimate landscape metrics of aquatic habitat types and floodplain extent on three distance buffers around the occurrence points of the species as a proxy of distribution. As control variables, we calculated the position of the species within the drainage basin and extracted age estimates from the latest published phylogeny for the family. We modeled the response of distribution range size and the proxies of distribution to potential drivers like specialization level, feeding guild, species age, or position along the Amazon drainage basin, among different species and clades within the Serrasalmidae family. Preliminary results shows that frugivores and other herbivores are related with wider distributions. Frugivores are associated with higher extensions of floodplain. This could be explained by the close relationship of this feeding guild with the flooded forest as a food resources provider. Herbivores were related to the Shannon landscape diversity index, indicating a higher use of different resources. These partial results suggest that feeding traits influence the spatial distribution of the Serrasalmidae species in the Amazon drainage basin.

Keywords Feeding guilds, Serrasalmidae, Macroecology, Amazon basin

Response of Amphibians and Reptiles to Secondary Succession in a Tropical Dry Forest of Mexico

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Secondary forests (SF) are in many regions replacing native tropical forests (TF), one of the most threatened forest systems in the world. SF might play an important role in the conservation of TF biodiversity. To evaluate the response of amphibians and reptiles to the conversion of TF to SF in western Mexico, we selected a total of 15 one-ha plots representing the following five successional vegetation stages: pasture, early forest, young forest, intermediate forest, and old-growth forest. There were three replicates for each vegetation successional stage. To compare the structure and functional diversity of herpetofauna assemblages among successional stages (SSF), as well as the response of these assemblages to the accumulative effect of hurricanes, we conducted a long-term survey (2009-2018) of anuran, lizard and snakes within the successional stages. We addressed the following questions: a) To what extent do species richness and functional diversity of amphibian and reptile communities differ among successional stages?, b) What is the magnitude of the turnover of species among vegetation successional stages?, and c) Will cumulative effects of hurricanes result in a decline of abundance, richness and diversity of herpetofauna assemblages? Our results indicated low levels of herpetofauna ß diversity among forest successional stages, and the lack of marked changes in species composition. Additionally, we observed that under the impact of low intensity hurricanes, SSF might function as buffers that promote herpetofauna resilience. However, cumulative effects of hurricanes resulted in a homogenization tendency among SSF, suggesting a negative effect for ecosystem functioning. The role of SSF as promoters of the resilience of amphibians and reptiles is modulated by the type and intensity of disturbances.

Keywords Tropical dry forest, amphibian and reptiles, disturbance

Amphibians and Reptiles and Their Implication for the Management of the Huascaran Biosphere Reserve, Perú

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The Tropical Andes, as an area of high biodiversity where millions of people depend on its natural resources, is considered one of the most vulnerable places to climate change where adequate biological information that helps to complete our understanding of its effects will be key to proper management. UNESCO's Man and the Biosphere (MAB) program aims to integrate the conservation of places of high biodiversity with human well-being across multiple disciplines, including ecology. High Andean amphibians and reptiles are specially poorly known given their rarity but known to be vulnerable to climate change give different biological and ecological features. In this study, we evaluated the biodiversity, environmental and microclimatic associations of amphibian and reptile communities in the Huascarán Biosphere Reserve (HBR) along an altitudinal gradient of 2000 m (2,500 - 4,700 msnm). Both, reptiles and amphibians data were collected using the Visual Encounter Surveys (VES) along 130 survey units with three spatial replicates visited during the dry and wet season. We use Multiple-species Occupancy Models (MSOM) for both reptiles and amphibians independently while correcting for detectability. Site covariates included vegetation cover, elevation, habitat type, degree of human perturbation (e.g. cattle, mining), distance to water and roads whereas observation covariates include time and enviromental temperatura for reptiles and water temperatura, pH, total dissolved solids and water conductivity for amphibians. Reptile species richness decreases with elevation, probably associated with the steady decrease in temperature while amphibian species richness was máximum at intermediate elevations and areas associated with constant water availability. Both reptiles and amphibians were found above treeline, in shrubby ecosystems and small water bodies. No amphiams or reptiles were recorded in zones impacted by

artesanal mining. Additionally, cattle negatively impact the occupancy of both groups. Indeed, many reptiles in areas with cattle were infected with mites but were clean in not-impacted areas. A permanent population of *Liolaemus chavin* were recorded at 4,583 m witch may represent one of the lizard population at highest elevations. Distribution maps within the Huascaran National Park helped to identify conservation priority areas that once implemented into the online platform, allows decision makers to access this to improve the management of the HBR. Both reptiles and amphibians are showed to be useful indicators of the degree of human impact in this National park, specifictly for cattel and artesanal mining that, if not well managed or controlled, can be affecting the integrity of highly vulnerable ecosystems in the High Andes.

Keywords Distribution, Biodiversity, High Andean Amphibian Reptiles, Management, Huascaran Biosphere Reserve

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Here Be Dragons: Establishing Baselines for the Rewilding of Large Reptiles

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Trophic rewilding has been suggested as a potential approach for ecological restoration. By introducing or reintroducing species, top-down interactions and associated trophic cascades can be restored, promoting self-regulating and biodiverse ecosystems. To date, such approaches have primarily been applied in the temperate Northern Hemisphere, with a focus on the top-down effects of large mammalian predators. As these approaches begin to be applied to the tropics, it is important to determine how rewilding can incorporate tropical keystone species and guilds that don't have analogues in temperate ecosystems. One such group are large predatory reptiles. Large reptiles play important roles within tropical ecosystems, contributing key ecosystem services. In most tropical ecosystems the biomass of large predatory reptiles outweighs that of mammalian predators, whilst the variation in diet between different size classes of a single reptile species exerts predation pressure upon a wide array of prey species. As such, reptiles exert predation pressure on ecosystems in a distinct way to mammals. One group of large predatory reptiles that should be considered for trophic rewilding programs are the monitor lizards (Varanidae). Varanids are among the largest terrestrial predatory reptiles and are often the dominant predators in the ecosystems in which they occur. Furthermore, many species of varanid have been extirpated from their former ranges. Research is sorely needed to investigate the potential of varanids as rewilding candidates. In this study, we take an interdisciplinary approach to establish restoration baselines for varanids. We use species distribution models to identify drivers of varanid distributions and go on to use these variables in combination with fossil data to reconstruct past communities of varanids. We find that temperature and precipitation are the major drivers of varanid distribution over and above biotic and anthropogenic variables such as competition, agriculture, and urbanization. We therefor utilize climatic variables to reconstruct varanid communities using ecometric techniques. Future work will go on to combine these data with fossil data to robustly forecast future distributions of varanids under climate change scenarios as a means of identifying restoration baselines.

Keywords Restoration, Rewilding, Reptiles, Varanus, SDMs, Ecometrics, Conservation Palaeobiology

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Amphibians and Reptiles on Limestone Habitat on Dinagat Islands, Philippines: Distribution, Status and Implication for an Island-wide Conservation

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Limestone karst habitat is one of the most fragile ecosystems in the world and endangered arks of biodiversity. Its complex geological history and structural complexity are expressed by enormous landscape variation. This extraordinary habitat shelters exceptional and highly specialized organisms that thrive on extreme microclimatic conditions. Although previously unappreciated and received little attention in the Philippines, recent efforts identify limestone karst ecosystem as one of the diverse and unique habitats in the country. Despite this, knowledge and information on this biologically significant habitat remain scarce, poorly understood, and threatened by anthropogenic pressures, deforestation, and modification of habitat. We hypothesize that Dinagat Islands is a home of diverse and endemic herpetofauna, inhabiting limestone karst ecosystem. We surveyed 5.0 hectares (i.e. 50,000 square meters) of limestone karst ecosystem in 16 sampling localities on western Dinagat Islands using a standardized 100x10m strip transect. A combination of acoustic and visual encounter survey, opportunistic sampling, microhabitat search (e.g., burrows, cave walls, leaf flitter, limestone outcrops and crevices, tree branch, temporary pools, small groundwater tributaries), and trapping method (e.g., adhesive tape) was done in surveying amphibians and reptiles. A total of 1152 person-hours were spent during the whole survey by a team of eight young enthusiastic individuals including our local guides. Field survey resulted in 58 new records (13 frogs, 26 lizards, 16 snakes, 1 turtle, 1 crocodile) of herptile species inhabiting limestone karst ecosystem of which 31 species (57.4%) are endemic, 17 species (31.5%) are new distribution record, four species (7.4%) are potential new novel discoveries and three threatened species (5.5%). Complementing this data together with the previous historical records and recently published accounts summarizes the 95 species of amphibians and reptiles known to occur on Dinagat Islands. This research provides basic knowledge of limestone karst herpetofauna in Dinagat Islands paving the way to advance ecological studies, implement conservation initiatives, and increase biodiversity awareness in this region.

Keywords Conservation, diversity, ecology, endemic species, new species, new records, protection

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Histopathological Alterations in Some Tissues of Heteroclarias Exposed to Diclofenac with Ameliorative Potential of Neem Leaf (*Azadirachta indica*)

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Background: There are increasing reports of pharmaceuticals in considerably high amounts in the aquatic environment globally, these effluents eventually contaminate water bodies and accumulate in aquatic biota leading to severe health consequences. **Hypothesis:** Diclofenac being one of the most common non-steroidal anti-inflammatory drugs (NSAID) found within aquatic environments – both in surface and groundwater samples, has been reported to be a potential toxicant with the ability to induce varying alterations in tissues of aquatic biota. However, there is relatively scarce information on its ecotoxicological effects on tropical fish. The study herein aimed to assess the histopathological alterations induced by diclofenac (DCF) on juvenile Hybrid Catfish, *Heteroclarias*, with an ameliorative potential of Neem leaf, *Azadirachta indica*. **Method:** The fish were exposed to varying lethal concentration (0.0, 4.0, 8.0, 12.0, 16.0 and 20 mgL^{-1}) of DCF for the period of 96 h. Subsequently, fish were exposed to sub-lethal concentrations (10.8 mg/L) estimated from the 96 h LC50 for 30 days. Fish were fed on a diet with varying percentage inclusion (0%, 1%, 2%, 3% and 4%) of Neem leaf for an ameliorative experiment during this period. At the end of the exposure period, the fish were sacrificed to remove the gills, liver, and kidney for histopathological assay. **Results:** Varying degrees of pathological lesions such as lamellar fusion, epithelial lifting, rupture of epithelial cells, and lamellar disorganization were observed in the gills. Vacuolation, infiltration, and aggregation of cells and necrosis were observed in the liver and kidney of DCF exposed fish compared to the negative control group. However, 1% inclusion of Neem leaf in the diet of the fish reduced the pathological damage after 30 days. **Conclusion:** Based on this finding, DCF

is found to be a potential toxicant which does not only have capable of inducing behavioural abnormalities but with the ability to cause mild to severe histopathological alterations on vital organs of *Heteroclarias*. Whereas the use of neem leaf to neutralize the toxic effects of DCF on fish showed that 1% inclusion in fish diet has great ameliorative potential by restoring the normal histology of the tissues. This may, however, result in the commercialization of the plant for large-scale use in bioremediation.

Keywords Histopathological, Pharmaceutical effluent, Non-steroidal Anti-inflammatory Drug (NSAID), *Azadirachta indica*, Diclofenac

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Fish and Fire: Cascading Effects of Floodplain Forest Fires on Amazonian Fish Communities

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Severe droughts facilitate burning of even the wettest and most isolatedregions of Amazonia covered by floodplain forests. After repeated fire, blackwater floodplain forests remain in an open vegetation state of arrested succession which favors soil erosion and facilitates their transition towards a white-sand savanna-like vegetation. Vegetation shifts from closed, unburned, floodplain forests to open fire scars and eventually white-sand savannas may have profound implications for fish communities that depend on floodplain forests for food and recruitment. Moreover, changes in fish communities may ultimately affect forest regeneration and contribute to the arrested forest recovery after fires and the transition of floodplain forests to other vegetation states. We explored the impact of floodplain forest fire on fish communities. We sampled fish in 27 sites divided into three flooded forest habitat types: unburned forests, fire scars, and white-sand savannas in the middle Rio Negro region (Brazil) during two consecutive flooding seasons. In those habitats, we compared the abundance, species richness, and the taxonomic and trophic composition of fish assemblages. We found fish communities in burnt floodplain sites to represent a possible intermediate state between unburnt forests and white-sand savannas. Furthermore, our results indicate that forest fires trigger profound shifts in the fish assemblagesof blackwater floodplain forests, from highly diverse communities in unburnt sites towards depauperate communities characterized by a predominant loss of smaller-sized, omnivorous fish species in burnt sites, and that these effects are proportional to the fire scar size.In summary, our study demonstrates the cascading effects of floodplain forest loss on Amazonian fish communities. These results are relevant because flooded forest loss by fire is expected to accumulate as the frequency and severity of extreme drought events increase.

Keywords aquatic-terrestrial coupling, Igapó, resilience, tropical forest, white-sand savannas

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Using Cutting-Edge Tools in Conservation Science

Session Recording: https://youtu.be/CI1Y12goyus

Preferences of Tourists towards Biodiversity in Tropical Rainforests: A Global Scale Assessment Using Social Media Data

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Tourism in tropical rainforests has a potential to contribute to conservation by providing tourists with opportunities to directly interact with biodiversity and raising their awareness for conservation. However, it is also pointed that the major objective of tourists in tropical rainforests is activities such as camping, trekking and boating and they may not be interested in observation of biodiversity, except for large-bodied mammals though they are rarely available and watchable. If this is the case, tourism in tropical rainforests may have little impacts on conservation awareness for tourists. Since there is no systematic and global-scale study on what tourists enjoy and appreciate in tropical rainforests, we conducted photo content analysis using social media data of Flickr. Particularly, we focused on the following research questions: a) was the number of activity-photos higher than biodiversity-photos? b) was the number of mammal-photos higher than photos of other biodiversity? and c) were there differences in photo contents among different continents? We mined publicly available geotagged photos uploaded on Flickr during 2010–2019 for 25 popular protected areas in the tropical rainforests around the world. We randomly sampled 1000 photos for each area, and totally 25000 photos were classified based on their contents. We used GLM to test the questions above. Contrary to our expectation, the number of biodiversity-photos were significantly higher than that of activity photos in the 25 protected areas. Among biodiversity elements, the number of photos of birds, arthropods and plants were high and not significantly different from mammals. Photos on mushrooms were also common. We also found differences in contents of biodiversity-photos; birds were popular in Asia and Central/South America while large-bodied mammals were common in Africa. Our results indicated that tourists in tropical rainforests actively posted photos related to biodiversity, not only large-bodied mammals but also birds, arthropods, plants, reptiles, mushrooms, etc. This implies that even though their major objective might have been other outdoor activities or watching large-bodied mammals, they were interested in and impressed by non-mammal biodiversity they encountered in the forests. Many protected areas provide information on charismatic mammals but not insects and mushrooms at information center or on their websites. Since biodiversity other than mammals is huge and more likely to be encountered by tourists, offering more information on non-mammal biodiversity will enrich tourists' interaction with biodiversity and raise their awareness for conservation.

Keywords Biodiversity conservation,Flickr,social media,tropical rainforest,ecotourism,protected areas

Spatial or Temporal Sampling? Assessing Diversity Levels in a Bornean Rainforest Using Bioacoustics

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Current environmental crises demand cheaper, time-efficient, and scalable methods of biodiversity sampling. Conventional ways to measure biodiversity are challenging and expensive to carry out at a sufficient spatial and temporal scale, and over more than one taxonomic group. Biodiversity surveys are often limited to spatial data collection of one taxonomic group in one season, limiting our understanding of biodiversity patterns. Using autonomous bioacoustic recorders, we assessed alpha, beta, and gamma diversity for all vocalizing taxonomic groups to investigate the role of spatial and temporal sampling of soundscapes, with and without selective logging. We synchronously recorded all the sounds in a landscape (soundscape) for 24h a month at 15 mature forest sites in East Kalimantan, Indonesia, for a year. For spatial sampling, we randomly selected one minute during the dawn and sampled the same minute for all 15 sites. For temporal sampling, we selected 2 sites (one never logged, and another selectively logged for the first time) to sample the same dawn and a dusk minute every month for a year. We manually labeled all the animal sounds in each minute sampled and used the number of different sonotypes (unique vocalizations) as a proxy of species richness of birds, insects, mammals, and amphibians. In a total of 63 minutes, we annotated >3000 vocalizations of > 400 sonotypes. Preliminary results suggest that, for birds, sampling over space yielded a similar alpha and gamma diversity as over time, but the sonotypes detected with each sampling regime were distinct, with only 13% of overlap. For insects, the spatial sampling yielded 30% more sonotypes in total than the temporal sampling, and there was a 23% overlap of sonotypes between temporal and spatial sampling. Selectively logged site had a lower turnover of bird sonotypes and higher turnover of insect sonotypes in time when compared to the never-logged sites. The majority of biodiversity surveys consider only the spatial dimension, at one snapshot in time. We demonstrate that even in a low-seasonality tropical forest, the richness and composition of the vocalizing diversity vary greatly throughout the year, to a similar degree as spatial variation. To truly understand the impacts of human activities on biodiversity, it is necessary to sample biodiversity over both space and time.

Keywords bioacoustics, soundscapes, rainforests, sampling, birds, insects, gamma diversity, species composition

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The Relationship between Acoustic Indices, Elevation, and Vegetation, in a Forest Plot Network of Southern China

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Introduction: Sound-based monitoring technology using autonomous recording units is an important new method for biomonitoring during our era of global change. Acoustic indices run on these data may efficiently estimate animal diversity and compare habitats. As yet few studies, however, have placed autonomous units on long-term vegetation plots and tried to correlate plant and animal data using the acoustic indices. **Objectives and Hypotheses:** We investigate what kinds of biodiversity patterns the acoustic indices could detect on on a forest plot network of southern China. We expected that the indices would show strongest relationships with elevation, because of its large variation over this regional plot network. Based on the animal diversity literature, we hypothesized that acoustic indices would have medium-intensity relationships with vegetation structure (vertical heterogeneity, canopy height and tree density), and the weakest relationships with tree species diversity. **Methods:** Each of 27 1-ha plots was sampled for at least 30 consectutive days during the bird breeding season across three years. The autonomous recorders were scheduled to record two 10-min recordings per day (after sunrise, recording primarily birds, and after sunset, recording primarily insects). From each recording we calculated values for seven different indices. We then constructed generalized linear mixed models, followed by model averaging, to understand the relative influence of the predictor variables. **Results:** Elevation had the strongest relationship with the acoustic indices: for 6/14 models (7 acoustic indices x 2 times of day) there was a strong (confidence intervals did not cross zero) negative relationship, and the factor

had the highest importance factor averaged across models. Vertical heterogeneity had the second highest important factor, but one of its two strong relationships was negative. The only other strong relationship was a positive one with tree species diversity. Morning and evening recordings had similar results, despite representing different taxa with different acoustic characteristics. However, the seven acoustic indices gave dissimilar results, with the H index having three strong relationships compared to the ACI, BIO and AR indices with none. **Conclusions:** We conclude that acoustic indices can be used to describe ecological patterns on long-term vegetation plots as long as multiple indices are used. These plots are one of the greatest investments the world has made in ecological research, and autonomous recorders can reduce observer disturbance to them. It is necessary now to investigate different plot networks to see at what scales relationships between animal and plant diversity can be detected.

Keywords acoustic biomonitoring; bird diversity; long-term plots; permanent plots;

Interplay between Local- and Landscape-scale Characteristics in Shaping Aerial Insectivorous Bat Responses across a Fragmented Amazonian Landscape

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Introduction / Background / Justification: For many taxa, including bats, there is limited knowledge about how local habitat quality interacts with landscape characteristics in determining species responses in today's ever-expanding tropical human-modified landscapes. In this context, multifaceted approaches that jointly consider the three complimentary biodiversity dimensions (taxonomic, functional and phylogenetic diversity) can provide a comprehensive understanding of the drivers of biodiversity change across human-modified landscapes. This research is of great importance for informing conservation and management decisions and will provide valuable knowledge on an ensemble that remains underrepresented in the bat fragmentation literature. **Objective(s)/Hypothesis(es):** Our main study aim was to assess the responses of aerial insectivorous bats to local vegetation and landscape-scale characteristics from a multidimensional diversity perspective, i.e. focusing on taxonomic, functional and phylogenetic diversity. We further investigated the extent to which relationships between diversity facets and local and landscape characteristics are scale dependent. **Methods:** We used a unique acoustic data set collected at the Biological Dynamics of Forest Fragments Project (BDFFP) in the Brazilian Amazon. Data were collected over three years at 33 sites (continuous forest and fragment interiors, fragment edges, and secondary forest matrix) using passive acoustic recorders. Using mixed-effects models, we explored, at ten focal scales, the relationships between the three diversity facets and local vegetation structure and measures of landscape composition (forest cover) and configuration (edge and patch density). **Results:** Preliminary results of this research indicate subtle scale-sensitive associations for all three diversity facets with local and landscape scale metrics, whereby predictor variables were generally negatively correlated with all diversity facets, with the exception of functional diversity and local vegetation structure, which showed a positive relationship. **Implications/Conclusions:** This study indicates that scale-sensitive measures of local and landscape structures are needed for a more comprehensive understanding of the effects of fragmentation on aerial insectivorous bats and the wider tropical biota generally. It is likely that forest fragments surrounded by regenerating forests can buffer the effects of deforestation but diversity can only recover to a certain extent and so it must be emphasized that pristine primary forest is of irreplaceable value and conservation efforts should focus on preserving large expanses.

Keywords Chiroptera, aerial insectivorous, deforestation, fragmentation, bioacoustics, diversity, spatial scale, Amazon

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Liberating Social Media Posts of Plant Observations In Indonesia

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Knowledge of wild plant species tends to be associated with a passion for conserving them. However, developing plant identification skills in species-rich tropical countries is challenging, especially where easy-to-use field guides are unavailable. In Indonesia, social media has become one of the primary ways to share plant knowledge, because of the wide use of smartphones and their social media apps, and also because the informality of online groups encourages the asking of questions. One of the most active forums is Plants Community, a Facebook group started in 2012 by plant enthusiasts in Pontianak, West Kalimantan (Borneo), and now a community of over 2,000 members. Several times each day, photos of plants are shared, commented on and identified. The observations are often of rare species and/or of fertile individuals, making this a unique and valuable record of plant diversity in Indonesia. Despite its benefits as a forum, a Facebook group is however a poor repository for storing information: the images are locked into a corporate silo not accessible by the internet public, and recent changes in Facebook's search options mean that older posts are no longer findable. Aware of these limitations, we began an effort to rescue the images and metadata before they were completely lost, and repost them to a public website and database: https://indonesia-plants-community.org/. The project was strongly supported by members of the group, who had created the images. We looked into automated ways to extract the posts using the Facebook API, but in the end chose a process of manual downloading images, reading comment threads, uploading images to the website, and recording metadata (original post author, date, location, determination and determiner). To date (May 2021), 2,990 observations belonging to 906 different genera from across Indonesia have been transferred, going back to February 2012. All metadata fields are searchable. Besides Facebook posts, the repository can store any plant observations, and we are in the process of adding other collections of images from community members. In the conference presentation, we will describe the Plants Community group, its value for Indonesian botany, and the process of creating the new website.

Keywords Plants community, Plant observations, Indonesia, Social media, Findable repost

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BioOmiteca Atlantic Forest: A Digital Library of Omics and Biogeographic Data to Promote Valorization and Conservation of This Biodiversity Hotspot

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Bioprospection strategies are crucial to the conservation of biodiversity and continuous provision of its ecosystem services to support human health and prosperity. To achieve a prosperous bioeconomy, bioprospection acts on the search for chemotypes and natural compounds with potential for agricultural and industrial applications. An important field supporting bioprospection is metabolomics of plants. Considering the high number of existing plant species and the various biosynthetic pathways capable of producing extraordinary chemical diversity, neotropical environments' biodiversity offers a rich range of molecules that can be used as models for nutritional and medicinal industries. Bioprospection can also be optimized with knowledge about geographic distribution of target species. Currently, species distribution modeling (SDM) is the most used approach to address this issue. SDM allows to identify potential suitable areas for target species' populations, which can be prioritary for conservation, regeneration, and reinforcement actions in their native ranges. Our project aims to develop an integrative approach between these scientific fields (metabolomics and SDM), using orchid species as models of economic interest from the Atlantic Forest (AF) hotspot, through a science communication effort. Combined results will be available online in the BioOmiteca Atlantic Forest platform, with information adapted to reach a wide range of stakeholders, from lay audience to traditional communities, farmers, and policy makers. Three orchid species were analyzed through metabolomics techniques of liquid chromatography coupled with mass spectrometry and chemometrics. Also, their distribution data are being used to generate informative biogeographic models, to evaluate their congruence with the current network of Protected Areas (PAs) and to elucidate conservation gaps. Preliminary results show that important molecules belonging to the flavor

of commercial vanilla were identified in both Vanilla species studied. In Cyrtopodium glutiniferum, identified molecules and chemical classes are commonly associated with antioxidative activity and may justify the use of this plant medicinally. Preliminary analysis of the distribution model of C. glutiniferum revealed that the current PAs network covers mostly low environmental suitability areas, indicating that potential occurrence hotspots of this species are not protected under any legal sphere of conservation areas. The BioOmiteca platform is under development to allow for consultation of these results and also for external collaborators to share their own omics and biogeographic data about AF species. Altogether, the BioOmiteca features will showcase the value of Atlantic Forest species through their bioeconomic and occurrence potential, helping to support decisions about conservation and sustainable use of biodiversity in this prioritary hotspot.

Keywords bioeconomy, metabolomics, species distribution modeling, science communication, Atlantic Forest, hotspot

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Connect and Conserve: A First of Its Kind Conservation Database Providing Critical Sector Data

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Introduction: Connect and Conserve is a non-profit initiative that is aggregating pertinent data from each and every conservation organization around the globe. These data will be available freely to researchers and publicly visualized in a map-based interface with searchable data dashboards and organizational profiles to connect with conservation practitioners, funding agencies, and the public. The conservation sector strives to maintain the integrity of our ecosystems but is doing so largely without critical contextual knowledge of its efforts. Siloed conservation organizations cannot reach their full potential and would greatly benefit from the increased connectivity and access to pan-network information which Connect and Conserve is aiming to provide. **Objectives:** Collecting and visualizing pertinent conservation data into a digital ecosystem will allow for the mapping of the conservation sector at an unprecedented scale, thus enabling critical performance monitoring, planning, and evaluation of the entire conservation field. Conservationists, researchers, and donors will be able to view their combined efforts in a way that can easily guide their future efforts with the Connect and Conserve platform. By tracking how funding is spent, we will have a much better idea of which species and areas are most in need of our assistance. Methods A portion of this information has been scraped from public resources, though gaps in this data are significant and difficult to collect and validate. To address this issue, a web of initiatives provided by The Biodiversity Group has been created to provide broadly desired benefits for participating organizations which will not only incentivize these organizations to provide their activity data but also bolster their efficacy. **Results:** Data from over 6,000 organizations have been aggregated and the results of the preliminary mapping of US-based conservation expenditures can be viewed via the CnC website. **Implications/Conclusions:** Data curation and analysis are still in progress and require participation from the conservation community. By monitoring and evaluating our efforts, conservationists can be even more strategic in the use of the limited funds available. With a more coordinated group of conservationists working to save our world's forests, the effects of climate change will be further reduced and untold future crises can be averted.

Keywords evaluation, nonprofits, network, fundraising, open-source, website, monitoring, organizations, donations, community

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Snapshot Serengeti Online: A Fully Online, Open-source Inquiry Lab on Tropical Ecology

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Background: The Snapshot Serengeti Lab is a multi-week, inquiry lab designed to teach undergraduate students the full scientific process using authentic data from an ongoing camera-trap research program on African wildlife. The lab has been refined over five years and is regularly cited as a highlight of students' experiences in several undergraduate biology courses at the University of Minnesota. Despite its success, however, the lab has been difficult to disseminate to other institutions because it relies on complexity, proprietary statistical software and materials built for a specific learning management system. OCELOTS (A Platform for Facilitating Online Content for Experiential Learning of Tropical Systems) is an international network of tropical biologists, educators, software developers and media specialists dedicated to the development of free, fully online educational experiences that integrate authentic research, data analysis, and local perspectives in tropical ecology. **Objective:** The Snapshot Serengeti Lab served as an initial case study for the OCELOTS network because it was well worked out and included online elements. Our goals were to revise the lab such that it retained its inquiry-based nature while 1) removing the dependency on the proprietary statistical software, and 2) transferring the lab freely available, online platform. **Methods:** We used the open-source software RShiny to design an interactive, web-based graphical analytics dashboard. We also rewrote the lab to exist entirely on the free, online Gala platform. The dashboard integrated seamlessly into Gala, allowing students to explore and use the data set to answer questions. Ultimately, the students used the dashboard to answer their own question as part of an independent research project. **Results:** The revised version of Snapshot Serengeti has been deployed at 3 universities, where it is in various stages of development. The response from students and faculty at these universities has been overwhelmingly positive, especially to the new online analytical and data visualization totals. In sum, the analytical dashboard provided a wide degree of flexibility, while greatly reducing student and faculty time spent on software questions. **Implications:** The renovation of Snapshot Serengeti has improved the lab and made it more accessible than previous iterations, yet challenges remain. For instance, while the lab no longer requires expensive and complicated proprietary software, there are still costs associated with hosting RShiny applications e.g., paying for subscription-based hosting services or in-house servers. The Snapshot Serengeti Online Lab, nonetheless, demonstrates a way forward for the development of fully online research-focused teaching.

Keywords Online learning, inquiry lab, undergraduate biology, African wildlife

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Replacing Flesh and Bone with Wires and Chips: The Use of Technology to Fill in for Human Observers

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In a world where species conservation and rehabilitation revolves around community engagement, animal monitoring, habitat restoration, animal translocation, and biodiversity assessments, the requirement for manpower is substantial. Anybody who has tried to conduct conservation research or reintroductions of endangered species will tell you that it is mentally and physically exhausting to design each component of the program, let alone implement it to the degree required. Traditionally monitoring released animals, assessing local biodiversity and habitats are labor intensive activities which need tremendous manpower to implement but also the management of these activities. This is a luxury which during the current Covid-19 pandemic is not available to many, as restrictions are placed on travel, and key project workers are harder to source. We have to think outside the box and use alternatives methods for these activities. Here we discuss the use of technologies which are proving incredibly helpful when running components of site conservation and endangered species reintroduction projects without the large teams traditionally required. These key components include; Site assessments for threats and suitability for conservation activities, Assessing and identifying site biodiversity, and Monitoring translocated animals within a site. Prior to any animal translocation or site selection you need to identify

whether the site is suitable for the long term. Judging its size, habitat structure, heterogeneity and viability, level of threat and whether there are remaining populations of your species or competitors. Depending on the size of the site this could take more than a year with teams of 5-20 people involved in the site assessment recording habitat, biodiversity and threat assessments on foot. These activities are now being made easier, without losing significant data, through the use of drones and remote camera traps. Once you have selected the site and introduced your species, your next challenge is monitoring their survival and multiple other individual and cohort ecological interactions. Technology is again coming to our aid with the use of drones and cameras but also, the now more affordable and easy to use, GPS tracking systems with remote downloads allowing you to see where and what your introduced animals are up to at any time. These technologies have reduced our need for grand teams and days of potentially disturbing or damaging trekking through the forest, and in the current climate may very well save a lot of projects and provide the necessary monitoring needed to discover problems before it's too late.

Keywords Technology, Pandemic, Cameras, GPS, Telemetry, Philippines, Talarak, Endangered Species.

Canopy Height Variation in Relation to Topography and Vegetation Types at Landscape-scale - A LiDAR-based Approach in

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Maximum canopy height and vertical forest structure are key drivers of many ecosystem processes which are often governed by fine-scale topography. With the advancement in remote sensing techniques such as airborne laser scanning (ALS), high-resolution information of tree canopy height and underlying topography can be derived at a larger spatial scale. But we still have limited understanding of how these fine-scale topographic heterogeneities and vegetation types drive variation in tree height at a large spatial scale e. g. landscape scale ($>$100km^2). In this study, we analyzed high-resolution information of the vertical structure of trees such as individual tree height from ALS in relation to fine-scale topographic controls and vegetation types that were derived from other sources. The study was conducted in a secondary forest-dominated area of 230 km^2 in Kyoto, Japan, spanning an elevation gradient from 70 – 1000 m. a. s. l. ALS derived tree height was on average higher in plantation forest (PL) than evergreen needle forest (ENF), and followed by evergreen (EBF) and deciduous (DBF) broadleaved forests respectively. Tree heights exhibited a non-linear association with elevation with the peak value (on average 22 m in PL) in mid-altitude (461–560m), and tree heights were on average 5-10 m higher in the concave valleys than the convex topography. We employed a set of multiple linear regression and machine learning models to explain variability in maximum canopy height and ranked the best predictor variable from model outputs. In our analysis, Random Forest stood out as the best predictive model ($R^2 = 0.38$, RMSE $= 4.54$, and MAE $= 3.5$) with distance from nearest canopy gap, topographic curvatures, and neighboring tree density as key predictor variables. The analytical approach developed in this study would be useful to plan a proper land design and maintain a healthy forest stand at a regional scale.

Keywords Individual tree height, microtopography, canopy gap, topographic curvature, remote sensing.

Spotting the Deer through the Herd: Using Spot Recognition Software for the Endangered Visayan Spotted Deer Reintroduction

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The Visayan Spotted Deer (*Rusa alfredi*) is under threat and requires urgent action to rescue its wild populations. Endemic to Negros and Panay, Philippines, R. alfredi populations have declined to <1000 mature individuals remaining. The disappearance of the species within protected areas implies a need for adequate assessments of remaining populations. Within a small reintroduced population, there is a need to monitor the fate of each individual. While GPS and telemetry techniques are effective, their use is limited by financial and human resource constraints, leaving remote camera trapping as a low resource alternative. Using photo-ID techniques, we trialed the first study for individual identification on a population of *R. alfredi* reintroduced to a reserve in Negros. Fourteen male *R. alfredi* released into the 300ha reserve were monitored using camera traps beside 6 artificial feeding stations. After 6 weeks, we cross-referenced the images with control images of the same individuals from captivity. Camera trap images were matched to control images by human observers and the software Hotspotter. We collected 118 images from 9 deer. The software identified 7 of the individuals in 66 separate images whilst human observers identified 9 of the individuals from 93, while 14 images were not matched by the software or human observers. As assessments begin to re-evaluate the status and size of the *R. alfredi* populations in the wild, photo-ID and assisting software will be intrinsic to population modeling, individual health monitoring and early indicators of local population collapses.

Keywords Endemic, Endangered, Deer, HotSpotter, Technical, Fieldwork, Philippines, Telemetry, identification.

Discrimination of Three Madagascar Commercial Valued Dalbergia Species Using NIRS, toward the Development of an Identification Tool for Supporting CITES Enforcement

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Dalbergia species, which include rosewood and palissander are overlogged and traded to supply the illegal market, especially in tropical countries such as Madagascar. The difficulty in species identification from wood without leaves and fruits compounds the difficulty of control operations in the forests, at the ports and customs level. The development of helplful tools such as the calibrated Near InfraRed Spectrometer (NIRS) to identify these species on the basis of their woods characteristics is therefore an issue for the management and sustainable trade of these resources. The objective of this study was therefore to assess the potential of NIRS to discriminate three large-diameter tree species of *Dalbergia* from Madagascar. For this purpose, 43 corewood samples were collected inside and outside of several protected forest areas scattered across the five bioclimatic zones in Madagascar. All the samples belong to three *Dalbergia* species including *D. chlorocarpa*, *D. greveana* and *D. neoperieri*. The corewood samples were first conditioned to 12% moisture content. Near-infrared absorbance spectra were then measured from the heartwood using a portable MicroNIR spectrometer VIAVI 1700. Several pre-processing methods were applied to remove noise and distortion on the spectra. A discrimination model was then calibrated from the Three-quarters of the pre-processed spectral data set using Partial Least Square Discriminant Analysis. Finally, the model was tested to predict the names of the remaining quarter spectra. Testing of the model on the validation spectra set results in 83.34% of discrimination accuracy. The model allows a good separation of *D. chlorocarpa* from *D. greveana* and *D. neoperieri*. However, one sample of *D. greveana* and one sample of *D.neoperieri* were misclassified as *D. chlorocarpa*. Compared to previous research on the discrimination of *Dalbergia* species from Madagascar using NIRS, the model developed in this study was calibrated based on many more samples. However, the number of samples used is not yet sufficient for the model to be applied in the routine of Madagascar's precious woods identification. The results of this study will then be further enriched over time to provide reliable discrimination models for laboratory and field identification.

Keywords Dalbergia, Near InfraRed Spectroscopy, Partial Least Square Discriminant Analysis, CITES

Impacts of Agriculture on Tropical Ecosystems and Alternatives Towards Sustainability

Session Recording: https://youtu.be/Bf6BDbCVR00

A Steep Decline in Biodiversity with Increasing Coffee Yields along a Gradient of Management in Arabica Coffee's Native Range

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Tropical agroforestry systems provide farmers with goods, but are also well recognized as refuges for biodiversity. However, there might be a trade-off between yield and biodiversity in these systems. If such a trade-off is present, the potential for synergy will depend partly on the shape of the trade-off, i.e., if the relationship is concave, linear, or convex. We studied the relationship between biodiversity and coffee yield along a gradient of coffee management in southwestern Ethiopia, coffee's native range. We inventoried species richness and community composition of woody plants, herbaceous plants and bryophytes, and measured coffee management related variables at 60 sites in which we also assessed coffee yield for three consecutive years. Species richness of woody plants had a concave relationship with coffee yield, i.e. the tree richness declined fast initially before levelling out at higher yields, whereas there was no relationship between coffee yield and species richness of herbaceous plants or bryophytes. Species composition of woody plants, herbaceous plants and bryophytes all had a concave relationship with coffee yield. The concave relationship between biodiversity components (species richness and composition) and yield suggests that there is a strong conflict between the goals of increasing production and conserving biodiversity. Our findings also highlight that minor intensification of management in the most natural sites may rapidly erode biodiversity, and that paying premium prices to farmers may be needed to keep these systems. However, more productive sites often harbour considerable levels of biodiversity and may play important roles for biodiversity conservation at the landscape scale, by increasing connectivity and acting as buffers around core areas.

Keywords Agroforestry, biodiversity conservation, biodiversity-yield trade-offs, coffee, management gradient, southwestern Ethiopia

A Community-wide Approach to Understanding the Relationship between Biodiversity and Yield in Tropical Agroforestry

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Agroforestry, the practice of planting crop trees under a canopy of shade trees, has the potential to combine high yield and high biodiversity in the tropics. However, the evidence for this has thus far been mixed, with some studies showing win-win scenarios of biodiversity and productivity, and others the opposite. The main impediment to understanding the trade-offs and synergies between biodiversity and yields is the multi-dimensionality of the system; agroforestry contains a range of species across different trophic levels that interact with their environment and with each other, potentially affecting yield in different ways. We tackle this issue using a community modelling approach, with the objective of understanding how farm management interplays with animal community composition to influence yields. Over 2 years in 28 varyingly managed cocoa farms in Cameroon, we surveyed birds and bats using mist-nets and acoustic devices, insects using a combination of common sampling techniques (sweep nets, malaise traps, visual surveys) and we interviewed farmers for information on yields. We will characterize the trophic links between these species by metabarcoding bird and bat faecal samples (pilot sample size = 64), and by observing consumption of cocoa by pests. We propose a Bayesian hierarchical modelling framework that combines these data and estimates the net effect of each species on the rest of the species in the community. We will present preliminary results from certain sections of the model, and describe the next steps towards the full community model. Our results will provide novel insights into the biotic interactions in these agricultural habitats; most importantly, they will illustrate how tropical agroforestry systems can be managed to influence animal community composition, pest control, and yield.

Keywords Afrotropics, agroforestry, Bayesian community model, biodiversity, faecal metabarcoding, pest control

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Diverse Tropical Insects Visit Cocoa Flowers

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Cocoa is a major tropical commodity crop planted in diverse agroforestry systems. Climate change is negatively affecting cocoa production in the world. One opportunity to increase cocoa productivity is boosting pollination success. Research focuses on mosquitoes of the genus *Forcypomia* as the primary pollinator of cocoa flowers. Studies emphasize identifying brooding materials within plantations or potential attractants to *Forcypomia* to enhance pollination. Recently many researchers have highlighted that a diversity of insects might be responsible for pollination in cocoa. To evaluate which insects are accountable for cocoa pollination, we conducted a detailed study of floral biology and flower visitors in cocoa plantations in Colombia. We followed 400 flowers from opening to wilting. We made observations every four hours. We took note of the time of anthesis, as well as pollen viability and stigma receptivity. Floral visitors were collected during day and night and also in farms near and far from the forest. Cocoa flowers opened in the early morning. Anthers opened and are emptied the first day. Stigmas were receptive after 24h of flower opening. Flowers complete cycle can last 4-5 days, male and female activity is concentrated in 48h. The main flower visitors are insects of the orders Hymenoptera (Apidae, Formicidae, and Vespidae), Diptera, and Coleoptera. Coleoptera are the primary visitors during the night. Melipone bees are the main visitors during the day, and they were observed to carry large pollen loads. *Forcypomia* mosquitoes were seen sporadically and only with small pollen loads. A more diverse set of insects was reported in locations near the forests than farther away. We conclude that contrary to common belief, bees and not flies are the most important pollinators of cocoa, at least in Colombian plantations. Project funded by Universidad Militar Nueva Granada INV-CIAS 2945.

Keywords *Theobroma cacao* L., floral biology, sustainable agriculture, pollination

Tropical Tree Planting: People Plant Trees for Utility More Often than for Biodiversity or Carbon

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Tree planting is both a promising and controversial solution to climate change and biodiversity loss. However, this controversy is largely theoretical because we lack detailed information of how tree planting is proceeding on-the-ground. Here, we compiled a pantropical dataset of 174 tree planting organizations to determine the type of organizations involved in tree planting, their geographic locations and tree planting approaches. We found that the number of organizations have increased by 288% in the past 30 years, especially for-profit organizations. These organizations reported planting nearly 1.4 billion trees across 74 countries since 1961. Most frequently organizations reported establishing agroforestry systems or mixed species and single species plantations or using assisted natural regeneration (ANR) suggesting that tree planting programs are designed to support local communities as well as environmental objectives. Moreover, the most frequently reported species were commercial or utilitarian, with the top five including cacao, teak, moringa, mango and coffee. Finally, despite widespread efforts to plant more trees, there was a pronounced lack of monitoring on websites and in reports; only 18% of organizations mention monitoring at all, and only 5% mention measuring survival rate of plantings. Greater transparency and greater communication are needed between planting organizations and researchers to apply the most effective ways to restore forest cover. Further, while organizations often aimed to counter environmental problems, the use of the same sets of commercially useful species to meet economic development goals across the global indicates a need for greater coordination among organizations to avoid biotic homogenization.

Keywords reforestation, forest restoration, tree planting, tropical, NGOs, agroforestry, cacao

Forest Age Affects Coffee Yields across Large Regions

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Natural forest regeneration is crucial for achieving cost-effective restoration goals for the current decade, as it reduces the cost associated with active restoration while favoring biodiversity recolonization. After twenty years, secondary forests seem to recover biodiversity and carbon stock capacity similar to old gown forests in tropical regions. Nonetheless, less is known whether regenerating forest contributes to agricultural production through ecosystem services. We present evidence that coffee landscapes mainly composed of regenerating forests, lower forest contribution to yields. With data from 610 municipalities in the Atlantic forest in Brazil, 20% of the world's coffee production is concentrated. We were able to calculate the amount of old-grown forest (more than 20 years) and regenerating forest (less than 20 years of age) in the 2 km buffer surrounding the municipality's coffee fields. We found that increasing forest cover results in higher coffee yields when the forest is composed predominantly of older grown forest landscapes. Moreover, this effect is more robust in municipalities producing the highly pollinator-dependent coffee species (*C. canephora*) than those producing *C. arabica*. Our results further reinforce that forest relationship with crop yield across large regions might be mediated by changes in biodiversity composition, as young regenerating forests are not expected to harbor high biodiversity levels. Hence, explaining the lower spatial stability of service provision in landscapes dominated by young regenerating forest fragments. Our results have clear implications for conservation policies, as most of the restoration needs to occur within agricultural landscapes. We present evidence that there is a delay in forest ability to contribute to agricultural production. Human land-use management is currently restraining regenerating fragments from achieving older ages, resulting in a rejuvenation of forests across the tropics. Policies directed only at forest amount targets could result in less engagement from private properties to undertake restoration as fewer benefits might be perceived in the short term. We suggest that forest conservation policies promote agroforestry managements to engage farmers' revenue in the short term to attain the forest's long-term maturity.

Keywords Agroecology, secondary forest, pest control, ecosystem service debt

High Philopatry, Sex, and Body Size Influence the Use of Agricultural Land by Galapagos Giant Tortoises

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As the human footprint of agriculture expands, interactions between wild animals and farmland are increasing globally. Understanding the nature of such interactions is vital to inform the management of human-wildlife co-existence. We investigated patterns of space use of two critically endangered Galapagos tortoise species on privately owned and agricultural land (hearafter 'farms') on Santa Cruz Island, where a human-wildlife conflict is emerging. We used GPS data from 45 tortoises tracked for up to nine years, coupled with data on farm characteristics to identify factors that influence tortoise movement and habitat use in the agricultural zone. Sixty-nine percent of tagged tortoises used the agricultural zone, where they remained for an average of 150 days. Large male tortoises were most likely to use farms for longer periods than female and smaller individuals. Tortoises were philopatric (mean overlap of farmland visits = 88.7% $\pm$ 2.9%), on average visiting 4 farms and occupying a mean seasonal range of 2.9 ha ($\pm$0.3ha). We discuss the characteristics of farm use by tortoises, and its implications for tortoise conservation and coexistence with humans. Inexorable expansion of the human footprint means that understanding the temporal and spatial distribution of wildlife on farms is increasingly critical for conflict mitigation and the promotion of coexistence

Keywords Agriculture; conservation; continuous time movement models; habitat use; human-wildlife conflict

Natural Regeneration and Secondary Forests

Session Recording: https://youtu.be/T1pvGomG79c

Gap Dynamics Help to Maintain Functional Tradeoffs in Neotropical Forest Succession

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Introduction/Background/Justification: Five demographic strategies (fast, slow, intermediate, short-lived breeders, long-lived pioneers) spanning the growth-survival and stature-recruitment tradeoffs capture the successional dynamics of secondary and old-growth forests in central Panama. However, the mechanisms that allow for the maintenance of these strategies are still a mystery. **Objectives:** One possible mechanism that may promote demographic diversity along tropical forest regeneration is gap dynamics. Here, we aim to answer the following question: Can the demographic strategies we observe in the Neotropics be maintained solely through gap dynamics and height-structured competition for light in the canopy? **Methods:** We parameterize a Perfect Plasticity Approximation forest patch model with gaps (Farrior et al. 2016) and annual growth, mortality, and fecundity parameters for five strategies and four canopy layers from BCI, Panama (Rüger et al. 2020). Patches are connected by stochastic seed rain, and strategies differ in how much recruitment is favored in gaps. We investigate whether competition for light following gaps generates coexistence of the five strategies. To quantify the coexistence of strategies in these stochastic simulations, we report the average time of the first extinction (average coexistence time) and the necessary strength of conspecific negative density dependence (CNDD) needed to maintain coexistence for 10,000 years in 90% of the simulation runs. **Results:** Our preliminary results show that gap dynamics promote coexistence among two strategies across the growth-survival and stature-recruitment tradeoffs independently, and significantly enhance the average coexistence time of the five strategy simulations with stochastic seed rain. Given the metacommunity structure, we estimate that 80% more imposed CNDD is needed for five strategies to coexist for 10,000 years when gaps are not included than when they are. When we eliminate species differences, gaps hinder the coexistence of neutral models. However, five strategy neutral models with gaps coexist longer than niche models with gaps. **Implications/Conclusions:** Our analysis shows that a simple model of competition for light following patch-level disturbances can promote empirically observed demographic diversity. However, the findings that neutral species coexist better than those with different strategies highlight the need for still other mechanisms to explain observed tropical forest demographic diversity.

Keywords Neotropics, Tropical forest regeneration, Gap dynamics

Influences of the Fern/vine Thickets Formation on the Above-ground Biomass Recovery Rate in a Bornean Logged-over Secondary Forest

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Approximately one-half of the tropical rainforests have been modified by human activities. It is, therefore, important for achieving sustainable use of forests to understand the recovery processes of secondary forests. It has been reported that above-ground biomass (AGB) of tropical secondary forests can recover to the level of mature forests within decades. However, we observed that the AGB of some forests in Borneo has not recovered at all although 20-30 years have passed after the last logging. Such forests are highly degraded and the forest floor and sometimes even canopies are covered by fern (*Diernopteris linearis*) / vine thickets. The presence and abundance of such thickets may affect the AGB recovery rate and secondary succession processes but they have not been well examined. In this study, we hypothesized that the greater coverage of fern/vine thickets retards AGB recovery by decreasing recruitment of new individuals, growth and survival of remnant trees and tested them by field survey. We established a total of seventeen 20-m radius circular plots, in logged-over forests in the Deramakot and Tangkulap Forest Reserves in Sabah, Borneo, with a varying degree of fern/vine thickets coverage. The mean absolute recovery rate of AGB between 2014 and 2019 was 1.38 Mg ha^{-1} $year^{-1}$ and the relative recovery rate was 2.24 % $year^{-1}$, which were much lower than previous reports of the recovery rate of tropical secondary forests (e.g. 2.9 Mg ha^{-1} $year^{-1}$ in Sabah and 2.6 Mg ha^{-1} $year^{-1}$ in Amazon). AGB recovery rate was lower in the forests with higher fern/vine coverage and became zero or negative in some plots. In the forests with higher fern/vine coverage, the number of remnant small-diameter trees, as well as the number of recruited trees, were lower, relative growth rate of pioneer tree species was suppressed and mortality of remnant trees during 5 years increased. The results clearly showed that the coverage of fern/vine thickets inhibited AGB recovery through modifying the process of secondary succession. Tropical rainforests have been disturbed widely for harvesting timber on the assumption that logged-over forests can unconditionally recovery after the disturbance. However, our study strongly suggests that there is a danger of the loss of resilience depending on the initial conditions of secondary succession.

Keywords Borneo, Resilience, Secondary succession, AGB recovery rate, Fern, Vine

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Vertical Light Gradients Drive Tree Performance and Forest Dynamics during Tropical Secondary Forest Succession

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Introduction: In tropical forests, the vertical light gradient from the forest floor to the canopy strongly determines light competition among tree individuals. During secondary forest succession, the vertical light gradient builds up, with profound consequences for tree height growth (i.e., vertical stand development), the mortality of suppressed individuals (i.e., stand mortality rate), and the size inequality amongst individuals (i.e., stand differentiation). **Objectives:** We evaluated how changes in the vertical light gradient during tropical secondary forest succession drive tree growth and mortality, and hence vertical development, stand mortality rate and stand differentiation. **Methods:** To describe successional patterns in vertical light gradients, tree performance and forest dynamics, we established plots in 14 Mexican secondary forest stands that differ in age (1-24 years) since agricultural abandonment and monitored them for seven years. We used allometric equations to describe the vertical light gradient and forest structure and estimated the height inflection point of the vertical light gradient (HIP, the absolute height at which 50% relative light intensity is intercepted) for each stand and year. For each individual we calculated the distance to the HIP of the forest stand and year (i.e., the difference between tree height and HIP) as an indicator of vertical tree position regarding light availability, and assessed how the distance to HIP was related to individual tree performance during succession. **Results:** Individuals above the HIP (i.e., the distance to HIP>0) generally had a faster height growth rate and lower mortality rate compared to individuals below HIP, especially early in succession. Canopy height of the stand increased faster over time when individual height growth was more affetced by the distance to HIP.

In contrast, stand mortality rate was more determined by the forest age than by HIP and decreased during succession. An increase in canopy height and stand mortality rate both increased the size inequality among tree individuals. **Conclusions:** During tropical forest succession, tree individuals generally perform better under well-lit conditions. The benefit of being above the HIP for growth and mortality rate decreased over time, likely because of an increased proportion of shade-tolerant species in later successional stages that response less strongly to light. Vertical forest development was driven by the competition for access to light, whereas stand mortality rate was driven by forest development. Stand differentiation during succession is therefore determined by the light competition-driven changes in vertical stand development and the succession-driven changes in stand mortality rate.

Keywords Forest dynamics, Tree performance, Tropical forest succession, Vertical light gradient

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Soil Resistance and Recovery during Neotropical Forest Succession

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The recovery of soil conditions is often poorly considered in ecosystem recovery and restoration practices. Here, we assess soil resistance to forest conversion and land use, soil recovery during tropical forest succession, and how resistance and recovery depend on climate, soil type, and land-use history. We measured soil properties from 21 Neotropics sites using standardized sampling design and lab analyses. Within each site, samples were taken from different forest ages and two depths. Soil carbon (C) and nitrogen (N) generally decrease during land-use change, and changes in all soil properties depended on environmental conditions and land-use type. During succession, bulk density decreased likely caused by increased root growth and macrofaunal activity, and pH decreased possibly caused by cation uptake by vegetation. C and N increased during succession in abandoned croplands and fertile sites, whereas they decreased in abandoned pastures likely due to high initial amounts of C and N from grass roots and low input due to slower forest recovery. Extractable phosphorus (P) did not recover during succession, suggesting increased P limitation as forests grow older. These results indicate that site conditions determine the success of natural regeneration and can help define the best strategy for effective soil restoration.

Keywords soil, tropical forest, nitrogen, phosphorus, carbon, pH, bulk density, recovery

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Effects of Dung Beetle Activity on Early Phases of Plant Regeneration in a Tropical Rainforest

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Background: Through the processing of feces, dung beetles can have positive effects on plants. In tropical forests, dung beetles are often chosen as a focal taxon, partly due to their functional importance. However, quantitative information about the effects of their activity comes mostly from crops, grasslands, or greenhouse studies. Except for seed burial, few of their ecological functions have been quantified under natural conditions in tropical forests. We aimed to increase our understanding about the effects of dung beetle activity on tropical forest plants under natural conditions. We asked: (1) Does dung beetle activity decrease the spatial aggregation of seeds and seedlings, and does this improve seedling establishment?; (2) How does dung beetle activity redistribute the soil seed bank, and does this promote seedling establishment?; and (3) Does dung beetle activity increase nutrient content in understory seedlings, with positive effects on seedling performance? **Methods:** We carried out field experiments in which we manipulated the presence of dung and dung beetles in a Mexican rainforest. To answer the first question, we carried out two experiments with seeds of two

tree species. To answer the second question, we carried out three experiments: one using plastic beads, one with seeds of two tree species, and one with the natural soil seed bank. To answer the third question, we experimented with seedlings of six tree species. **Results:** We found that dung beetle activity (1) reduced the spatial clumping of seeds and seedlings but had no effect on the probability of seedling establishment; (2) caused the re-distribution of seed-bank seeds along the soil vertical axis (seeds were moved both upwards and downwards), and increased seedling establishment from the soil seed bank; and (3) did not have a positive effect on nutrient content or performance (growth, survival) of understory seedlings. **Conclusions:** Our study confirms that dung beetle activity lowers the aggregation of defecated seeds, but this effect does not necessarily enhance the probability of seedling establishment. Our study confirms that, besides moving seeds present in feces, dung beetles also move seeds already buried in the soil, which in turn promotes seedling establishment. Finally, contrary to results from other systems, we found no evidence that through bioturbation and nutrient incorporation into the soil, dung beetle activity has positive effects on established seedlings. Extrapolating results from other systems into tropical forests should be avoided, instead dung beetle functions in tropical forests should be quantified directly through field experiments.

Keywords Mexico, Scarabaeinae, seed burial, seedling establishment, seedling performance

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Seed Size-dependent Effects on Seedling Recruitment along Environmental Gradients in Tropical Andean Forests

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Plant regeneration is a crucial process in tropical rainforests. However, there is still little known on how the early phases of plant regeneration vary along environmental gradients. Here we set up a multi-species sowing experiment along a natural elevational and a human-induced habitat gradient to quantify variability in seedling recruitment in relation to abiotic and biotic factors. We hypothesized that abiotic and biotic factors shape seedling recruitment and that these effects would be contingent on seed size. We sew over 8000 seeds belonging to 5 tree species with differently sized seeds in the tropical mountain forest of Podocarpus National Park, southern Ecuador. Seeds were sown into 54 subplots at three elevations (1000 m, 2000 m and 3000 m a.s.l.) in natural forest and pastures. We compared seedling recruitment of small-seeded and large-seeded species over a 1-year period and harvested seedlings to measure belowground and aboveground biomass at the end of the experiment. We found profound variation in abiotic factors, such as temperature and soil moisture, across elevations and habitats, whereas variation in biotic factors, such as herbivory, was less pronounced. Overall, we found higher seedling recruitment at low elevations compared to the higher elevations. Seedling recruitment of large-seeded plants was higher than that of small-seeded plants, but only in the forest. Both belowground and aboveground and biomass were higher for large-seeded plants independent of habitat type. Our study shows that seedling recruitment in the tropical mountain forest is more efficient at low than at high elevations. Notably, seed size is a key trait to mediate seedling recruitment processes along human-induced habitat gradients. Our findings can be useful to inform reforestation projects in human-modified habitats of the tropical Andes.

Keywords plant regeneration, seedling recruitment, Ecuador

Large Overlap in Tree Demographic Spaces across a Successional Gradient in Tropical Wet and Dry Forests

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Introduction / Background / Justification: Secondary tropical forests are of increasing importance for carbon storage and sequestration as well as biodiversity conservation. Understanding successional trajectories is therefore imperative. Forest succession is driven by the demographic rates (growth, survival and recruitment) of the given set of tree species, i.e. their demographic strategies (viable combinations of demographic rates). However, demographic strategies have so far mainly been studied in old-growth forests. **Objectives / Hypotheses:** Here, we ask whether demographic spaces (i.e. the ensemble of species' demographic strategies) observed in old-growth forests are representative of earlier successional stages. Specifically, we ask whether there are shifts in demographic spaces over the course of succession and whether these shifts arise from species turnover or from changes in the species' demographic rates. We also explore whether there are systematic differences between wet and dry tropical forests regarding these questions. **Methods:** We use chronosequence data from four Neotropical forests spanning a rainfall gradient and calculate growth and survival rates in three canopy layers to account for size and light dependence as well as recruitment for all woody species in early successional (0-30 years), late successional (30-120 years) and old-growth forests. We then compare demographic spaces across successional stages for each site. **Results:** We found that demographic spaces largely overlapped across successional stages, except for a group of species with exceptionally low survival that was only found in the early successional stage in the wet sites. The lack of these low-survival species in later successional stages resulted from species turnover, since nearly all of these species had disappeared by 30 years. In general, species- and canopy-layer-specific growth and survival rates were consistent across successional stages, while recruitment rates generally decreased over succession. Overlap was larger in dry than in wet sites and there was no clear evidence for demographic strategies exclusive to the early successional stage in dry forests. **Implications / Conclusions:** Our results suggest that tree demographic strategies observed in old-growth forests miss a low-survival strategy confined to early successional stages, but otherwise reliably capture ranges of growth and survival. Accurate predictions of species-rich tropical forests' successional dynamics, however, are likely to rely on information on changes of recruitment rates across succession.

Keywords life-history strategies, demographic rates, secondary succession, tropical forest, Neotropics

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Assessment of Assisted Natural Regeneration in Anuradhapura District, Sri Lanka

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Assisted natural regeneration (ANR) is one of the best practices for forest restoration, which accelerates the natural succession processes in abandon or cleared lands. In Sri Lanka, department of forestry started the ANR programme Island wide however, success of the project is unknown. Therefore, this study was aimed to assess present status, success rate, and species suitability for ANR at Palugaswewa beat of Kekirawa forest range in Anuradhapura district, Sri Lanka. Four ANR sites, which are categorized as replanted and maintain sites, were examined. Sampling plot was laid at the dimension of 20m $\times$ 20m square plots. Sampling plots were selected at three zones based on the distance from forest boarder such as short (0-500m, 1-3 plots), middle (1000-1500m, 3-7 plots), and long (>1500m, 7-10 plots) where tree height and diameter at breast height (DBH) were measured. A total number of trees (height 5 m and DBH10 cm), saplings (height 0.6- 5 m, DBH

< 10 cm), and seedlings (height <0.6 m and DBH < 10 cm) were measured. Result showed that the study area was reforested with 32 tree species. In replanted ANR site of Thumbikulama, survival percentage (SV) was significantly higher ($P<0.0001$) for *Madhuca longifolia* (Mee) (72 %) than *Syzygium revolutum* (Damba) (31.25%), similarly, in Mahasengama site, *S. revolutum* was significantly ($P<0.030$) higher SV (78.4%) than other plants, while T*erminalia arjuna* (Kumbuk) was least (53.2%) significant ($P<0.04$). However, SV of *Azadirachta indica* (Neem), *Albizia saman* (Maara) and *M. longifolia* were not significant ($P<0.24$). From the Probit analysis, a significant ($P<0.0081$) different on survival of the species in the study sites were described that *M. longifolia* was not significant with *A. indica* (0.233) and *S. revolutum* (0.5933), while *S. revolutum* was not significant with *A. indica* (0.1720) and *T. arjuna* (0.043), similarly plant compare with *A.saman* (0.5526) and *A. indica* (0.3954) were not significant with *T. arjuna* at α-value (0.05). This study also showed that the total number of saplings was greater than trees in both study sites (Thumbikulama: 170 and 55 stems ha^{-1}; Mahsengama: 190 and 55 stems ha^{-1}) and these results revealed that both sites were fairly regenerated with plant species. More number of species were logged in maintained ANR site where as it was minimum in abandon farm land area. *Pterospermum suberifolium* and *Chloroxylon swietenia* were logged highly in respected sites. Overall, *S. revolutum* and *M. longifolia* were adaptive species for ANR activities in the study sites.

Keywords ANR, dry zone, Sri Lanka, restoration, regeneration species

Restoration Ecology: Current Status and Next Steps

Session Recording: https://youtu.be/groD4eZ68Cs

Restoration Plantations Accelerate the Recovery of Coarse Woody Debris by Almost 50 Years in Costa Rican Premontane Forests

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Carbon sequestration is an important goal of many forest restoration projects. Ten to 20% of carbon is stored in dead wood globally but the volumes of dead wood present in intact and second growth tropical forests are understudied. In this study, we aimed to evaluate (1) the recovery pattern of dead wood volumes across a chronosequence of secondary tropical forests, and (2) the efficiency of two common restoration strategies to recover dead wood volumes similar to those found in old-growth forests, all in a tropical premontane landscape in southern Costa Rica. The two restoration strategies consisted of plantations and natural regeneration. Plantations consist of plots where two endemic and two naturalized species were planted in rows, a total of 313 seedlings across 2,500m^2. Plantations are not harvested, their understory is not trimmed or weeded, and cattle are excluded through fencing. Natural regeneration consists of plots where no trees were planted, but where agriculture or cattle are excluded though fencing and vegetation is allowed to regenerate naturally. We hypothesized that (1) dead wood volumes increase with forest age, and that (2) restoration plantations recover dead wood volumes more quickly compared to naturally regenerated forests. We measured dead wood volumes in a total of 35 forest fragments and 10 restoration sites using strip transects. We found that dead wood volumes significantly increase with increasing forest age. In addition, we found that plantations (15 to 17 years old) recovered 41% of dead wood volumes found in old-growth forests >100 years old, whereas naturally regenerated forests of the same age only recovered 1.7% of dead wood volumes found in old-growth forests. These results point out restoration plantations as an efficient strategy to recover carbon pools stored in dead woody debris in tropical premontane forests. In fact, when we compare dead wood volumes in the chronosequence to those found in restoration plantations we find that plantations are on average 70 years old whereas naturally regenerated sites are 0 years old in terms of dead wood volumes.

Keywords ecological restoration, coarse woody debris, tropical forests, carbon, chronosequence

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Using Legume Trees for Soil Bioengineering in the Caribbean: Ways for Conservation and Restoration of Riparian Forest

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Soil bioengineering is an important restoration tool to control erosion along slopes and riverbanks which are increasingly threatened by human use. It can be efficient to trigger successional trajectories and to reestablish local riparian plant communities. Legumes are particularlly relevant in soil bio-engineering because of their ability to improve soil quality through nitrogen inputs and their high ecological tolerance, especially in flood-prone areas. Among the territory of the Caribbean Islands hotspot, Guadeloupe shows a remarkable biodiversity and almost 20 native legume tree species are harbored in 34 different ecosystems. In the context of global change and erosion of biodiversity, species conservation and ecosystem restoration are priorities, particularly in places under anthropogenic pressure such as riparian areas. The breadth of indigenous legume tree species richness carries the promise of finding suitable species to contribute to the development of soil bioengineering in Guadeloupe. In order to provide practical tools for the use of Caribbean legume tree species in soil bioengineering, we assessed the germination, growth, morphological traits and herbivory of 5 candidate restoration native legume species during the first stage of development. Five native legume tree species (*Inga ingoides* (Rich.) Willd., *Inga laurina* (Sw.) Willd., *Lonchocarpus heptaphyllus* (Poir.) DC., *Lonchocarpus roseus* (Mill.) DC., *Pterocarpus officinalis* Jacq.) adapted to riverine environments of different ecosystems (Swamp forest, Seasonal evergreen forest, Rainforest) were selected. Thirty seeds per species were sown in nursery. Germination rate, number of herbivory injuries, survival rate, stem length, taproot length and diameter, shoot and root biomass were measured on 3-month-old seedlings. All the species showed high germination and survival rate, but distinct performance and traits were observed. *Lonchocarpus heptaphyllus* appeared to be the most sensitive species to herbivory and also showed the lower growth rate with the less developed root system. *L. roseus*, a critical endangered species, had the lower shoot and root biomasses, and shoot root ratio. *Inga ingoides* and *Inga laurina* showed high shoot and root growth rates. *Pterocarpus officinalis* had the highest shoot and root growth rates. Despite of the differences observed between species, native legume tree species present a high potential for a use in soil bioengineering in Guadeloupe and in the Caribbean at large.

Keywords Native Caribbean species conservation; Tropical riparian forest restoration; Soil biengineering

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Selecting Species and Developing Seed-coatings for Direct-seeding to Restore Forest Ecosystem in Northern Thailand

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Direct seeding is a promising technique to restore forest ecosystems because of its potential to be applied on a large scale. However, seed predation and the harshness of the environmental conditions of restoration sites can significantly limit seedling establishment. Therefore, selecting suitable tree species and developing techniques to reduce seed loss are essential to increase seedling establishment. This study aims to determine suitable tree species for direct seeding and to test seed coating material for its ability to reduce seed loss. To determine which species are suitable for direct seeding, seeds of 23 native tree species with three replicates were sown randomly in two degraded sites. Seed removal, germination and seedling survival were monitored every week. Nine months after sowing, five species had no seed removal, whereas on average 3.7% ($\pm$ 1.73 SE) of seeds of 18 species had been removed. The correlation analysis indicated significant negative correlation between seed size and percent seed removal (p value <0.05). Eight species failed to germinate at all. Eight species had low germination (9.52% $\pm$ 1.82 SE), whilst four species had moderate germination (26.5% $\pm$ 1.72 SE), and three had high germination (65.7% $\pm$ 1.72 SE). Of the 15 germinated species, 13 species established their seedlings. The percent survival varying from 0.17% ($\pm$0.17 SE) in *G. arborea* to 13.17% ($\pm$ 0.75 SE) in *A. microsperma*. In addition, five of the 23 species were used to test three coating materials (biochar, soil mixture and polysaccharide mixture), applied 0.5 cm thick. The biochar treatment significantly decreased seed removal (0.33%, $\pm$ 0.21 SE), compared with the control (3.5%, $\pm$ 0.72 SE). However, all coating materials

significantly reduced percent germination by 11.28% on average and did not increase seedling survival. The coating technique may limit water imbibition, gas exchange, and light availability, which are essential for germination of tree species. In conclusion, *A. microsperma*, *S. pinnata* and *A. kurzii* are recommended for direct seeding because of their relatively low seed removal, high germination and seedling survival. Biochar did appear to reduce seed predation but modifications, perhaps using thinner coats to reduce germination inhibition, are needed before the technique can be recommended.

Keywords direct seeding, forest restoration, seed coating.

Restoring Timber Species in Mexico's Maya Forest through Patch Clear-cuts and Natural Regeneration

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Background: The Maya Forest of Mesoamerica is the largest contiguous tropical forest north of the Amazon, and covers 80% of the state of Quintana Roo, Mexico. There, over 150 communally-owned 'ejidos' manage 730,000 ha of forest, harvesting approximately 20 timber species. Outside their managed forests they practice slash and burn agriculture for subsistence. Maintaining populations of timber species has become a critical issue, both for sustaining the economies of forestry ejidos and for conserving the forest and its biodiversity. About 80% of commercial timber species are shade-intolerant and do not regenerate in the small gaps produced by selective timber harvesting. Silvicultural interventions must be tested and implemented to provide for their regeneration. **Objectives:** This study sought to determine which of three different methods for creating silvicultural clearings within the forest was most favorable to the natural regeneration and growth of timber species. **Methods:** In each of four different managed forests, two half-hectare experimental clearings were created using each of three different treatments: 1) slash, fell and burn (burned); 2) machine-cleared using bulldozers; or 3) clear-felled (felled). Eleven years later, trees that had regenerated on the eight replicates of each type of experimental clearing and on eight control plots in the neighboring forest were identified and measured. Analyses focused on 15 currently commercial timber species and 12 with timber potential. **Results:** The composition and timber value of stands varied among treatments: after burning and after machine-clearing, 40% to 47% of the Basal Area (BA), respectively, was made up of currently commercial timber species: 29% - 39% decorative hardwoods and 11%- 8% lesser value softwoods, respectively. On both these treatments, the valuable decorative hardwood, *Lysiloma latisiliquum*, currently the principal income source for most forestry ejidos, made up more than 25% of the BA. On felled treatments, decorative hardwoods accounted for only 6% of the BA: 22% was softwoods and 1% precious woods. On controls, currently commercial species made up 27% of the BA: 21% hardwoods, 5% softwoods and 1% precious woods. *L. latisiliquum* was rare or absent after those two treatments. The proportion of new trees that had regenerated through sprouting varied: 30% on felled treatments, 19% after burning, and 11% after machine-clearing. The fastest-growing trees on burned and machine-made clearings had grown almost 1 cm in diameter (DBH)/year. **Implications/Conclusions:** Results revealed that creating small clearings using slash and burn treatments or machine-clearing can restore diverse and valuable timber stands.

Keywords Slash and burn, Yucatan, shade tolerance, *Lysiloma latisiliquum*, sustainable forestry

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Restoring Riparian Areas in Oil Palm Systems: The Riparian Ecosystem Restoration in Tropical Agriculture (RERTA) Project

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Oil palm is a widely grown tropical crop. In comparison to forest habitats, oil palm is less structurally complex, supports fewer species, and has lower levels of ecosystem functions. Ecological restoration is a promising management strategy to re-introduce complexity into plantations, improve levels of biodiversity and functioning, and potentially benefit crop yields through increased delivery of ecosystem services. However, experiments that test the effectiveness of restoration strategies within tropical agricultural systems are rare. We introduce and present findings from the Riparian Ecosystem Restoration in Tropical Agriculture (RERTA) Project: a large-scale before-after control-impact (BACI) experiment that tests strategies for restoring riparian areas in established oil palm plantations that are in the process of being replanted. RERTA has implemented a passive restoration treatment (mature oil palms maintained), two active restoration treatments (a mix of seedlings from six native tree species planted under mature palms or after mature palms are cleared), and a no-restoration control, across riparian areas surrounding two rivers in Sumatra, Indonesia. We have collected data on biodiversity, ecosystem processes, and crop productivity within long-term monitoring plots located within riparian areas, just outside riparian areas, and deep within the oil palm landscape. We present findings on the survival and growth rates of planted seedlings, and the biodiversity of flying invertebrates and spiders, which provide important pollination and pest control services within oil palm. Our findings show that restoration of riparian areas within oil palm plantations is possible, and indeed can be done relatively quickly, with high but variable survival and growth recorded after two years. For instance, many seedlings that were planted in our active restoration treatments are now > 7 metres high, and these areas are beginning to resemble forest. Our surveys of terrestrial invertebrates also indicate that biodiversity is benefiting from this restoration. However, impacts vary between different orders (flying invertebrates) and species (spiders), and also between different microhabitats within the plantation. Importantly, our findings indicate that, in comparison to a passive approach, active approaches to restoring riparian areas deliver greater benefits to biodiversity and ecosystem processes. As our restoration treatments are still in their early stages, we expect that these ecological benefits will only increase over time. Our findings have important implications for guiding future restoration initiatives in tropical agricultural landscapes, and for informing sustainability certification criteria, such as those of the Roundtable on Sustainable Palm Oil, in oil palm ecosystems.

Keywords oil palm, riparian, restoration, replanting

Assisting Natural Regeneration as a Technique in Tropical Forest Restoration: A Review of the Literature

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Significant portions of tropical forest have been lost or degraded from development, agriculture, or pasture establishment. One common restoration approach is Assisted Natural Regeneration (ANR), which refers to the purposeful facilitation of targeted tree species originating from different forms and conditions of naturally established regeneration *in situ*. Facilitation treatments remove competition and support regeneration through methods such as weeding, burning, and fertilization. To maximize the benefits of ANR, it is critical to understand factors of success across different geographies, species, and techniques. We review the literature on ANR in tropical forest regions to assess geographical distribution of the studies, species patterns, previous land uses as well as treatments used and their measures of success. We found that the term ANR was used inconsistently throughout the literature. As a result, we propose a working definition of ANR that aligns the

term used in newer ecological literature with a refined version of the traditional silvicultural understanding of release. Species regenerated in ANR treatments were mostly long-lived pioneer species with a utilitarian purpose (e.g. timber, fuelwood, fodder, agroforestry, medicine, fruits) as compared to conservation, watershed stabilization, or ecological value. Over 51% of studies were reported from the Neotropics and 46% from tropical wet forest regions. The four most common species used in ANR studies by order were *Cordia alliodora*, *Spondias mombin*, *Simrouba amara*, and *Swietenia macrophylla*. By synthesizing different understandings of ANR, we aim to close significant gaps in the literature on when, where, and how ANR has been used and tested in tropical forest restoration and provide a conceptual framework for ANR, its implementation context, and factors promoting its success under specific local conditions. Our findings provide support for detailed identification of site conditions prior to designating ANR treatments.

Keywords Assisted Natural Regeneration, Tropics, Restoration, Release, Forest Degradation, Succession, Tropical Silviculture, Forest Recovery

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Importance of Stem Cuttings in the Dry Forest Restoration in Southwestern Madagascar

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Forest restoration is an important strategy for biodiversity conservation given the currently high rates of deforestation, forest fragmentation, and biodiversity threat. Success rates of forest restoration in the dry forest are very challenging, given the frequent drought reinforced by insect pests. From reforestation activities carried out in the Lemak'i Onilahy Territory (LOT) as well as in the Bezà Mahafaly Special Reserve (BMSR), located in the dry habitat of southwestern Madagascar, many species have shown difficulties to propagate from seeds. Faced with this issue, it is necessary to develop other possibilities using vegetative plant material. The main objective of this study is to show the importance of using stem cuttings in reforestation projects. We then hypothesized that the four endemic species of *Commiphora* studied (i.e., *C. brevicalyx*, *C. simplicifolia*, *C. aprevali*, *C. grandifolia*) gave better survival rates from stem cuttings than from wild seedlings; and stem cuttings should be taller to ensure a quick recovery. For that purpose, reforestation activities were carried out in different forest sites in LOT and BMSR in February – March 2018. The collections and the plantations of stem cuttings and wild seedlings were done on the same day as the plantation. At least 100 seedlings and at least 250 cuttings with different lengths per species were planted and monitored. Plantation follow-up were carried out after 6 months and one to two years after planting, and their survival rates recorded. Our results indicated that stem cuttings are important options for reforestation project in *Commiphora* spp. It is more effective in the two (i.e., *C. aprevali*, *C. grandifolia*) out of the four targeted species of *Commiphora*. These two species showed fast recovery and better adaptation with stem cuttings than with wild seedlings. Stem cuttings over 1.5 m in length are seen to be more vigorous ensuring quicker recovery. Additional experiments need to be conducted to identify optimal environmental conditions, and test other tree species and propagation methods to improve forest restoration in the dry forest in southwestern Madagascar.

Keywords Forest restoration, stem cuttings, wild seedlings, dry forest, southwestern Madagascar

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Restoration Opportunities in the Montane Tropics

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Secondary forests are increasingly dominate in human-modified, tropical biomes. In this body of work we look at evaluating the potential value of secondary forests through two lens, firstly, what is the biodiversity value of secondary forests? and secondly, how can land management intersect with secondary forest recovery (secondary sparing)? Focusing on a global hotspot of threatened biodiversity, the Colombian Choco-Andes, we look at land-use transformations across montane cloud forest, cattle pastures and naturally regenerating secondary forests. We evaluate bird and dung beetle communities, across functional diversity and avian phylogenetic diversity metrics, and in the context of land-sparing land-sharing management scenarios. We find critical value in these regenerating forests, in particular, sparing secondary forests promotes substantial species, functional, and phylogenetic diversity benefits for both birds and dung beetles, including species of conservation concern, compared to land-sharing models. Promoting the recovery and protection of secondary forests under the land-sparing model provides a critical mechanism for protecting tropical biodiversity, with important implications for global restoration targets.

Keywords secondary-forests, agriculture, Neotropics, montane, Scarabaeidae, avian, land-use, conservation, forest-recovery

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Indirect Restoration of Ecological Interactions: How Reintroduced Howler Monkeys Plant Large Trees via Dung Beetles

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The biased loss of large and medium frugivores alters seed dispersal and plant regeneration. Species reintroductions have been proposed as a strategy to reverse the consequences of species loss. However, the effects of reintroductions on ecological processes are seldom assessed, which hinders the comprehension of reintroductions' potential to reestablish functioning ecosystems. In this study, we investigate the effect of howler monkey (*Alouatta guariba*) reintroduction on the plant regeneration of Tijuca National Park (TNP), a defaunated Atlantic Forest fragment. Howlers are folivore-frugivore primates, whose large clumped defecations attract dung beetles, which provide secondary dispersal by burying seeds present in the howlers' feces. Thus, we expect that the fate of seeds dispersed by howlers will differ from those dispersed by other frugivores present in the Park. We followed the fate of seeds between 3 and 14mm in diameter in three steps of the seed dispersal loop, each one consisting of a different experiment. First, we estimated secondary seed dispersal and burial depth probabilities according to the frugivores' defecation pattern; then, predation probability in different burial depths and defecation patterns; and, finally, recruitment probability in different burial depths. Considering the final result of the three experiments, the howlers' reintroduction affected positively the regeneration of large seeds. The fate of 3mm seeds was little affected because they were seldom preyed upon at shallower depths anyway and could not recruit when deeply buried. On the other hand, seeds larger than 3mm reached the seedling stage more frequently when dispersed by howlers than when dispersed by other animals present in the Park. Thus, howler monkey reintroduction in defaunated areas, in addition to smaller frugivores, whose defecation patterns are less attractive for dung beetles, improves the regeneration of large seeds. We hope that this study will stimulate new howler reintroductions in defaunated areas.

Keywords *Alouatta*, dung beeltes, plant regeneration, secondary seed dispersal, seed fate

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Landscape Configuration, Local Forest Structure, and Climatic Variation Affect Biodiversity Recovery in Restored Montane Tropical Forests

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Introduction: Forest restoration is becoming a significant aspect of land-use dynamics in tropical forests. Understanding the relative influence of landscape configuration and local forest structure for biodiversity recovery through natural ingrowth in actively restored areas is critical to design appropriate restoration practices. **Objectives:** Our objective was to determine whether landscape configuration (i.e., natural forest cover and fragmentation), and plot scale tree variables affect the sapling community ingrowth in actively restored montane tropical forests. We predicted that landscapes with higher natural forest cover and less fragmentation would affect positively sapling regeneration, particularly of species dispersed by animals. Similarly, we expected that local forest conditions indicating successful forest recovery (i.e., larger plot level basal area and higher tree diversity) would have positive effects on the diversity of the sapling community, especially for trees that are zoochory dispersed. **Methods:** We collected field data for planted trees ($>$ 5 cm DBH) and naturally regenerated saplings ($<$ 5cm DBH) in 130 permanent plots established in forest restoration areas (7 to 9 years old) in Ecuador, along 2000 m of elevation gradient. We classified remote sensing images (Sentinel 2) to evaluate landscape characteristics, including natural forest cover and fragmentation 200 m buffer areas around each plot. Our plots presented a tree species richness gradient due to a variation in the number of species in the initial plantations and the distinctive survival of these planted trees. We performed the Bayesian counterpart of a least absolute shrinkage and selection operator (LASSO) regression to test if our standardized set of predictors (elevation, precipitation seasonality, percentage of native forest cover, landscape fragmentation, plot scale tree species richness and basal area) can explain variation of the sapling community (i.e., abundance, species richness, abundance and species richness of saplings dispersed by zoochory). **Results:** Our analyses indicated that sapling abundance and biodiversity recovery were dominated by local factors related to plot scale forest structure and tree species richness, possibly masking to some extent the effect of landscape on sapling regeneration. Planted tree species dispersed by animals were particularly important for the recovery of the sapling community. **Conclusions:** This study indicates that active restoration techniques can be important for natural biodiversity recovery in tropical montane forests. Local conditions determined by the restored forests are critical determinants of the rates of biodiversity recovery through natural ingrowth. Diverse tree plantations including trees dispersed by zoochory syndromes seem particularly important to enhance biodiversity recovery in restored forests.

Keywords Andes, reforestation, biodiversity, landscape configuration, Ecuador

Effects of Anthropogenic Disturbances on Fauna

Session Recording: https://youtu.be/0a1Bs_P2ZOM

The Cascading Effects of Hunting-induced Mammal Defaunation on Bird Community Composition in a Central African Rainforest

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Introduction: Mammal communities are estimated to be partially defaunated in 50% of pantropical forest area, with large-bodied species experiencing the highest declines. Because large mammals play prominent roles in structuring ecological networks, the loss of these species may initiate cascading effects on non-mammalian wildlife such as birds. Avian communities are important for the provisioning of several key ecosystem processes, but how mammal defaunation may disrupt the ecological roles that birds play remains unknown. **Objectives:** In this study we examine how different avian functional groups respond to the hunting-induced defaunation of tropical mammals. By characterizing the pattern of avian community response in this way, we aim to understand how large mammal loss may impact particular ecological processes with strong associations to specific bird guilds. **Methods:** The Dja Faunal Reserve in Cameroon is one of the largest remaining areas of protected primary rainforest in Central Africa. The reserve and adjacent buffer zone represents a strong contrast in hunting intensity and mammal abundance that occurs entirely within otherwise undisturbed habitat. This quasi-experimental setup allows for the comparison of bird communities under different treatments of mammal defaunation while controlling for potential confounding factors such as habitat turnover. We established a transect 60km in length situated perpendicularly to the reserve boundary, with 30km inside the protected area and 30km outside. This transect represents a gradient of mammal defaunation along which we annually surveyed vegetation structure, large mammal abundance, and bird community composition between 2018-2020. **Results:** We first confirmed that habitat (tree community structure) remains constant along the gradient, while mammalian defaunation differs considerably between hunted and non-hunted areas. Second, using mist netting and principal component analysis, we demonstrate that the composition of bird communities is significantly different at the two ends of the gradient. We found that ground foraging granivores and insectivores are most adversely affected by the removal of large mammals while frugivores and nectarivores that forage in the mid-storey respond most positively. **Implications/Conclusions:** This research documents the cascading consequences of anthropogenic defaunation on avian community structure. This disruption may have major implications for the maintenance of several ecological processes. Future work will focus on the effects that these avian responses may have on seed predation, forest regeneration patterns, and the transmission of avian pathogens (processes associated with granivorous and/or ground-dwelling bird species). Given the increasing prevalence of defaunation, our discovery of the effects of mammal loss on avian communities is of broad significance.

Keywords Defaunation, Hunting, Afrotropical Rainforest, Avian Communities, Ecosystem Processes

The Impact of the Extinction of Threatened Frugivorous Mammals on the Dynamics of the Atlantic Rainforest

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Tropical ecosystems cover a significant proportion of Earth's landmass and provide vital services for the existence of life. Among the many existing tropical forests, the Atlantic rainforest is one of the most threatened biomes worldwide, with less than 20% of its original cover left across small fragments. As a consequence, many native species from this biome are threatened to extinction. Frugivorous mammals account for a significant proportion of the seed dispersal in tropical forests, playing important roles in forest succession. However, close to 25% of all frugivorous mammals in the Atlantic rainforest are threatened with extinction. On the other hand, different frugivorous mammal orders are not only threatened to different extents, but also play different roles in forest dynamics through seed dispersal. However, it is not known the impact of these species extinctions on the ecosystem services they provide and the dynamics of the forests which they occupy. In order to verify the importance of frugivorous mammals with different levels of threats to the Atlantic rainforest dynamics, we have evaluated the impact of simulated species extinctions of frugivorous mammals orders on the network structure between mammals and the plants in their diet. We have found that primates, which are the most threatened mammal order in this biome, and species with decreasing population trends have had higher betweenness centrality values, while least concern species were responsible for the consumption of different plant species than threatened and near threatened species. Thus, the extinction of primates and species with decreasing populations would lead to network fragmentation into isolated modules of interactions, which can decrease the connectivity and permeability of the landscape for frugivorous mammals. Nevertheless, species extinctions together with the lack of diet redundancy between threatened and least concern species is likely to result in the loss of interactions and ecosystem services in the Atlantic rainforest. Thus, we recommend the protection of threatened frugivorous mammal species due to their important role in the conservation of unique interactions. In special, we recommend the preservation of primate species in the Atlantic rainforest and for actions to be taken in order to decrease the impact of their main threats on their populations, such as restoration of degraded areas and higher efforts for the control of illegal hunting and zoonoses outbreaks. Moreover, we need to preserve species with decreasing population trends, since they are vital for the maintenance of different ecosystem dynamics in the Atlantic rainforest.

Keywords Atlantic Forest; Ecological networks; Frugivory; Seed dispersal

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Changes in the Prevalence of Woody Plant Seed Traits as Signals of Defaunation and Downsizing of Frugivores in Afrotropical Forests

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Tropical forests provide irreplaceable ecosystem services, but their ability to do so is contingent on numerous ecosystem functions, most of which are underpinned by tree-animal interactions and are thus endangered by defaunation. Defaunation is known to hinder forest regeneration, but a long-term perspective on how defaunation affects tree reproductive functionality is needed. Using a trait-based approach, I ascertained how seed dispersal functionality varied across mature tree age cohorts, and between Ghana and Gabon (the former more heavily defaunated). There was no significant inter-country difference, but the proportion and seed-width of gut-dispersed trees were lower in younger cohorts, suggesting both increased defaunation and frugivore downsizing. Thus, seed dispersal networks have degraded, likely decreasing ecosystem resilience. Furthermore, gut-dispersed tree species had denser wood than abiotically dispersed species, suggesting that defaunated forests have a reduced carbon storage potential. In summary, fauna must be protected to ensure tropical forest functioning and ecosystem service provisioning.

Keywords defaunation; tropical forest functioning and ecosystem service provisioning

Fungi and Insects Compensate for Lost Vertebrate Seed Predation in an Experimentally Defaunated Tropical Forest

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Overhunting reduces important plant-animal interactions such as vertebrate seed dispersal and seed predation, thereby altering plant regeneration and even above-ground biomass. It remains unclear, however, if non-hunted species can compensate for lost vertebrates in defaunated ecosystems. We use a nested exclusion experiment to isolate the effects of different seed enemies in a Bornean rainforest. In four of five tree species, vertebrates kill many seeds (13–66%). Nonetheless, when large mammals are excluded, seed mortality from insects and fungi fully compensates for the lost vertebrate predation, such that defaunation has no effect on seedling establishment. The switch from seed predation by generalist ver- tebrates to specialist insects and fungi in defaunated systems may alter Janzen–Connell effects and density-dependence in plants. Previous work using simulation models to explore how lost seed dispersal will affect tree species composition and carbon storage may require reevaluation in the context of functional redundancy within complex species interactions networks.

Keywords Janzen-Connell, conspecific negative density dependence

Effect of Human Activities on Temporal Activity Patterns of Mammals on Borneo

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In this study, we investigated the effect of human activities such as tourism and illegal hunting on temporal activity patterns of animal species: main hunting target ungulates (bearded pigs, mouse deer spp., muntjac spp., sambar deer) and carnivores (common palm civets, Malay civets), using camera traps at three study sites in Sabah, Malaysian Borneo. All the study sites are located in protected areas, and non-lethal tourism activities are officially conducted. However, evidences of poaching in two of these sites are reported. We found that bearded pigs clearly showed different temporal activity patterns in one site where illegal hunting for this species was most active from those in the other two sites. They reduced diurnal activity and increased activity in twilight and night times. Meanwhile, there were no statistical differences in temporal activity patterns of the other three main target ungulate species and two civet species among the three sites. The peak of activity level of common palm civets in one study site was apparently delayed and seemed to avoid the period of nocturnal tourism activity using spot lights. Therefore, their temporal activity patterns might be affected by tourism though the difference was not significant. Our results indicate that some animal species could be affected by anthropogenic disturbances, not only hunting but also non-lethal tourism activities. Eco-tourism is one of the main components for conservation and sustainable development in an ecosystem, but we recommend regular monitoring of any changes in activities of animals inhibiting subject areas and assessing contents of the tourism.

Keywords temporal activity pattern, illegal hunting, tourism

Multi-scale Determinants of Species Diversity: The Case Study of Lizards and Small Mammals in Amazonian Insular Forest Fragments

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Hydropower development is one of the primary drivers of habitat loss and insular fragmentation in tropical forests. Despite the growing number of studies quantifying vertebrate responses to habitat insularity, most are limited to local-scale taxonomic metrics, often overlooking species identity and their functional and phylogenetic roles. We examined taxonomic, functional and phylogenetic diversity responses to habitat loss and insular fragmentation of two major taxa exhibiting relatively low dispersal ability – small mammals and lizards – within (a) and between sites (b). Small mammals and lizards were surveyed across 25 islands, ranging in size from 0.55 to 14,660 ha, and four/five adjacent continuous forest sites, respectively, in the Balbina Hydroelectric Reservoir, Central Amazonia. Taxonomic diversity was assessed using Simpson index, functional and phylogenetic a-diversity using Rao's Quadratic entropy index. These metrics were related to spatial and habitat variables. Functional composition was examined using community-weighted mean trait values, and community redundancy using species-level functional uniqueness. b-diversity was further partitioned into their richness (βrich) and replacement (βrepl) components. Based on 65,520 trap-nights and 5,447 trap-days, we recorded a total of 884 small mammals (20 species) and 1,123 lizards (17 species), respectively. All dimensions of small mammal and lizard α-diversity increased with forest area. Individual small mammal (body mass and matrix tolerance), and lizard traits (heliothermic mode and habitat type) were also predicted by forest area. For both taxa, species functional uniqueness decreased with forest area, and all dimensions of β-diversity were predominantly partitioned in βrich. Functional and phylogenetic responses of both taxa mirrored the taxonomic approach, indicating that any of these dimensions can be used to assess the co-effects of habitat loss and fragmentation. Species persistence on small islands was only possible for generalist lizards and small mammals able to traverse the aquatic matrix. Indeed, forest area acted as an environmental filter that shaped assemblages of both taxa. Our study demonstrates that all dimensions of diversity are reduced on small forest islands, while larger forest sites were essential to ensure ecosystem resilience to disturbance. To maintain ecosystem integrity, we recommend to avoid creating a myriad small island over large expanses of floodwaters in future hydropower development.

Keywords habitat loss and fragmentation, environmental filter, functional diversity, functional uniqueness

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Diversity and Diel Activity of Mammals, Many Globally Threatened, in a Community Forest in the Democratic Republic of the Congo

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Introduction / Background / Justification: Despite the vast conservation potential of the forests of the Democratic Republic of the Congo (DRC), decades of inaccessibility and insecurity have led to limited formal protection and ecological research in the region. Community-based conservation efforts in the lowland forests of the 1,300 km^2-large Nkuba Conservation Area (NCA) aim to change that by protecting a unique forest ecosystem and developing exhaustive ecological research agendas. **Objective(s)/Hypothesis(es):** The first research objectives for the NCA were to obtain an overview of the large mammals and gain a basic understanding of their ecology, specifically to address their diel activity patterns. **Methods:** We conducted camera trap (2014-2018; 136 cameras; 16,414 camera trap days) and line transect (2013-2019; >91 4-km transects) surveys to determine the species composition of the mid-to-large bodied terrestrial mammal community, after which we modeled diel activity, determined core activity times, and calculated overlap between activity times of selected species pairs. We also recorded the presence of infants and juveniles in footage and determined whether animals were recorded in (small) groups or strictly solitarily. **Results:** We identified 29 mammal species weighing $>$ 1 kg using our camera traps, whereas line transects yielded 22 species, for a total of 33 mammal species between the two methods. Seven of these species are globally threatened, including two great apes (Grauer's gorillas *Gorilla beringei graueri* and eastern chimpanzee *Pan troglodytes schweinfurthii*). Among this community were species

with short core activity periods, e.g., African brush-tailed porcupine *Atherurus africanus,* as well as cathemeral species with long activity periods, notably African golden cats *Profelis aurata* and leopards *Panthera pardus*. Fourteen species showed bimodal or trimodal core activity periods. We found different degrees of overlap between species, from near-complete separation in activity patterns (e.g., between two duiker species) to over fifty percent overlap between certain sympatric carnivores and the great apes. We recorded infants and juveniles of an apparent pre-weaning age of nine species and found that species sometimes aggregated in surprisingly large groups (e.g., four individuals of the honey badger *Mellivora capensis*). **Implications/Conclusions:** The NCA harbors mammals of a broad range of body sizes and trophic guilds, including a large number of globally threatened species. Documenting this rich mammalian fauna offers starting points for future ecological research and validates efforts to protect forests—or, at least this particular forest—outside the formally protected areas of eastern DR Congo, for example via community-based conservation efforts.

Keywords camera trap, Congo basin, diel activity patterns, great apes

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Breaking New Grounds: An Integrated Approach to Prioritize Carnivore Conservation in Shared Landscapes

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Worldwide, ecosystems are being transformed dramatically for human sustenance, with nearly 40% of global land area under croplands and pastures, and expected to increase further. The consequent impacts have amplified the pace of species extinction. Carnivores, due to their biological requirement for large habitats, are severely at risk of range contraction caused by land use change. Creation of corridors and stepping-stone habitats through restoration is an important strategy to counter the impacts of fragmentation on threatened carnivore populations. While protection of public lands has been the cornerstone of conservation strategy, private lands can play an important complementary role. India harbors 23% of the global carnivore species, threatened by a rapidly growing economy and high human densities. We adopt a social-ecological systems approach to prioritize private agricultural lands for conservation intervention in the buffer area of one of India's premier Tiger Reserves. We used systematic conservation planning tools and combined data on (1) habitat use of four wide-ranging carnivores, (2) landowner willingness to modify land-use, and (3) monetary cost of program implementation, to identify priority areas based on cost-effectiveness. Our results show that with species conservation targets of 10%, 20% and 30%, an 8-year incentive-based agroforestry program can be implemented at a cumulative cost of USD 56 million, USD 95 million, and USD 140 million, respectively. Integrating farmer willingness in spatial prioritization produced more cost-effective solutions compared to selection of areas using ecological data only. Ignoring social costs may not only prove to be expensive but can also result in conservation interventions becoming less effective, or potentially counter-productive. Partnering with and incentivizing local private landowners can help in expanding the effective size of small, isolated, and fragmented protected areas. Our integrated approach can be applied to other human-dominated landscapes to identify areas that balance the trade-off between ecological suitability, social acceptability, and economic viability.

Keywords Conservation planning, social-ecological system, Marxan, opportunity, restoration, spatial prioritization, India

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Habitat Characteristics Affect Multiple Aspects of a Ground-dwelling Vertebrate Community in Neotropical Forest Remnants

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Habitat loss and habitat modification are considered two major threats to species persistence. Habitat predictors are environmental conditions which dictate patterns in species occupancy and thereby community distribution. Understanding habitat predictors at multiple spatial scales can aid conservation measures and advance theoretical knowledge in land-use decisions. Habitat predictors of ground-dwelling Neotropical vertebrates are often poorly known. To address this knowledge gap, we documented vertebrates, using camera traps, in 19 tropical premontane wet forest remnants in and around the UNESCO World Heritage Site, Área de Conservacíon Guanacaste, Costa Rica. For our study, we chose mammals and largely ground-dwelling birds, such as currasows and tinamous, as vertebrates. We detected 32 species in 5053 trap-days spread over three seasons. We calculated 13 aspects of the vertebrate community as response variables such that they characterise trophic functions, community composition and need for conservation. We tested the ability of 12 habitat variables, measured at the scale of the camera trap point (250 m^2), forest patch (27 ha) and landscape (1250 ha) to explain variation in the response variables using linear mixed effect modelling in an AIC-based model averaging framework. We tested the following hypothesis: 1. Measures of connectivity can affect the dispersal of species and thereby, metacommunity persistence; 2. The amount of forest area, of a single forest and in surrounding landscape, may limit high trophic level species; 3. Size and density of trees may affect species through impacts on availability of herbaceous food resources and 4. Distance of forest from road may affect presence of large bodied, hunting prone species. We found habitat predictors measured at the landscape scale to be more influential than those measured at forest patch or microhabitat scales. One of the most influential landscape variables was matrix type: more encounters of higher trophic levels and species were in forests surrounded by plantation matrix rather than pasture matrix. Total forest area within 2 km was associated with more encounters of medium-sized mammals and higher trophic levels especially greater carnivore richness. Species classified under the 'threatened' categories of the IUCN red list were mainly in large continuous forest areas. By contrast, herbivore richness increased near roads and older forests with widely-spaced trees harbored higher numbers of larger mammals. This study demonstrates how understanding the effect of multi-scale habitat characteristics on different aspects of the vertebrate community, apart from solely species richness, can guide future priorities for land management.

Keywords fragmentation, remnants, Costa Rica, vertebrates, trophic functions, mammals, birds, conservation, cameratrap

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A Multidisciplinary Review on Pangolins to Help Conserve the Most Trafficked Mammals in the World

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Introduction / Background / Justification: Pangolins are a group of mammals consisting of eight species found in the predominantly tropical regions of Asia and Africa. Pangolins have become a taxon of conservation eminence as they continue to be labeled as the most heavily trafficked mammals in the world, and have recently been mislabeled as potential intermediary hosts to the COVID-19 pandemic. Conservation biology is part of a multifaceted system where solutions to conservation issues require a holistic, multidisciplinary approach integrating research, social, and economic aspects. Yet pangolins have received little attention in all three aspects, despite their conservation status. **Objective(s)/Hypothesis(es):** We undertake a multidisciplinary review encompassing research, social, and economic aspects of pangolin conservation to produce holistic research and conservation guidelines. **Methods:** Applying a systematic review approach, we extracted pangolin-related publications since 1865 from five research databases (814 publications), whereby we manually reviewed each publication for information related to research categories, species, geographic locations and authorship dynamics. We analyzed 5,296 patents using text-mining software (VOSviewer) and patent class codes (Derwent),

and compared their trends with that of biomedical research. Data on online news trends (43,176 articles from GDELT) and societal interest (Google Trends and Wikipedia Pageviews) were analyzed to identify the causes of peaks in public interest in pangolins and how they related to other flagship species. **Results:** Although we detected a significant increase in pangolin-related publications through time, we observed glaring knowledge gaps in contextually important categories including immunology, education, and implications of trade or poaching to populations. All eight species have literature knowledge gaps, however African species are less represented. Fifteen African range-states have no pangolin literature, while the number of publications with non-range-state lead authors increased from 8% to 42.9% since 2017. Pangolin media output and societal interest have remained low relative to other flagship species, however COVID-19 is shifting these dynamics. Pangolin patent production was linked to Traditional Chinese Medicine, which was seemingly driven neither by science nor by traditional pharmacopoeia. **Implications/Conclusions:** We produced research and conservation guidelines aimed to reduce major knowledge gaps and conservation issues faced by pangolins. These include increased effort in health and field-based conservation research, directing more attention towards Africa, highlighting the importance of maintaining range-author contributions, and of factors that may lead to increased public interest in pangolins. We also provided a pangolin literature database for researchers and conservationists, which can be sorted by research category, species, and location.

Keywords Pangolin Holistic conservation guidelines Literature database Public interest Patents

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Assessing the Effects of Topography on Forest Elephant Movement through a Bayesian State-space Model Framework

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African forest elephants (*Loxodonta cyclotis*) drive important ecological processes that influence the structure and composition of tropical forests. However, they are relatively understudied and are threatened by poaching and habitat loss. Understanding how various environmental variables affect elephant movement can influence long term, landscape level conservation plans. Topography is a particularly interesting, yet under-modeled, variable to consider, as it is directly associated with energy usage by long-ranging terrestrial animals such as the forest elephants and has been linked with influencing human-wildlife conflicts. To quantify how topography affects the movement of forest elephants, we examined the hourly movement of 73 GPS collared individuals in Gabon, Central Africa, between 2015 and 2019. We then utilized a Bayesian framework through Hidden Markov Models to distinguish animal movements into two distinct states – exploratory (fast and directional) and encamped (slow and meandering)– and analyzed the influence of topography on forest elephant movement in the context of other known environmental drivers: precipitation, time of day, and sex. With steeper topography, we found that the encamped state became more common, while movement speed decreased by more than 20%. This occurred for both sexes at a rate of about 1.6 m/hr/degree slope. Turning angle concentrations also decreased with steeper topography, with angle concentrations declining by nearly 50% for both sexes. Furthermore, topography had a greater effect on exploratory movement than all other metrics examined, emphasizing its relative importance in driving forest elephant movement. Taken together, these results highlight the importance of topography in forest elephant movement and the need to include this variable in future movement modeling studies. Doing so could influence future conservation efforts such as designing wildlife corridors, which depend on a quantitative analysis of how environmental variables affect movement.

Keywords forest elephant, movement, topography, momentuhmm

Anthropogenic and Natural Disturbances in Tropical Ecosystems

Session Recording: https://youtu.be/caMtHb7ZiQc

Evaluating the Impact of Human Disturbance in Tropical Rainforests through Canopy Science

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Introduction: Human degradation-induced stressors are a pressing driver of disturbances and associated changes in rainforests and inhabiting species communities. Microclimatic studies have shown that intact canopies buffer the impact of macroclimatic changes. Hence, the microclimate is more relevant in the context of several taxa, such as epiphytes and insects. These remain understudied, and microclimatic research is limited in the case of forest canopies, especially in south Asia. **Objectives:** We aimed to answer whether the canopy microclimate differs between secondary (selectively felled in the 1950s and 1960s) and old-growth forests, and whether beetle and vascular epiphyte species communities respond differently to microclimatic differences, arising from human degradation of tropical rainforests. **Methods:** We recorded the air temperature and light intensity (microclimate) within tree canopies using sensors (HOBOs), in old-growth and secondary forests in the southern Western Ghats, India. Each HOBO was placed at a randomly chosen point in the canopy of 36 *Cullenia exarillata* trees (18 each in the old-growth and secondary forest sites) for three to five days, during March and April 2021. Vascular epiphytes were sampled in the selected trees, and four baited traps were placed in each tree for the same duration as the HOBOs, to collect beetles. **Results:** Our work provides empirical evidence that even after nearly five decades of human disturbance, the canopy air temperature differed significantly across all hours. The light intensity showed a similar trend, however, not significant. We collected 171 beetles, from 65 morphospecies. The beetle abundances and richness were significantly higher in the secondary forest. We sampled several hundred epiphyte individuals across 10 species, however, the epiphyte abundances and richness although not significant, were higher in the primary forest. **Implications:** Although a pilot study and a first for Indian rainforests, this work will contribute towards conservation and global knowledge, which remains limited in various aspects of rainforest canopies. Responses of canopy biodiversity to human disturbances in the context of microclimate are yet to be understood, particularly for taxa such as beetles and epiphytes. Lastly, we hope that the knowledge from this work will encourage practitioners and authorities to further canopy ecology in the southern Western Ghats.

Keywords Canopies, Rainforest Degradation, Beetles, Microclimate, Vascular Epiphytes, Conservation

Long Term Monitoring Two Major Cervids in a Human Dominated Semi-arid Landscape of Western India

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Introduction: Ungulate population being the primary consumers in a forest ecosystem acts as a bridge in the trophic cascade between the primary producers and the secondary consumers, therefore, long term evaluation of their population size, the associated demographic parameters, and its change over time becomes very crucial. Population structure or sex ratio is another important demographic parameter that determines fecundity, growth, reproductive fitness and mortality of a population. Age and sex composition also provide information about the present status and the future of an ungulate population in a given landscape. Given the recent re-introduction of tiger in Sariska Tiger Reserve due to local extinction, long term information of the aforementioned parameters of the ungulate population would be crucial in the management of this endangered species. **Objective:** With the rationale that size, structure and social organization being the fundamental elements of any ungulate population, a five-year study (2011-15) on two major cervid species (sambar and chital) was conducted in the human dominated, semi-arid landscape of Sariska national park to monitor their population density along with their grouping pattern and sex ratio. **Methods:** Distance sampling using line transects was carried out to estimate the demographic parameters of both the cervids in the study area. **Results:** Estimated overall density of sambar and chital respectively ranged from 10.5 to 18.23/km^2 and 19.36/km^2 to 34.62/km^2. In case of sambar, 71% of encounters were observed to be in small family units or solitary whereas 70% of the chital encounters were mostly observed in small to large groups. Overall adult male: adult female: young ratio in the study area was found to be 30:100:19 and 38:100:12 in sambar and chital respectively. A biasness towards adult females and a growing trend in young to adult female ratio was observed in both species. **Implications:** The results of our study pertaining to both the species were comparable with the findings of other studies in similar landscape. Studies on food habits of tiger from our study area have showed both the species to be the major wild prey contributors in its diet, with sambar being the principal prey (58% of the total prey biomass consumed/collectible scat). The implications from our study will be critical in the recovery and management of this endangered reintroduced apex predator in Sariska, which would depend on healthy and stable wild prey populations for long-term viability and sustenance.

Keywords primary consumers, sambar, chital, distance sampling, population, tiger, principal prey

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Effects of Chronic Anthropogenic Disturbances and Environmental Factors on Regeneration Mechanisms in a Dry Tropical Caatinga Forest in Brazil

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Natural regeneration is an important ecological process for the understanding of forest recovery following natural and human disturbances. Despite this, information on how these disturbances affect regeneration, and how the regenerating community reacts to them is limited. To address this knowledge gap, we assessed the effects of chronic anthropogenic disturbances (CAD) and environmental factors on regeneration mechanisms (woody plant regenerating assemblages) in the Caatinga dry forest. The study was carried out in the Catimbau National Park in eighteen 0.1-ha plots (20 m x 50 m) covering a wide range of rainfall and disturbance intensity. We sampled adult trees in each 50 m $\times$ 20 m plot, saplings were recorded in three 5 m $\times$ 5 m subplots located in the centre of each 50 m $\times$ 20 m plot and separated by 10 m. Seedling communities were sampled in two 2 m $\times$ 1 m subplots located in the centre of each 5 $\times$ 5 m subplot. The community of saplings and seedlings in each plot was examined for sprouting by digging a 30 cm hole around each stem when was necessary We used a model selection approach (Candidate models with qAICc$<$ 2) to evaluate the isolated and combined effects of CAD, soil fertility, light (LAI) and water availability abundance, species richness, diversity and species composition of seedlings, saplings. We found very low dense and impoverished regenerating assemblages with high variability across the different regenerant types (true seedling, true sapling and sprouts). Resprouting was the most important mechanism of regeneration, mostly from the stem. The influence of chronic disturbance and

abiotic factors on regenerating assemblage abundance and species richness varied depending on the size class and source of plant regeneration (sprout or seed). Plant abundance, species richness and abundance of sprouts were explained by CAD and the combined effect of rainfall and CAD. True sapling abundance was positively affected by LAI and annual rainfall had a positive influence on a structure and species composition. Our results demonstrate the negative effect of CAD and reduced rainfall on regenerating woody plant assemblages. The effect of reduced rainfall on regeneration was more pronounced in disturbed areas. Thus, given the predicted increased aridity associated to increased human disturbance, the Caatinga dry forest may experience shifts in its regeneration patterns with unknow effects on long-term forest dynamic, biodiversity persistence and forest resilience.

Keywords Key-words: community assembly, human disturbance, rainfall, regeneration mechanisms, regenerating plant

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Does Hurricane Disturbance Create Conditions for Density-independent Population Growth? Anolis Responses to Hurricane Maria in Puerto Rico

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Background: Hurricanes are arguably the textbook example of a catastrophic stochastic event. They result in high mortality for many organisms, large-scale changes in vegetation, and shifts in ecosystem processes. Nevertheless, many populations, particularly in the Caribbean, are returning to their original dynamic stable state within a few years after disturbance. *Anolis* lizards are an example of a highly adaptable group of animals that can recover from hurricane disturbance relatively quickly. **Objective(s)/Hypothesis(es):** The objective of this study is to describe how phenotypic characteristics, habitat use, and body condition of three competing *Anolis* species recuperate after hurricane disturbance. **Methods:** We leverage data that we collected as part of a long-term study of three *Anolis* species (*A. gundlachi*, *A. evermani*, *A. stratulus*) living in El Verde field station in the Luquillo Experimental Forest in Puerto Rico. In 2017 Hurricane Maria devastated Puerto Rico as a very strong category four storm that left most of the island without power for months. We have been collecting data twice a year for two years before the hurricane and continue to do so two years after the hurricane. The data includes measurements of lizard limb size, body size, body condition, substrate type, and substrate size. We also estimated catch per unit effort (CPUE) as a proxy for lizard density. A similar effort was conducted for sampling insect abundance a year before and a year after the storm. We analyzed the data using generalized linear models in a multi-model comparison framework where every model represented a priori hypotheses of the factors that influence the response. **Results:** Limb sizes relative to their body size of all species increased after the hurricane, but recuperated to levels similar to pre-hurricane sizes a year after the storm and maintained the same pattern the following year. Substrate type changed after the hurricane but recuperated to pre-hurricane levels a year after the storm. The size of the trees used by the different lizard species increased after the storm and while on average it decreased through time, it still does not reach pre-hurricane levels. Catch per unit effort decreased for *A. gundlachi*, but increases slightly for *A. evermani* and *A. stratulus* after the hurricane. Surprisingly, the body condition of the lizards increases after the storm correlated to an increase in insect abundance. **Implications/Conclusions:** These results suggest that *Anolis* may face optimal conditions for density-independent growth after hurricane disturbance which may partially explain their quick recuperation.

Keywords Hurricane, *Anolis*, density-independence, body condition, lizards, Caribbean, Puerto Rico

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Linking Resource Availability to Forest Response and Resilience to Cyclone Disturbance

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Introduction / Background / Justification: Tropical cyclones have global environmental and socio-economic impacts, causing nearly \$26 billion y^{-1} in damage. Because these disturbances are becoming stronger and occurring at higher latitudes in recent decades, understanding the underlying mechanisms governing their influence on forest response (resistance) and resilience (pace of return to pre-disturbance values following perturbation) is necessary. **Objective(s)/Hypothesis(es):** We investigated the influence of soil resource availability on forest response and resilience to cyclones pantropically. Specifically, we conducted a pantropical meta-analysis across sites that varied widely in soil phosphorus (P) concentration. We expected forests on low-P soils to be less responsive and less resilient to cyclones than forests on high-P soils. **Methods:** We evaluated cyclone-induced and post-cyclone litterfall, an indicator of ecosystem function and essential conduit for nutrient recycling in forest ecosystems. We compiled site-level litterfall data representing 73 case studies in Australia, Guadeloupe, Hawaii, Mexico, Puerto Rico, and Taiwan. We calculated the response and resilience effect sizes of cyclone disturbance on litterfall mass flux ($g/m^2/day$), P, and nitrogen (N) concentrations (m/g) and fluxes ($mg/m^2/day$) during the first three years post-disturbance. We assessed the effect of total soil P and 16 other covariates on the degree of cyclone impact on litterfall using random forest and mixed-effects models. **Results:** Pantropically, total litterfall mass increased from 2.5 ± 0.3 to 22.5 ± 3 $g/m^2/day$ due to cyclones, with individual responses varying from a minor change in Taiwan after Haima to an increase by 2 times the annual input in Bisley, Puerto Rico post-Irma. In Puerto Rico, 75% of the individual responses were higher than the pantropical mean. Relative to pre-cyclone means, leaf fall P concentration increased by $58.6 \pm 2.3\%$ and N concentration by $21.6 \pm 1.2\%$ after cyclones. Total soil P and wind speed moderated litterfall responses to cyclones. In terms of resilience, 32.6% of the case studies compiled in our database contained pre- and post-cyclone observations that allowed the calculation of short-term post-cyclone trajectories. Total litterfall mass flux reached pre-disturbance levels within one year of the disturbance. A significant interaction of soil P with time since the cyclone and gale wind duration best explained ($R^2 = 0.4$) the variability in the litterfall mass flux resilience. **Implications/Conclusions:** Our findings corroborate previous studies in Australia and Hawaii, but now at a pantropical scale. These results suggest that forest response in the face of intensifying cyclone disturbance will be determined, in part, by soil resource availability.

Keywords Biogeochemistry, climate change, ecosystem function, hurricane, nutrient economics, soil fertility.

Wood Anatomical Responses to a Major Hurricane

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Introduction: Major disturbances dramatically alter local conditions and patterns of resource availability. The ability for species to capitalize on high resource conditions following disturbance depends on their life-history traits that are linked to resource acquisition and use. However, the extent to which phenotypic plasticity facilitates the ability of individuals to exploit post-disturbance resource pulses is unclear. In 2017, two major hurricanes struck the island of Puerto Rico causing nearly complete defoliation, high tree mortality, and extensive damage to the forest canopy. As a result, surviving trees were exposed to a pulse of nutrient inputs, dramatically higher light availability, and likely reduced competition. In fact, individual trees from a range of species exhibited elevated post-hurricane growth rates. We asked whether shifts in wood anatomy were coupled with these elevated growth rates. **Objectives:** We examined anatomical characteristics of wood produced before

and after a major hurricane to address the following questions: 1. To what degree is wood formation modified in response to the resource pulse associated hurricane disturbance? 2. Does wood produced during the resource pulse have hydraulic properties that facilitate rapid growth? **Methods:** We collected wood samples with an increment borer from 70 trees (7 individuals of 10 species) that had exhibited elevated post-hurricane growth rates. We prepared cross-sections and measured a suite of anatomical traits including vessel area, vessel grouping indices, and theoretical hydraulic conductivity. Using data on diameter growth, we compared anatomy of wood formed before and after the hurricane. **Results:** Species exhibited a high degree of variation in wood anatomical traits that was largely related to their general life-history strategies. Interspecific variation accounted for 75% of the total anatomical variation across our samples while intraspecific variation and within-individual variation accounted for 20% and 5%, respectively. Across species, post-hurricane growth rates were correlated with some anatomical traits but within-species relationships were generally weak or non-existent. Additionally, we found only limited evidence for shifts in mean anatomical traits before and after the hurricane. Our results suggest the potential of transient shifts in anatomical traits. **Conclusions:** Disturbance-driven shifts in wood anatomical traits can be associated with altered growth rates and resource exploitation. Although we have so far found only limited evidence for such shifts, we did find significant amounts of variation within individuals that indicates the potential for transient shifts in anatomical traits. Moreover, even relatively minor shifts in anatomical traits related to tree hydraulic architecture can influence resistance and resilience of trees to future disturbances.

Keywords forest, wood anatomy, Puerto Rico, hurricane, growth, dynamics, disturbance

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Post-fire Recovery of Forest Structure, Species Composition, and Aboveground Biomass in a Moist Forest of the Southwestern Amazonia

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Forest fires are a recurring environmental problem in the Amazonian forests. The consequences of forest fires are multiple, among those the loss of forest cover, and biodiversity, and the emission of greenhouse gases with the concomitant increase of global warming. This is worrying in the southwestern Amazonia at the frontier among Madre de Dios (Peru), Acre (Brazil), and Pando (Bolivia), a region harboring Brazil nuts (*Bertholletia excelsa*), among other species pivotal for livelihood, and forest conservation. We evaluated changes in forest structure, species composition, and biomass recovery nine years after a forest fire. For this purpose, in 2011 plots of 0.75-ha were installed in burnt, and preserved forests in sites of Brazil nuts gatherers in Pando. The impact of fire on the species was evaluated, and the diameter at breast height above 10 cm of living trees was measured. The basal area of living trees in the preserved forest was 20.66 m^2/ha, and in burnt forest 15.10 m^2/ha, while the biomass was 234.2 t/ha and 164.28 t/ha, respectively. In 2020 both basal area and biomass in the preserved forest increased. In the burnt forest, the recovery was 76% of the basal area, and 88% of the aboveground biomass of that of observed in the preserved forest. Pioneer species contributed more to abundance and basal area in the burnt forest than in the preserved forest. As for *B. excelsa*, after nine years, abundance decreased in the postfire plots. Most likely this species is vulnerable to fire environmental stressors, threatening the local economy highly dependent on non-timber forest products. Monitoring the rate of natural recovery of Amazonian forests is important to determine the vulnerability of species to fire and to inform early 6101 warning systems to avoid further degradation.

Keywords Postfire, recovery, basal area, aboveground biomass, *Bertholletia excelsa*, southwestern Amazonia

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Post-fire Aboveground and Soil Carbon Succession in Lowland Atlantic Forest

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Forest fire is one of the major sources of greenhouse gas emissions and can affect biodiversity, biogeochemical cycles, soil properties, and secondary succession. Fire events have been frequent in the Brazilian Atlantic forest, threatening its structure, functions and services. Understanding the role of fire and the successional trends of forest carbon pool is critical to design efficient mitigation strategies. Here we investigated the effects of fire and succession on aboveground C (AGC) and soil organic C (SOC) stocks and evaluate whether the relative distribution of C between AGC and SOC pools vary with succession. We hypothesized that (i) fire affect negatively AGC and SOC, (ii) AGC and SOC increase and (iii) their relative distribution changes during succession. We established ten 10x10m plots (0.1 ha) in 14 lowland Atlantic forests: eight secondary forests (SGF) at different successional stages (17 to 28 yr since fire disturbance) and six old-growth forests (OGF), located in southern Bahia State and northern Espírito Santo State. Stand basal area was used to indicate succession. We tested the effects of fire on carbon stock by comparing SOC and AGC (not normally distributed) between forest types using a one-way t-test and Mann-Whitney-Wilcoxon test, respectively. The relationship between SOC and AGC with the basal area was tested using GAM models and GLM with log-transformed AGC, respectively. To verify successional changes in the relative contribution of SOC and AGC to total C stock we performed beta-regression analysis. We selected the best-supported models with the lowest AICc and ΔAICc < 5. The AGC of OGF was on average more than four times greater than that of SGF, while the average SOC did not differ between forest types. We found that fire affected negatively AGC and caused no changes in SOC and that AGC increased while SOC did not change with the basal area. Our results were similar to those reported in other tropical forest studies. Interestingly, soil contributed more to carbon storage in younger forests (< 7 m^2/ha) shifting to a greater and growing contribution of the aboveground pool during stand development. Our findings show that fire did not affect soil C pool, old-growth forests store large amounts of carbon and secondary forests recover AGC over time, highlighting their key roles in the global C balance. We conclude that promoting the conservation of these forests, the regrowth of secondary forests and the conservation of soils are essential to mitigate carbon emissions.

Keywords Brazil, carbon, fire disturbance, soil, trees, tropical forest, regeneration

Conservation Genetics and Genomics in the Face of Global Change

Session Recording: https://youtu.be/hEQ0XOLjP4g

Patterns and Drivers of Phylogenetic Diversity and Endemism of Woody Plants in the Western Ghats, India

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One of the oldest known patterns of biodiversity is that diversity decreases from the tropics to the temperate. Similar trends are reported for beta diversity as well, with higher turnover at lower latitudes and higher nestedness at higher latitudes. These trends have been attributed to climatic stability, area, and higher ecological opportunity. We explored if similar trends are observed at relatively smaller scales in the Western Ghats (WG, 8°N – 21°N) mountain chain in peninsular India. WG is a biodiversity hotspot due to high levels of diversity and endemicity. Based on phytogeography, the WG is classified into three biogeographic regions - northern, central and southern WG (NWG, CWG, SWG). The SWG, is likely to have been a refugia for several taxa during the Cenozoic. Additionally, there is a decreasing gradient in seasonality in the current climate from SWG to NWG. Previous studies have shown that the high taxonomic and phylogenetic diversity in the SWG is a reflection of this gradient in historic and current climate, and topographic complexity. However, studies that explicitly examine the nestedness and turnover component of phylogenetic beta diversity (phylobeta) of woody plants are lacking. Since more than 60% of the woody plants in the WG are endemic, patterns of endemism (yet to be studied comprehensively) are likely to drive the phylobeta pattern. Here, we aim to examine the relative influence of the past and current climate on driving the phylogenetic diversity of woody plants in the WG. We plan to explore this at the tips and the basal nodes of the phylogenetic tree with respect to environmental and spatial predictors. We expect higher nestedness in the SWG and higher turnover of the phylobeta in the NWG, primarily due to climatic stability and topographic heterogeneity. Additionally, we explore if historic climatic stability and subdued climate contributed to higher endemism in the SWG, for older and younger lineages. The NWG was affected during the Cretaceous volcanic activity ($\sim$ 65 million years ago) and is unlikely to have paleo-endemics, as the assembly is likely dominated by re-colonization. By examining these drivers for a single vegetation type of tropical evergreen forest, which are longitudinally restricted, we avoid other confounding factors such as including other forest types. The results of this study will help discern whether the patterns seen across large latitudinal ranges resemble similar patterns at lower latitudes and for a smaller range as well, although driven by different biogeographic processes.

Keywords endemism, nestedness, peninsular India, phylobeta diversity, turnover

Conservation Genomics of Wallacea's Endemic Ungulates

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The Wallacea region in Indonesia is an archipelago that hosts exceptional endemic vertebrate diversity, including iconic species such as anoa (*Bubalus* spp.; "dwarf-buffaloes") and babirusa (*Babyrousa* spp.; "deer pig"). As the local government plans to accelerate economic development in the area, these species have been threatened by habitat loss and further increase of hunting pressure. To assist conservation efforts of anoa and babirusa, we generated whole genome sequences of anoa and babirusa to assess how the anthropogenic disturbances in the Wallacea affect their long term survival. More specifically, we assess the extent of recent inbreeding and abundance of deleterious mutations as proxies of past population changes. Our results suggests that anoa underwent more recent population decline, potentially because of stronger hunting pressure, and did not have enough time for purging deleterious mutations within its homozygous regions. By comparing genetic make-up of individuals sampled by naturalists throughout the 19th-20th centuries and modern populations sampled in in the 2000s, we can evaluate whether anthropogenic disturbances affect the evolutionary potential of small populations of endemic island mammals and assist their long-term population-level management.

Keywords inbreeding, small population management, evolutionary history, population genetics

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Assessment of Genetic Variation and Genetic Structure in *Shorea albida* (Dipterocarpaceae) in Brunei Darussalam Using Microsatellite Markers

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Background: Peat swamp forest is one of the major forest types of tropical Southeast Asia. This forest type develops on peat formed by the accumulation of poorly decomposed organic matter, and hosts endemic species. However, peat swamp forests have been affected by deforestation, leading to emission of carbon and loss of biodiversity and endemic species. Information on constituent tree species is crucial for the conservation and recovery of peat swamp forests, but are still lacking. **Objective:** *Shorea albida* (Dipterocarpaceae) forms monodominant stands in peat swamp forests in north Borneo. Although this species is threatened by logging and deforestation, *S. albida* peat swamp forests remain abundant in Brunei Darussalam. Populations of *S. albida* in Brunei are divided by other forest types, and the genetic differentiation among populations has not been described. Here, we examine the genetic variation in natural populations of *S. albida* in Brunei, with the aim of supporting future projects on peat swamp forest conservation. **Methods:** To evaluate genetic diversity and the degree of genetic differentiation among populations, we collected cambium or leaf samples from 11 locations in Brunei and analyzed each sample for variation in simple sequence repeats (SSR) at 18 genetic loci. **Results:** We found no difference in genetic diversity among populations, but one population showed a higher inbreeding coefficient than other populations. Significant genetic differentiation was observed among some populations. Furthermore, two genetic clusters were inferred, and its composition for two populations were different from others. However, no correlation was detected between genetic distance and geographic distance among populations. **Implications:** These results may suggest ongoing genetic divergence among populations and inbreeding in each distributed population of *S. albida* in Brunei Darussalam.

Keywords Genetics structure, *Shorea albida* (Dipterocarpaceae), peat swamp forest, microsatellite

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Molecular Identification of Endophytic Fungi Associated with *Vitellaria paradoxa*

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Vitellaria paradoxa is an important plant growing in the University of Ilorin campus and widely valued for its great economic importance in the production of Shea butter and its numerous uses domestically and medicinally. However, despite its great economic importance, little information is available regarding the endophytic fungi associated with the plant and how they may be influencing the physiological mechanisms of the plant. This study was carried out to identify the dominant endophytic fungi associated with the green leaves of *Vitellaria paradoxa* in the said location. Green leaves of *V. paradoxa* were collected and processed for isolation of the endophytic fungi using Potato Dextrose Agar(PDA) and the dominant fungus was identified through molecular techniques using the ITS region and TEF-1 gene sequences. The endophytic fungus present was identified as *Lasiodiplodia theobromae*. The findings from this study provides information on the dominant fungus present in the leaves of *V. paradoxa* and on its potentials as a source of secondary metabolite production which could improve the plant's resistance and viability and in turn serve as a major economic boost. This study constitutes to the authors' knowledge, the first report of *L. theobromae* as endophyte in *V. paradoxa* leaves in Nigeria.

Keywords Endophytic fungi, *Lasiodiplodia*, *Vitellaria*, ITS, Potato Dextrose

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Contribution of DNA Typing to the Illegal Wildlife Trade Survey in Cameroon

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The bushmeat trade represents a serious threat to the survival of terrestrial vertebrates –mostly mammals– in the tropics. Despite the fact that hunting has been forbidden in Cameroon (West Africa) since 1994, the bushmeat trade remains an open, widespread activity. Assessing the volumes of trade at market places provides a commonly used measure of its intensity and impact on biodiversity. However, most of the carcasses sold on bushmeat markets are already processed (smoked or butchered), posing serious challenges to the accurate identification of hunted species. Our first objective was to describe the spectrum of species sold on the bushmeat markets of southern Cameroon, using a DNA-typing approach based of four mitochondrial genes (cyt b, COX1, 12S and 16S) and relying on a queriable, expert online database (DNAbushmeat). Our second objective was to evaluate the factors related to the erroneous visual identification of bushmeat carcasses on the markets, and determine which mammalian taxa were most error-prone. We DNA-typed 318 bushmeat items representing five mammalian orders and 43 morphological species hypotheses from 21 Cameroonian urban and rural bushmeat markets. Final taxonomic identification was based on the DNAbushmeat decision pipeline (integrating both genetic distance- and phylogeny-based criteria). We performed binary logistic regression function (GLM) to evaluate the cumulative effect of selected variables (taxonomy, gender, and preservation mode) on the failure to reach correct species level identification using morphological criteria. Our multilocus approach allowed to (i) identify a total number of 35 mammalian species and two 'reptiles' sold on the bushmeat markets, and ii) successfully assign c. 90% of the samples to the species level. A total of 43% of the samples were re-identified or had their taxonomic identification improved through DNA-typing. High levels of genetic polymorphism across genes and taxa, together with excellent resolution observed among species-level clusters (neighbour-joining and Bayesian trees, barcoding gap) support the usefulness of DNA-typing for accurate bushmeat trade surveys. Because incorrect morphological identification was significantly predominant in smoked samples ($P < 0.01$) and Primates ($P < 0.001$), our approach can be considered as a well-needed tracer of the bushmeat trade. Conservation implication: Our approach allowed the accurate molecular identification of bushmeat species in Cameroon where visual identification proved challenging, notably among primates, duikers and cryptic rodents. We provide a useful tool to trace the Cameroonian bushmeat market and fill the existing gap in molecular databases of Cameroonian mammals.

Keywords DNA typing, bushmeat trade, West Africa, conservation genetics, mammalian biodiversity

Current and Future Aspects of Conservation Genetics of the Endangered Malayan Tapir

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The Malayan tapir (*Tapirus indicus* Desmarest) is an endangered species dwelling in the tropical forests of Southeast Asia. Faced with anthropogenic threats of habitat loss and deforestation, road-kill and non-target trapping, its population size as estimated by the International Union for Conservation of Nature (IUCN) is not more than 2,500 mature individuals worldwide. With a foreseeable further decline in the species' wild populations due to anthropogenic disturbances into the future, conservation management strategies such as captive breeding programs are important maneuvers to ensure the continuity of the species' existence and are often tailored to maximize genetic diversity and minimize inbreeding. However, current practices in many captive breeding facilities or zoos rely mainly on the studbook information for population management due to a lack of genetic tools and data. In this study, we have conducted genetic studies using seven cross-species microsatellite markers and mitochondrial DNA (mtDNA) control region in Malayan tapir individuals from Japanese zoos ($n = 20$) and Peninsular Malaysia ($n = 67$; 57 wild and 10 captive individuals); mtDNA control region sequences were compared to published data of Thailand captive individuals ($n = 37$). With discriminant analysis of principal components (DAPC) based on seven microsatellite markers, we did not find distinctly isolated groups among the samples by population, but AMOVA test on Fst (0.113) supported population differentiation between the Japanese zoo populations and Malaysian populations ($p < 0.05$). From a partial sequence (507bp) of mtDNA control region, we have identified 11 novel haplotypes (among which three unique haplotypes were detected in Japanese samples) and two distinct haplogroups or clades that have diverged around 1.46 Mya. Individuals in Japanese zoos consisted of maternal lineages originated from Thailand and Malaysia, and according to the studbook, from Sumatra of Indonesia. Current and prospective projects include development of 38 novel microsatellite markers from a whole-genome assembly deposited in GenBank and development of single nucleotide polymorphism markers through whole-genome re-sequencing of a few individuals selected from Japanese zoos. In conclusion, the outcome of this research will benefit the conservation management of the Malayan tapir, allowing population managers to incorporate molecular genetic data in future management plan. Furthermore, Japanese captive population is genetically diverse and is therefore a valuable genetic resource for future management. In future, we hope to collect and analyze more samples from Southeast Asia, as well as individuals managed elsewhere for a comprehensive genetic diversity assessment of the Malayan tapir individuals worldwide.

Keywords Tapirus indicus, microsatellite, mtDNA control region, conservation, genetics

Soils and Biogeochemical Cycles in Tropical Ecosystems

Session Recording: https://youtu.be/tTVek6k3nhY

The Effects of Above-ground Forest Degradation on Soil Physicochemical Properties and Microbial Activities in Logged-over Tropical Rain Forests, Borneo

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Logging is well known to cause degradation in above-vegetation, but may also affect soil biogeochemical processes and soil microbial activities. However, how forest degradation affects below-ground systems has not been well studied. The contemporary landscapes of Borneo consist of variously degraded tropical rain forests due to logging since the mid-1970s, ranging from highly degraded to moderately degraded to pristine forests, which are juxtaposed to each other. These forests are considered to represent a trajectory of forest degradation. Our study aimed at exploring the effects of above-ground forest degradation on soil physicochemical properties and microbial activities in a trajectory of degradation and understanding the relationship among microbial activities, microbial communities, and environmental factors. A total of 35 forest sites with varying degrees of degradation were sampled for vegetation and soils. The 35 forests were sorted along the axis-1 of nMDS when applied to tree genus composition, and their nMDS axis-1 values represented the magnitude of degradation. We considered axis-1 as a degradation trajectory. Soil pH, organic carbon (SOC), and total nitrogen (TN) in topsoils (10-cm depth) were analyzed. In addition, microbial biomass carbon (SMBC) and nitrogen (SMBN) were determined by chloroform fumigation. The activities of acid phosphatase (ACP) were determined with pNPP as substrate. Those of leucine aminopeptidase (LAP), β-glucosidase (BG), and N-acetyl-glucosaminidase (NAG) were detected by a high throughput fluorescent measurement. Microbial communities were determined each for bacteria and fungi by 16S amplicon sequencing. The results showed that SMBC and SMBN decreased with the aggravation of degradation in a trajectory and the activities of the four extracellular enzymes were also decreased. Both bacterial and fungal communities also shifted along a degradation trajectory. The result of the stepwise model showed that different soil extracellular enzymes were affected by different environmental factors and microbes. ACP was influenced positively by SOC and negatively by Acidobacteria abundance, BG was influenced positively by SMBC and negatively by Ascomycota, NAG was influenced positively by SMBC and Ascomycota, while negatively by Acidobacteria, LAP was influenced positively by SMBC and Firmicutes, while negatively by pH and other unknown bacteria. We suggest that soil physicochemical properties and soil microbial biomass and communities are affected by forest degradation, which in turn influences the activities of soil extracellular enzymes. Thus, the effects of above-ground forest degradation are transmitted to soil biogeochemical functions via the changes of soil physicochemical properties and microbial communities.

Keywords Forest degradation, Soil physicochemical properties, Soil microbial activities

Soil Respiration in Monsoon Tropical Forests Is Influenced by Altitude and Land Use

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Tropical forests play an important role in the global carbon cycle contributing *ca.* 1/3 to the net terrestrial ecosystem production. In Vietnam, most forests are replaced by agricultural lands and plantations. Natural monsoon semi-deciduous forests are located mainly in the national parks (NP). However, even there, human impact is not completely eliminated. We compare soil respiration in natural tropical forests along the altitudinal gradient under various levels of anthropogenic impact. The research was carried out in the following national parks of southern Vietnam: (1) Nam Kat Tien NP (alt. 140 m, no anthropogenic impact); (2) NP Yok Don (alt. 230 m; anthropogenic impact includes heavy grazing and repeated prescribed burning of dry litter), and (3) NP Bu Gia Map (alt. 430 m, recreation). In each NP, 2 sample plots in the forests dominated by *Dipterocarpus* sp. or *Lagerstroemia* sp. were established. Total soil respiration (TSR) was measured during 3 years at the end of the dry season (FebruaryMarch) and at the end of the wet season (NovemberDecember). During the dry season, the lowest soil respiration rate (1.562.11 g $C/m^2/day$) was observed on both sample plots in the Yok Don NP characterized by the lowest soil moisture (1.3-2.0 vol. %) caused by heavy grazing and the absence of litter. The sufficiently moist (20.625.8 vol. %) soils in the Bu Gia Map NP demonstrated the highest respiration rate (4.376.82 g $C/m^2/day$). The dominating tree species (*Dipterocarpus* sp. vs. *Lagerstroemia* sp.) did not influence the soil respiration rate. The TSR values in the Nam Kat Tien NP comprised 1.702.57 g $C/m^2/day$. In comparison with the dry period, the soil respiration rate during the wet season increased by 2 times in the Nam Kat Tien NP (both plots), and by 3 times in the Dipterocarpaceae forests in the Yok Don NP. The soil respiration rates during wet and dry seasons did not differ significantly in the Bu Gia Map NP (both plots) and *Lagerstroemia* sp. plot in the Yok Don NP. Thus, soil moisture was a key factor in explaining the difference between TSR during the dry and wet seasons in the in undisturbed forests. These pattern was not observed in the forests under strong anthropogenic impact. We did not observe an effect of altitude on the TSR values.

Keywords soil CO_2 emission, moisture effect, anthropogenic impact, natural tropical forests

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Effects of Substrate Quality on Tank-bromeliad Habitats and Their Freshwater Organisms

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In the Neotropics, a substantial fraction of the freshwater available is impounded within the rosettes of tank bromeliads. The rosettes collect rainwater and leaf litter and provide a habitat for aquatic organisms. The morphological properties of the tank-bromeliad habitat, such as water volume and rosette diameter, were found to drive the diversity, biomass, and density of its freshwater organisms. Morphological plasticity is frequent in bromeliads and has always been related to light gradient. Yet, the quality of the substrate on which bromeliads grow has never been taken into consideration because the roots are usually believed to have a mechanical role in plant anchorage and not in resource acquisition. However, recent investigations showed that the roots of some bromeliad species also play a role in resource uptake. This study aimed at evaluating the effects of substrate quality on the bromeliad morphological properties, performance, and freshwater organism's density. We hypothesized that the quality of the substrate during seedling and juvenile stages influence tank bromeliad growth, performance, and subsequently, their morphological properties and hosted organisms. The tank bromeliad Aechmea aquilega was grown in a greenhouse in French Guiana from seeds of a single mother

plant in three different substrates: sand-rich, organic-rich, and an intermediate sand/organic substrate. After 15 months, plant and leaf traits such as rosette diameter, number of leaves, leaf length, photosynthetic capacity, leaf chemistry were measured. Water volume, pH, and aquatic microbial density was also considered. We found that a shift from sand-rich to organic-rich substrate had a significant and strong effect on the morphological properties of the rosette, but only a weak effect on the overall bromeliad performance. Bromeliads growing in sand-rich substrate were smaller than plants growing in organic-rich substrate. Sand-rich substrate created severe dwarfisms that had strong effects on the morphological properties of the rosette, so that water volume and the density of aquatic microorganisms were smaller while water pH higher. Our results revealed that substrate quality during tank bromeliad establishment has strong implications on the morphological properties of the rosette and cascading effects on water volume, pH, and freshwater organism's density. Finally, aquatic organisms were mediated by cross- kingdom interactions that could be an important force for the aquatic community structuring and overall tank functioning.

Keywords aquatic organisms, cross-kingdom interactions, substrate quality, tank-bromeliad, morphological properties

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Soil Respiration Responds to Temperature in Andean Forest: Insights for Assessing Environmental Change Consequences

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Tropical forests, while only occupying 12% to 15% of the Earth's surface, store 40% of global terrestrial carbon stocks, of which 32% is in soils. Yet, recent studies in lowland humid forests have suggested that, in response to changing environmental conditions, in future decades tropical forests can switch their function from carbon sinks to carbon sources, with profound implications for the global carbon cycle. However, Andean tropical forests are also important determinants of regional-to-global biogeochemical functioning, and their sensitivity to future warming has been less studied than in lowland forests. In this study, we explore intra and interspecific thermal sensitivity of soil respiration and its components (autotrophic and heterotrophic) in 14 dominant tree species in the tropical Andes, through an experimental thermosecuence in the Colombian Andes that uses elevation as a proxy for warming. In this thermosequence, a common garden experiment was set up in three sites that represent a temperature gradient: the higher elevation site (2452 masl) corresponds to the base condition; the mid-elevation site (1326 masl) represents a warming of 5°C; and the lower site (575 masl) and it represents a warming of 9°C. We used Q_{10} values (the factor by which respiration increases for every 10-degree rise in temperature) to determine the temperature sensitivity of soil and root respiration. Our results indicate consistently higher root respiration with increased temperature, but not all species respond equally. The species with the highest sensitivity is *Quercus humboldtii* (Q_{10}= 3.92) and the least is *Tibouchina lepidota* (Q_{10}= 0.03). On the other hand for soil respiration, for a warming of 5°C and 9°C there is a temperature coefficient of Q_{10}= 2 and Q10= 3, respectively, indicating that that soil respiration can increase faster at higher temperatures. Notably, our results show that dominant species can have a differential response to environmental variations produced by climate change, highlighting the potential for differential effects of increased temperature in the composition and function of these strategic ecosystems. Furthermore, the Q_{10} results highlight the non-linearity of the effect of temperature on soil respiration, indicating that the potential for switching to carbon sources may be more intense than projected. Collectively, our results indicate that the management of tropical Andean forests imposes multiple challenges due to the high climatic sensitivity of biogeochemical processes. Such findings can help predict the future function of these ecosystems in the carbon cycle.

Keywords Andean tropical forest, soil respiration, climate change

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Canopy Soil Respiration in Response to Nutrient and Glucose Additions: Implications for Accelerated Carbon Losses under Climate Change

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Canopy soils develop in wet forest canopies through the accumulation of decomposed organic matter on tree branches. These soils support diverse communities of epiphytic plants and play a critical role in forest nutrient and water cycling. Because canopy soils are largely composed of organic matter, canopy soil decomposition may be sensitive to subtle changes in the biotic and abiotic environment. Tropical montane regions, where canopy soils are most abundant, are experiencing rising temperatures and increased precipitation variability. These changes may influence canopy soil carbon losses by directly altering decomposition or by indirectly influencing soil nutrient and carbon availability through shifts in epiphyte community composition. The response of canopy soil carbon losses to these changes has not yet been documented. Utilizing static chambers and CO_2 sensors to quantify canopy soil carbon dioxide (CO_2) respiration in situ, we examined the response of canopy soil carbon losses to natural temperature and moisture variability as well as in response to nutrient and 13C-glucose additions. To capture a range of temperature and moisture conditions and determine whether canopy soil from different sites responds differently to changes in the biotic and abiotic environment, the study was conducted in two Costa Rican forests: a tropical lowland rainforest (TLR) and a tropical montane cloud forest (TMCF). Canopy soil CO_2 respiration was overall lower in the TMCF. The effect of soil moisture on CO_2 respiration depended on site ($p<0.001$), with a positive relationship at the TLR and a negative relationship at the TMCF. CO_2 respiration did not respond to nitrogen or phosphorus addition. Glucose addition elicited contrasting responses between the sites: at the TLR, glucose addition initially suppressed CO_2 respiration but later stimulated CO_2 respiration 24 hours after addition ($p=0.06$). On the contrary, glucose addition at the TMCF site resulted in an immediate spike in CO_2 respiration followed by a return to baseline after 24 hours ($p=0.09$). Direct effects of changing temperature and precipitation on canopy soil respiration may depend on forest type. Indirect effects, such as changes to the epiphyte community, may lead to changes in the availability of nutrients and labile C in canopy soil. While it appears that changes in nutrient availability does not influence canopy soil carbon losses, these results indicate that increases in root exudation (proxied by the glucose addition) may indeed stimulate additional canopy soil carbon losses, with prolonged effects in lowland forests.

Keywords canopy soil, soil respiration, climate change, soil carbon

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Fertilization and Liming Reduce and Displace Collembolan Isotopic Niche: A Potential Indicator of Nutrient Input into Central Brazilian Savannas

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The Central Brazilian savanna (locally known as Cerrado) is an agricultural frontier. Together with the plowing, fertilizing, and liming legacy that impairs native savannas restoration, these ecosystems are also exposed to the expected nutrient deposition increase in the coming decades. Long-term fertilization and liming experiments in a woodland savanna have shown that nitrogen (N) plus phosphorous (P) addition alters plant diversity, structure, and stoichiometry. At the same time, liming affects herbaceous plant structure and microbial diversity. Such changes can affect both the quantity and quality of soil resources, but how it affects the trophic interactions in the soil food web is unknown. Here, we used descriptive metrics based on stable isotopes to evaluate the legacy effects of fertilization (with N, P, and N plus P additions) and liming on the isotopic niche structure of savanna epigeic collembolans. We found that fertilization and liming reduce and displace collembolans isotopic niche using litter-normalized $\delta^{13}C$ ($\Delta^{13}C$) and $\delta^{15}N$ ($\Delta^{15}N$) values of common collembolans between untreated (control) and treated plots. Collembolans accessed a lower diversity of basal resources and become more similar in their trophic preferences in the plots with N and P added alone, resulting in a shrinkage of the assemblage isotopic niche. This outcome was driven mainly by Paronellidae and Poduromorpha species. In N plus P and liming treatments, the collembolan isotopic niche has displaced to higher ^{13}C values. This

last outcome was driven mainly by Poduromorpha and Entomobryidae species, which appear to have expanded their range of baseline resources accessed. Our study suggests that increased deposition of N and P in native savannas or the liming legacy in restored savannas may impact soil trophic chains. Although we need more studies to investigate the mechanisms and functional consequences behind these effects, our outcomes already bring perspectives on the use of metrics based on C and N stable isotopes of collembolans as indicators of nutrient input into savanna ecosystems. These indicators could help detect N deposition, which is expected to grow in Cerrado, or assess whether the restoration of savannas in abandoned agricultural areas effectively restores the soil food web interactions.

Keywords Stable isotopes, springtails, nutrient deposition, trophic niche, Neotropical savanna

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Home Field Advantage Effects on Decomposition of Leaf Litter in Tropical Riparian Forests: Restoration Age, Litter Quality and Soil Nutrients

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Decomposition is a key process driving carbon and nutrient cycling in ecosystems worldwide. Over the last decades, the home field advantage effect (HFA) has been proven to accelerate decomposition rates for litter at sites where the litter originates from ("home") when compared to other ("away") sites. HFA effects have been often found in natural, temperate forests, but it is still poorly known how HFA plays out in tropical, riparian forests under restoration. Here, we tested if litter quality, soil nutrient concentrations and restoration stage (age) influenced HFA. We carried out three independent three-way reciprocal litter transplant experiments to test how small-scale environmental conditions, like litter quality, soil nutrient concentration and time since forest restoration (age) drive the strength and direction of HFA effects in riparian areas (hypotheses 1-3). In addition, we analyzed the results of the three independent experiments together to test how HFA varied with (the dissimilarity in) soil nutrients and litter quality across all experimental areas (hypotheses 4-5). We found that leaf litter generally decomposed very fast across all areas, possibly due to heavy rainfall at the end of the experiment, and we also detected that the magnitude of HFA was neither related to forest age, nor to soil and litter quality within each of the independent experiments (hypotheses 1-3). An effect of decomposer ability was also found in restored areas, effect that was sometimes positive (increasing decomposition rates at home – R1) and others negative (decreasing decomposition rates at home – R3). Further, across experiments (hypotheses 4-5), HFA increased with higher leaf litter quality (i.e., higher litter N:P) and dissimilarity in soil quality. Also, the effects of decomposer ability were difficult to separate from those of HFA, indicating the need for further studies to understand if/how these effects contribute separately to decomposition rates. Finally, our results imply that HFA could potentially play a key role in driving litter breakdown in restored tropical riparian forests, however we highlight the need to better understand how decomposer ability and HFA effects contribute to determine decomposition rates in these ecosystems.

Keywords Home Field Advantage; HFA; Decomposition; Restoration

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Species Composition and Climate Dynamics Drive Aboveground Wood Productivity in Tropical Forests of Colombia

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Tropical forests are an important component of the carbon cycle. They account for one third of global net primary productivity because of favorable conditions for plant growth, such as relatively stable and benign climate, high and constant amounts of solar radiation throughout the year, and high levels of biodiversity. In Colombia, however, the Andes divide into three ranges, giving rise to a wide range of climatic conditions, including their temporal dynamics, high levels of beta diversity, and a diversity of forest ecosystems. This makes Colombia ideal to study the effect of climate and biodiversity on forest growth. Here we analyze the effect of climate and biodiversity on the dynamics of aboveground wood productivity (AGWP) across 20 forest plots located in different ecoregions of Colombia over the last 25 years. To do so, we determine the importance of 8 climatic variables associated with the temporal dynamics of temperature and precipitation and 4 biodiversity variables using linear mixed-effects models and variable selection. We find that the main driver of AGWP is species composition followed by temperature variability over the study period. Precipitation and temperature trends indicating climatic changes had a weak but significant effect. Variables such as species richness, Shannon diversity, mean annual temperature and annual precipitation had no explanatory power in our analyses, which contradicts previous findings in tropical forests. Our results suggest that species composition and beta diversity across Colombian forests are important drivers of AGWP and that temperature increase over the last 25 years likely had a positive effect on AGWP. Our findings highlight the importance of studying the temporal dynamics of climate and the effect of biodiversity loss to better understand the primary productivity and carbon cycling of tropical forests.

Keywords Carbon cycle, tropical forests, wood productivity, climate, biodiversity

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Relationship between Vegetation Degradation and Soil Carbon Stock in a Tropical Timber-producing Forest

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Soil carbon stock across climate zones is thought to change as a response to vegetation variation. However, without a climate gradient, the impact of aboveground vegetation to soil carbon stock is unclear. This research was conducted on two tropical timber-producing forest reserves, Deramakot and Tangkulap, located in Sabah, Malaysia. Logging events of different intensities occurred during the last 30 years, where secondary succession is observed to be obstructed by intensive conventional logging. In total, 36 plots belonging to five different degraded forest classes were sampled in 2020. For each plot, a 50 cm-depth soil sample was collected with a 10-cm depth increment. Total soil carbon and nitrogen, amorphous iron and aluminum, crystalline iron and aluminum, soil pH and water content were measured following standard methods. Vegetation intactness was calculated in each plot though nMDS analysis. We found a positive relationship between vegetation intactness and soil carbon stock, and a significant negative relationship between intactness and soil pH. Amorphous iron concentration was closely linked with both intactness and carbon concentration in the top 30 cm soil, suggesting that weakened plant transpiration can lead to a more reduced soil redox environment, accelerating mineral dissolution and consequently promoting humus decomposition. This phenomenon indicates a potential decrease of soil carbon stock capacity because of mineralogical changes, which directly arises from aboveground vegetation degradation.

Keywords vegetation degradation, soil carbon stock, amorphous iron, C stablization

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Large Tree Mortality Leads to Major Above-ground Biomass Decline in a Tropical Forest Reserve

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Tropical forest protected areas are increasing worldwide, however, their effectiveness in safeguarding biodiversity is inconclusive. Evaluations of conservation effectiveness have overwhelmingly focused on diversity metrics, but other aspects of forest function, such as long-term biomass dynamics, should also be considered. We evaluate changes in plant community structure (i.e., abundance, diversity, composition, and aboveground biomass) in a 2.25-ha forest dynamics plot to test conservation effectiveness in a 365-ha reserve fragment in southern Costa Rica. We censused, mapped, and identified to species level all plants >5 cm diameter at breast height (DBH) in three surveys spanning 2010-2020. While there were no changes in late-successional species diversity, there were marked changes in overall species composition and biomass. The abundance of large (>40 cm DBH) old-growth dense-wooded trees (e.g., some Lauraceae, Rosaceae) decreased dramatically, leading to major biomass decline over time, possibly due to the impacts of recent drought events on large old-growth trees. Gaps created by large trees were colonized by early-successional species, but these recruits did not make up for biomass lost. Finally, stem abundance increased 20% over time, driven by increasing dominance of *Hampea appendiculata*. Results suggest this reserve may effectively conserve overall plant diversity, but this may mask large aboveground biomass loss that could successionally regress the reserve to a 'mature secondary forest'. If this pattern is pervasive across tropical forest reserves, it could hamper efforts to preserve forest structure and ecosystem services (e.g., carbon storage). Monitoring programs could better assess carbon trends in reserves over time simply by tracking large tree dynamics.

Keywords Las Cruces, gap dynamics, *Hampea appendiculata*, long-term, pioneer species, secondary

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Wild Pigs Mediate Far-reaching Agricultural Impacts on Tropical Forest Soil Microbial Communities

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Introduction, Background & Justification: Edge effects, the altered abiotic and biotic conditions on the borders of natural areas, rarely extend more than a few hundred metres. Edge effects have rarely been linked to altered soil biotic properties, which are key for shaping ecosystem processes including carbon storage, biogeochemical cycling, and plant performance. The increasing abundance of native pigs (Sus scrofa) that feed on oil palm plantations and then influence plant communities through various disturbances can be considered an 'edge-effect', but we do not know how these animals might influence soil micro-organisms. **Objective:** The aim of this study was to determine how agriculturally-mediated increased pig densities influence soil microbial communities (bacteria and fungi). **Methods:** We used a 22-year old fenced exclusion experiment in a primary rain forest in Peninsular Malaysia (Pasoh) from which we sampled soils, extracted DNA and amplified marker regions for bacteria (16S) and fungi (ITS2), and analysed soil chemistry. **Results:** The presence of pigs was associated with greater bacterial diversity, and an altered bacterial community composition (mediated by minor changes in soil pH). In contrast, the fungal community was more variable and not influenced by the presence of pigs. However, we did find reduced abundance and diversity of symbiotic ectomycorrhizal fungi in pig-impacted soils. There were only minor effects of pigs on soil chemistry or microclimate, so we suggest that changes in soil communities are driven by pigs' leaf litter removal and alterations to plant composition (e.g. a specific preference for ectomycorrhizal hosts, the Dipterocarpaceae, for nest building). **Implications/Conclusion:** Wildlife populations affect soil biotic communities at a distance well over that of prior estimated edge effects when they move between agriculture and natural habitats highlighting that indirect effects from agriculture can be transferred by wildlife into protected areas and this could have important repercussions for ecosystem processes and plant-soil feedbacks.

Keywords African swine fever, bacteria, boar, ectomycorrhiza, fungi, soil, trophic cascade

Conservation Status, Ecological Niches, and Demography of Tropical Species

Session Recording: https://youtu.be/tgX1Yw5fgFM

Population Demographics of a Tropical Conifer, *Pinus caribaea* Var. *Hondurensis*, in a Frequently-burned Humid Savanna

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Introduction: Tree population dynamics are fundamental to savanna ecosystem structure and function. Trees affect understory composition, fire regimes, water flow, and trophic linkages. In mesic/humid savannas, fire is credited as an important determinant of tree growth and survival. Despite the widespread distribution of pine savannas in the tropics, evidence of the relationship between fire regimes and population dynamics of Caribbean pine (*Pinus caribaea* var. *hondurensis*) in Central America has been largely anecdotal to date, challenging the species' management. **Objectives/Hypotheses:** We characterized Caribbean pine growth and survival in lowland savannas of Belize with respect to fire regimes. These savannas experience distinct wet and dry seasons, with most natural fires occurring between February and May. Although fire return intervals likely varied between one and ten years historically, the savannas in the study area experience a regime of nearly annual dry season fire resulting from local burning practices. We hypothesized that too frequent fires are limiting pine seedling recruitment, resulting in population declines. **Methods:** In early 2017, fourteen permanent monitoring plots were installed in open, shrubby, and dense savanna microhabitats in Paynes Creek National Park. Within each plot, we tagged all adult pine trees and seedlings and measured their DBH (diameter at breast height) and height, respectively. Plots were re-censused between February and May in 2018, 2019, and 2020. We conducted an additional experiment to examine seedling survival after fires in different seasons. We used these data in population dynamics models to understand the relative sensitivity of population growth to perturbations of different life stages. **Results:** Over half of all seedlings died regardless of fire or microhabitat. Ninety and sixty-five percent of all seedlings died within the first year with and without having experienced a fire, respectively. Fire occurrence was significantly associated with low survival in some microhabitats. Population models confirmed that the seedling stage is the recruitment bottleneck, and that pine population growth can be strongly limited by this stage. **Implications/conclusions:** Caribbean pine seedlings have low survival despite fire suggesting that other factors could be limiting their recruitment. Given that pines appear to be in decline, ensuring successful establishment of new individuals is critical. Identifying limiting factors would inform conservation approaches. Adult stages appear to be resistant to local fires; however, if large disturbances such as hurricanes remove a large percentage of adults (i.e., seed sources), it will likely take longer for the population to recover.

Keywords Belize, demography, fire, pine, populations, tropics

Are Black-lion-tamarin Populations Viable in the Long Term?

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Black lion tamarins are currently present in 17 fragments of Atlantic Forest in Sao Paulo state, southeastern Brazil. As a threatened species in a vanishing biome, the black lion tamarins face constant threats such as wildfire risk, deforestation, reduction of carrying capacity in small fragments, and climate change. The Population Viability Analysis (PVA) methodology explores the risk of extinction and other metrics of population viability based on life-history traits, population dynamics, genetic processes tracking, and the combination of stochastic and deterministic factors. Here, we estimated the current viability of the black lion tamarin populations using the Vortex software, which models, at the individual level, the effects of factors influencing population dynamics. Each scenario was simulated 1000 times, for a period of 100 years, representing approximately 14 generations for this species. We also integrated the current threats to the species and its habitat, such as the effects of climate change and fires on the carrying capacity of fragments harboring the species. We defined a viable black lion tamarin population as one that conserves at least 98% of gene diversity (GD) compared to a theoretical, large population, and has no more than a 2% probability of extinction (PE) in 100 years. When the viability of the 17 populations is analyzed individually, only two populations are viable, while the remaining 15 have a high probability of extinction within the simulated period. The minimum viable population for the species under different conditions was estimated. Our model suggests that at least 800 individuals in a single, panmictic population are necessary to meet PE $<$ 2% and GD$>$ 98% in 100 years. We also investigated the impact of management strategies that affect the viability of the species, such as the implementation of ecological corridors. The results of the quantitative analyses will serve to project the future of the species under different scenarios, allowing us to plan context-specific conservation strategies for each population. Our results stress that immediate management actions targeting both habitat and individuals are needed. In terms of habitat management, it is important to implement measures aimed at expanding and connecting the fragments, such as reforestation. More connected habitats will ultimately increase gene flow between populations. Likewise, effective management strategies involving individuals, such as translocations, are required for the recovery of small, genetically depressed, populations.

Keywords Black lion tamarins, Threatened species, Population Viability Analysis, Vortex

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Impact of Model Assumptions on Demographic Inferences Tested for Two Nocturnal Primates in Madagascar

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Quaternary climatic fluctuations have been acknowledged as a major driver of the extraordinary biodiversity observed in tropical biomes, including Madagascar. One main framework for Pleistocene Malagasy diversification assumes that forest cover was strongly shaped by warmer Interglacials (leading to forest expansion) and by cooler and arid glacials (leading to forest contraction), but predictions derived from this scenario for forest-dwelling animals have rarely been tested with robust genomic datasets. We generated genome-wide data and applied three complementary demographic approaches (Stairway Plot, PSMC and IICR-simulations) to infer population size and connectivity changes in two forest-dependent primate species (*Microcebus murinus*, n = 22 and *M. ravelobensis*, n = 55) living in partial sympatry in northwestern Madagascar. The analyses confirmed the occurrence of major but different demographic changes in both species that could be interpreted in two ways, depending on the underlying model assumptions (i.e., population panmixia vs. population structure). Under panmixia, the two species exhibited larger population sizes across the Last Glacial Maximum (LGM) and towards the African Humid Period (AHP). This peak was followed by a population decline in *M. ravelobensis*

until the present, while M. murinus may have experienced a second population expansion during the AHP and a sharp decline starting 3,000 years ago. In contrast, our IICR-simulations under population structure suggested decreasing population connectivity between the Last Interglacial and the LGM for both species, but increased connectivity during the AHP exclusively for *M. murinus*. Assuming that Pleistocene climatic conditions in the lowlands were similar to those observed in the Malagasy highlands, the older demographic dynamics of both species would be better explained by changes in population connectivity than in population size. However, changes in connectivity alone cannot be easily reconciled with a founder effect that was previously inferred for *M. murinus* during its colonization of northwestern Madagascar in the late Pleistocene. Altogether, our study contributes to a better understanding of species responses to past climatic changes in lowlands habitats, for which high-resolution paleoenvironmental data is still sparse. Our study also demonstrates that it is important to evaluate alternative models derived under different assumptions when inferring the demographic history based on molecular datasets to avoid premature conclusions.

Keywords Quaternary climatic oscillations, genomics, demographic modelling, Madagascar, mouse lemurs

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Rethinking the Role of Intraspecific Variability in Species Coexistence

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How species coexist while competiting for the same resources is a long-standing question in community ecology, particularly for hyperdiverse communities like tropical forests. In the past decades, intraspecific variability (IV) and its ecological consequences became of major interest, and IV was perceived as a potential mechanism enabling species coexistence, with contrasting results in the literature however. We argue that taking the nature of IV into account is important to understand its effects on coexistence, and hypothesise that environmental variation alone can produce IV in performance. Focusing on spatial environmental variation, we build a body of evidence to support this idea. First, we use a theoretical model using virtual data of individual growth across environmental gradients, using less explicative environmental variables in the model than to generate the data. Second we analyse a Eucalyptus clonal dataset in Brazil. Lastly we analyse three datasets from contrasting tropical forests: Paracou in French Guiana (Amazonia), Barro Colorado Island in Panama (Central America) and Uppangala in the Western Ghats in India (Southeast Asia). The theoretical model shows that observed IV can emerge due to the lower dimensionality of field observations compared with the high dimensionality of the environment, without any intrinsic differences between conspecifics; the clonal dataset analysis shows that IV can emerge from exogenous factors; the tropical dataset analyses show that IV in growth is high in tropical forests, that growth is broadly spatially autocorrelated, which we suppose is a mark of its environmental origin, and that locally, conspecifics have a more similar growth than heterospecifics. This body of evidence shows that IV can emerge from environmental variation and without any intrinsic differences between conspecific individuals. Based on theory, which shows that intraspecific competition must be stronger than interspecific competition to enable species coexistence, we link higher local similarity to higher competition and conclude that intraspecific variability does not preclude this condition, enabling multiple species to coexist in high dimensional and spatially structured environments.

Keywords Coexistence, Intraspecific-variability, high-dimensional-niche, spatial-structure, Performance, Competition

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Do Neotropical Flycatchers Exclude Each Other in Breeding and Wintering Grounds?

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Several recent studies have highlighted the important and poorly known migrations of flycatchers within the Neotropics. The city of Brasília is in the core area of the Cerrado region of Central Brazil, where we find both summer migrants such as the Crowned Slaty Flycatcher (*Griseotyrannus aurantioatrocristatus*) and winter migrants such as the Vermilion Flycatcher (*Pyrocephalus rubinus*). We made behavioral observations on both species since 2019, which suggest that summer migrants are dominant over the Vermilion Flycatcher, and in one case excluded it from an area used by both species cited above. We investigated whether there is evidence for non-overlap in the summer and winter distributions of these species, using records from the eBird database for South America through March 2021. Although we understand these records may contain data from various populations, including those with distinct migratory patterns, we decided a first cut with a general analysis would be useful. We modeled winter and summer potential distributions using the Biomod2 package from R 4.0, and the environmental data from Worldclim version 2.1 bioclimatic variables for 1970-2000 at 2.5 arc-minutes resolution. We drew on a script posted by Hannah Owens in gist, for a maxent ensemble modeling. Our results show clear differences between species in winter potential occurrence, with the Crowned Slaty Flycatcher present in the Amazonian region and the Vermilion Flycatcher further west towards the Andes. In summer both species have a predicted range in Southern Brazil, Argentina, Paraguay and Bolivia, but the Crowned Slaty Flycatcher is predicted to have higher preference in the western part of the range, while the Vermilion Flycatcher has a non-overlapping preferred predicted area in the eastern part of the range. These results suggest there may be indeed distinct ranges between these flycatchers of very similar size and feeding habits.

Keywords Migrations, hotspots, biodiversity, flycatchers, competition

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Population Density of Grauer's Gorilla (*Gorilla beringei graueri*) in the Nkuba Conservation Area, DR Congo

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The critically endangerd Grauer's gorilla (*Gorilla beringei graueri*) is endemic to the East of the Democratic Republic of the Congo. Over the past 20 years, this subspecies of the Eastern Gorilla suffered an estimated population decline of 80%. Habitat loss and hunting represent the biggest threat. There is an urgent need for effective conservation measures to counteract the negative impacts of fragmentation and loss of genetic diversity. In 2012, the Dian Fossey Gorilla Fund International established the Nkuba Conservation area. This community-based reserve of 1313km^2 is located between Maiko and Kahuzi-Biega National Parks. In 2020, we estimated the density of Grauer's gorillas inside the area. We recorded all nests found in 97 3km-transects. For each nest site found, we noted the perpendicular distance to the center of the nest site as well as the number of nests per site. Using Distance software we estimate the density of gorillas to be on average 0.14 weaned gorillas per km^2. These densities are close to those of Kahuzi-Biega NP indicating that community-based conservation is an effective strategy to protect Grauer's gorillas. As the Nkuba Conservation Area is home to around 5% of the world's Grauer's gorilla population this community-managed area plays an important role in its conservation. Furthermore, the conservation of the Nkuba forest represents an important step in the creation of a corridor between Maiko and Kahuzi-Biega National Parks. The expansion of community-based conservation areas will be critical for the survival of this subspecies.

Keywords community-based conservation, gorilla, density estimation

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Interannual Variation in Seedling Survival and the Strength of Density Dependence Are Modulated by Abundance of Recruits and Precipitation

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Background: Seedling dynamics are critical for determining community composition and future forest structure. Two mechanisms are thought to be key drivers of seedling vital rates: negative density dependence (NDD) and environmental filtering. In particular, NDD is considered among the main mechanisms favoring species coexistence. However, these effects can show temporal variation as a consequence of shifts in the number of neighbors and weather conditions, such as drought. There is limited evidence as to whether interannual variation of these conditions modulate biotic interactions (i.e., NDD), and its potential cascading effects of seedling survival. **Objectives:** 1) To evaluate the relative contribution of biotic vs. abiotic factors on seedling survival; 2) to test the effects of yearly abundance of new recruits (as high vs. low recruitment years) and total annual precipitation (dry vs. wet years) on the strength of NDD and ultimately on the survival of first-year seedlings; 3) to assess whether annual increase in conspecifics seedling density has a stronger negative effect than initial densities. **Methods:** We used seedling data collected over 17 years in a subtropical rain forest in Northern Taiwan. We modeled interannual variation in survival for the whole community using generalized linear mixed-effects models with several variables of neighborhood composition and abiotic conditions as predictors. **Results:** Seedling survival was higher in years with high abundance of new recruits and in dry years. High density of conspecific seedlings strongly decreased survival in years of low recruitment and abundant precipitation, but not when recruitment was abundant and precipitation was low. The increase in the density of conspecific neighbors had a strong negative effect. Environmental filtering had limited impact compared to NDD. **Conclusions:** Our results show that annual abundance of new recruits and total precipitation significantly affect temporal variation in seedling survival, and that these effects are mediated by changes in the strength of conspecific negative density dependence. These findings are in accordance with the economy of scale hypothesis, previously reported only at the seed-to-seedling stage, and support the hypothesis that precipitation fluctuations can impact biotic interactions in forests. Changes in precipitation regimes might significantly affect future forest dynamics and composition.

Keywords Fushan Forest Dynamic Plot, Economy of scale, Environmental filtering, Precipitation.

Source Height and Contact with Terrestrial Soil Drive Transplanted Vascular Epiphyte Mortality

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Epiphytes are characterized by their structural dependence on other plants to persist high in the forest profile and by their ability to survive without a root connection to the ground. Although epiphytes make up approximately one-fifth of Neotropical vascular plant diversity, the life-history and ecological trade-offs of this unique aerial growth habit remain largely untested experimentally. Mortality due to falling from the host tree has recently been raised as an underappreciated driver of epiphyte community dynamics. Mortality rates of fallen epiphytes generally exceed 70%, but little empirical evidence exists for why epiphytes do not survive when forced to become terrestrial. Moreover, the variation in mortality rates of fallen epiphytes among taxonomic groups, and among epiphytes which reside in the same vertical strata, remains relatively unexplored. Here, we experimentally test two hypotheses regarding the drivers of epiphyte mortality in a cloud forest of central Panama. We test whether simple contact with terrestrial soil is deleterious to epiphytes, preliminarily testing the Epiphyte Enemy Escape Hypothesis. We also test the Vertical Niche Differentiation Hypothesis, wherein epiphytes are specifically adapted for microsites throughout the vertical forest strata. By monitoring leaf loss, health status, and mortality of 270 transplanted epiphytes for a year and a half, we pinpoint the extent to which distance from the ground regulates epiphyte mortality. We found support for both of our hypotheses. After 77 months, epiphytes in contact with the ground had approximately half as many leaves left in comparison to those

transplanted just above the ground. Likewise, epiphytes in contact with the ground had a 26% lower survival rate versus epiphytes transplanted a few meters higher. Mortality rates were also mediated by original height where the epiphyte occurred in the host tree prior to transplanting. Our results demonstrate that contact with the terrestrial soil regulates early fallen epiphyte mortality, and epiphytes that occur high in the canopy are particularly vulnerable to mortality via falling. These results have important implications both for fundamental ecological theory and for biodiversity conservation management. Follow-up studies should explore the role of terrestrial soil microbes as potential drivers of decreased grounded epiphyte survival. Moreover, the high success and survival rate of epiphytes transplanted above the soil surface highlight an overlooked management technique: moving fallen epiphytes to nearby trees could help increase establishment or population stability of epiphyte communities. This would be particularly useful in relatively epiphyte-poor secondary forests and small forest fragments.

Keywords orchid, bromeliad, epiphyte, transplant, survival, niche, Neotropical, soil, cloud forest

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Using Demographic Modeling and Landsat to Predict Forest Recovery following Tropical Forest Disturbance Events

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The inclusion of dynamic vegetation demography in Earth System Models (ESMs) has been identified as a critical step in moving ESMs towards more realistic representations of plant ecology, and the processes that govern climatically important fluxes of carbon, energy, and water. To help this advancement, we integrated demographic processes using the Functionally-Assembled Terrestrial Ecosystem Simulator (FATES) in the newly developed E3SM Land Model (ELM). To test successful application, we then use ELM-FATES to investigate differences in forest recovery processes in a tropical evergreen forest in Brazil, and how variations in recovery could be due to trajectories of forest recovery being highly dependent on the disturbance and ecosystem type. Consistent, temporal measurements of these recovery trajectories, especially in the tropics, are scarce. Therefore, we used the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) and found that near infrared (NIR) band captured the dynamics of recovery pathways from clear-cuts in the Central Amazon. In general, following disturbance NIR increased with an increase in vegetation cover, reaching its maximum after the close of canopy by pioneers, and then decreasing slowly with the dynamics of succession. Consistent with inferences from the NIR observations, ELM-FATES predicted the higher peaks of initial biomass and stem density recovery after clear-cuts than after windthrows. ELM-FATES predicted recovery of forest structure and canopy coverage back to pre-disturbance conditions in 38 years (on average) after windthrows events and 41 years (on average) after clear-cuts. The similarity of ELM-FATES predictions of regrowth patterns after windthrow and clear-cut to those of the NIR results suggests the NIR band can be used to benchmark forest regrowth in ecosystem models.

Keywords Ecosystem modeling; disturbance; recovery; dynamic vegetation; Amazon

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Biotic Interactions in the Face of Global Change

Session Recording: https://youtu.be/x77yC3RT4gw

Seasonal Phytochemical Variation Affects Insect–plant Interactions in the Brazilian Cerrado

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Herbivory patterns are affected by variations in leaf quality, which is largely defined by its chemical composition. An important driver for these variations is the phenological response of plant species to seasonal climatic variation. The Brazilian Cerrado, a savanah-like bioma, comprises a mosaic of vegetation types adapted to the extreme variations in rainfall between dry and wet seasons. Concurrently, there is a high turnover for interactions between herbivorous insects and their host plants in the area, and these alterations are more prominent across the seasonal landscape.This work investigates the impact of seasonal phytochemical variations in herbivore turnover for some species of the Cerrado flora. Primarily, we aimed to verify seasonal plasticity of the plant metabolism at an intraspecific level, and then determine if these patterns are consistently expressed in different species. We selected 12 host species that include plants within diverse phylogenetic levels and assessed herbivore community by cataloging all caterpillars found these species, collected at four equidistant periods of the year. We also obtained the phytochemical profiles of these plants through Proton Nuclear Magnetic Resonance spectrum of their methanolic extracts. Phytochemical similarity was higher for samples of a given species within a season than across different seasons, thus supporting the hypothesis of climate-mediated chemotypes. Moreover, we verified in almost all species that samples are more chemically similar in the wet season months (September/December), and the dry season months (March/June), suggesting an influence of hydric stress on phytochemical composition. Although intraspecific similarity was largely dominant over seasonal variations, we observed one case in which samples from different species were more chemically similar due to their seasonal affiliation. For two co-generic species, we encountered that the same compound is differentially expressed in the wet season, and we anticipate that further investigation of the species will reveal similar biochemical patterns across higher taxonomic levels. A high turnover of caterpillars was also observed across the seasons for a host species. In most cases, herbivore community was more similar within a species, but as observed with chemical data, there were a few exceptions in which plants from different species in the same season had higher similarity. Comparing the similarity matrices generated from chemical and herbivore data, we found a significant and moderate relationship ($R = 0.41$). These preliminary results suggest that variations in phytochemical composition may influence the structure of herbivore communities, which encourage us to further investigate the underlying compounds.

Keywords herbivore diversity, phytochemical diversity, seasonal variation, insect plant interaction

Key Plant Species to Restore Plant-hummingbird Pollinator Communities in the Southern Andes of Ecuador

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In the Tropical Andes, knowledge associated with mutualistic networks has not been efficiently incorporated into restoration decisions. For this biodiversity hotspot, the community of hummingbirds and their pollinated plants is of particular importance for restoration. Within this specific mutualistic network certain plant species are key to sustain pollination interactions, and thus, identifying these key species is fundamental to design and apply more comprehensive restoration strategies. Our study was conducted in the southern Andes of Ecuador in the vegetation types old-growth forest, secondary forest, hedgerows and montane shrub. On each vegetation type we surveyed hummingbird visitation to plants and constructed a series of independent plant-hummingbird interaction networks per site and survey period. We used the information from each network to calculate a centrality index for each plant species and used this index to describe the role of individual species as either key or peripheral. We also explored how functional traits, including flower abundance, morphology and nectar characteristics, were associated with the variation in this index. We found a total of 123 unique pairwise interactions between 44 plant and 15 hummingbird species. Within each vegetation type we identified 4 to 11 key plant species. A shrubby life form and abundant flowers were the main traits associated with the key role of species. This study shows a cost-effective and robust protocol to select plants for the specific objective of recovering plant communities that sustain hummingbird pollinators.

Keywords Tropical Andes; plant-hummingbird interactions, centrality metrics, plant species selection

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Frugivore Community Composition and Interaction Frequency Are Vertically Stratified in a Liana Species Fruiting across Forest Strata

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During the last 30 years, improved access to the canopies of forests has changed our understanding of key ecosystem processes substantially. Thereby, vertical stratification was proposed a key feature of tropical forests. Previous work has shown that this vertical structure also shapes plant–frugivore interactions, but it is unclear whether this is driven by differences in plant community composition or inherent preferences of frugivores for specific strata. To test this, we conducted an in-depth analysis of frugivore community composition and interaction frequency in a plant–frugivore network in a Peruvian rainforest, where one side of the interaction network – the plant – is held constant. Marcgravia longifolia produces fruits across all strata, thus eliminating the confounding effect of plant species and stratum. During 540 observation hours, we recorded fruit removal from 24 M. longifolia individuals across the forest strata (understorey, midstorey, canopy) with a standardized sampling design. We recorded 876 interactions with 43 frugivore species (41 birds, two primates). We assigned these species into guilds according to dietary specialization (6 obligate, 28 partial, 9 opportunistic frugivores) and, for birds, determined four morphological traits (body mass, bill length, bill width, wing shape). Our network was characterized by a high interaction frequency of few species in the understorey, and a low interaction frequency of many different species in the higher strata. Partial frugivores were the most abundant species in our network, foraging with decreasing frequency and relative importance per stratum towards the canopy. Obligate and opportunistic frugivores were less frequent visitors. Whereas opportunistic frugivores foraged across strata, obligate frugivores were predominantly found in the canopy and the midstorey. Avian frugivores foraging in the canopy were mainly large-bodied species with pointed wings, whereas under- and midstorey avian foragers were smaller with rounded wings. Avian frugivores remained within their preferred vertical niche, even though an attractive food resource was available across strata. Vertical stratification appears to be an important driver of a species' interaction niche and is associated with its morphology. Hence, the niche differentiation of species along the vertical forest gradient may be a key factor promoting tropical forest diversity.

Keywords birds, diet specialization, frugivory, plant–animal interactions, primates, rain forest, seed

Invasion of Exotic Terrestrial Pest Gastropods into Tropical Rainforests of the Nuwara Eliya District, Sri Lanka

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Most of the alien gastropods in Sri Lanka are considered agricultural pests. They have established upcountry agricultural lands. Most of the agricultural lands are found in proximity to tropical rainforests (TR). There is a risk of these exotics invading the TR where many of the native species are found. This study design to evaluate the invasion of these exotic pest gastropods into TR in the Nuwara Eliya district. Sixty TR fragments in the Nuwara Eliya district were sampled for a period of one year. Each site was surveyed for terrestrial gastropods by establishing ten to fifty 1 m^2 sampling plots. Each plot was sampled for 15 minutes. A total of 1,224 individuals belonging to 46 species and 15 families were recorded. Out of them 18% were exotics, consisting of one slug species (*Deroceras laeve*) and five snail species (*Allopeas gracile*, *Bradybaena similaris*, *Lissachatina fulica*, *Paropeas achatinaceum* and *Subulina octona*), that are agricultural pests and two other snail species (*Glessula pusilla* and *Gulella bicolor*) that are yet to be confirmed as pest species. These exotic species were recorded from TR buffers and the marginal vegetation between forests and agricultural lands. Some of these exotics except *D. laeve*, *G. pusilla* and *G. bicolor* were highly abundant (100-500 individuals ha^{-1}). *B. similaris*, *L. fulica* and *A. gracile* were the most abundant species (>500 individuals ha^{-1}). Elevation, atmospheric temperature, rainfall and soil pH significantly affect their distribution. The exotic species have a wider range of tolerance for these environmental factors compared to the native species. Most of the exotic snails were found at mid-elevations (900-1500 m a.s.l), moderate temperatures (24 ºC-26 ºC) and in soils with a slightly acidic pH (5.0-6.5) while the exotic slug species was found at higher elevations (>1500 m a.s.l), low temperature (22 ºC-24 ºC), low rainfall (<5 mm day^{-1}) and in acidic soils (pH 4.5-5.0). The present study found that globally invasive gastropods such as *L. fulica* and *B. similaris* have invaded the TR in Sri Lanka. Climatic changes and anthropogenic activities may facilitate these encroachments further. If these exotics are able to establish in these natural habitats, they could pose a threat to the native gastropods and plant communities in these TR. The results from this study can help formulate management plans related to landscape planning and habitat transformation in Sri Lanka and other tropical regions.

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Keywords Agricultural lands, Invasive, Gastropods, Pests, Sri Lanka, Tropical rainforests

Distribution and Determinants of Animal Invasive Species

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Invasive species is a threat to biodiversity along with other factors such as habitat destruction, deforestation, population growth and climate change. They also have an impact on economy, human health, ecosystem services. Therefore, there is a need to identify the geographical regions where there is the highest invasion and assess its relationship with its environmental factors. This study aims to assess the distribution and patterns of animal invasive alien species across different geographical spaces. Secondly, to identify the socio-economic determinants which facilitate animal invasion. We considered 2814 invasive animal species for this study; obtained data from Global Invasive Species Database and Centre for Agriculture and Bioscience International. Species distribution data were collected from Global Biodiversity Information Facility and available literature. Socio-economic data, such as gross domestic product, air transport volume, containership volume, export, import, trade, population density, livestock etc., were obtained from World bank data, SEDAC (Socioeconomic Data and Application Centre) and OECD (Organisation for Economic Co-operation and Development). We

had considered ecoregions, biomes, realms, countries and continents as variables to assess the distribution and spatial patterns. This study was aimed to provide a detailed account about the distribution of all invasive animal species across the globe. The result suggested the most of the Oceanic Islands and European countries have higher invasive species per unit area than other parts of the world. Hierarchical cluster analysis highlighted the homogenization of species diversity belonging to different realms. General Liner Model result indicated that containership volume, rail route, trade and human capital index were correlated with the number of invasive species per country. The country with higher numbers of invasive species were likely to have more number of threatened species. As per distribution data, the Palearctic regions had the highest number of invasive species followed by Nearctic realm. Most invasive species were found to be in temperate broadleaf and mixed forests. Developed countries had a high count of invasive species as compared to developing countries. Temperate regions are more vulnerable to invasive species than tropical areas. Our analysis revealed the inadequacies of data from developing countries. This study provides detailed information on the distribution of all invasive animal species across the globe. There is a need for better documentation of invasive species from developing countries. There is an urgent need to develop an action plan to manage invasive animal species in order to prevent further invasion and mitigate their impact under future climate.

Keywords Invasive species, Biological invasion

Perceptions of Invasive Species and Control Efforts in a Novel Island Ecosystem

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Invasive species are a major ecological concern in many systems. Human perceptions of these species and of management approaches can hinder or aid conservation efforts. Fortunately, conservation managers can look to social science approaches to help communicate our efforts and to help predict social and political support. Invasive brown treesnakes (BTS) in Guam, an American territory in the Western Pacific, have created an ecological tragedy by essentially exterminating native forest birds. While this species has been a management priority for decades, public perceptions of the BTS, its impacts, and management, have rarely been studied. We conducted 23 small group discussions with residents of Guam, encompassing a variety of ages, backgrounds, and professions. Using grounded theory and qualitative methods, we analyzed transcripts of these discussions to discern major themes and recurring concerns. Participants voiced concerns about a variety of environmental issues. When discussing invasive species, participants worried more about coconut rhinoceros beetles, introduced more recently, than they did for BTS, a now familiar invasive species to Guam residents. They also expressed doubts about BTS control strategies and mixed levels of trust in agencies and institutions. Of particular concern was that a few participants questioned links between BTS and bird decline, sharing alternative hypotheses for the disappearance of Guam's birds. We also found differences between older and younger participants in their perceptions of management strategies, with older participants expressing more concern about pesticide-use or widespread broad applications of control techniques. This could impact plans for widespread BTS-control techniques, as well as control techniques for other invasive species. Estimating perceived risk of both invasive species and their potential control methods are necessary for avoiding stakeholder outrage. Understanding and incorporating societal factors into building conservation strategies will maximize public support, and therefore, maximize ecological successes as well.

Keywords invasive species, Guam, novel ecosystems, social science, risk perception

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Ecological and Evolutionary Explanations for a New Interaction between Stem Borer Weevils and Peach Palm in a Tropical Agroecosystem

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New crop-pest interactions constitute excellent opportunities to understand the origins and mechanisms of plant-pest relationships. The recent, unexplained mass deaths of the South American peach palms (*Bactris gasipaes*) in Colombian tropical agroecosystems enabled us to explore the ecological and evolutionary drivers of these peach palm - stem borer weevil interactions. We determined the identity of 419 palm weevils associated with 87 damaged peach palms from 32 plots within the Amazon, Andes, and Pacific regions in Colombia; 51 were *D. borassi* and 368 *R. palmarum*. We also related infestation levels measured in 4098 peach palms to 109 agro-ecological variables in all crops (e.g., type of management, surrounding forest cover, soil nutrients, climate, etc.). In the same 32 fields, *D. borassi* was determined as the primary pest attacking unopened inflorescences and tunneling the petiole towards the stem, favoring subsequent damage by *R. palmarum*. Both weevil species cause the crown toppling of peach palms. Weevil infestation was related to landscape variables in the three regions, particularly the density and shape of non-forest cover, which are indicators of forest fragmentation. Our data support the idea that deforestation and decreasing resources (inflorescences of native palms like *O. bataua*) for *D. borassi* pushed its populations to increasingly infest peach palm inflorescences, therefore initiating the damage that finally caused the massive deaths. We compared the measurements of 19 body parts of 26 *D. borassi* adults from peach palm (21) and natural host palm (5), and 102 *R. palmarum* from peach palm (43), sugarcane (59), new host in Colombia. The 21 *D. borassi* from peach palm and 59 *R. palmarum* from sugarcane were smaller in comparison with the specimens from natural host plants. The COI gene sequences of eight samples of *R. palmarum* from sugarcane were genetically different from 149 sequences (9 from peach palm of this study and 138 from Brazil and two from Costa Rica of the GenBank and Bold database). A similar analysis comparing *D. borassi* from peach palm and natural host palms is in preparation. This research opens new questions on the role of alternative host palm species and their interaction with landscape variables in the origin of peach palm's new pests. New crop-pest interactions constitute excellent opportunities to understand the origins and mechanisms of plant-pest relationships. The recent, unexplained mass deaths of the South American peach palms (*Bactris gasipaes*) in Colombian tropical agroecosystems enabled us to explore the ecological and evolutionary drivers of these.

Keywords Plant-insect interaction, Landscape ecology, *Dynamis borassi*, *Rhynchophorus palmarum*, *Bactris gasiapes*

The Impact of Shade Tree Identity and Canopy Cover on Arabica Coffee Pests and Diseases

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Arabica coffee naturally grows as an understory shrub in the moist Afromontane forests of southwestern Ethiopia. However, little is known about the impact of the of shade tree identity on coffee pest and disease regulation. We investigated the impact of shade tree species identity and canopy cover on major insect pests (the coffee blotch miner, the serpentine leaf miner, the coffee leaf skeletonizer, antestia and damage by other free-feeding herbivores), and coffee leaf rust and its hyperparasite, as well as the coffee berry disease. For this we carried out two complementary studies — in a commercial coffee plantation and across 58 sites in smallholder farms along a broad management gradient in southwestern Ethiopia. Shade tree species did not affect pest levels, whereas canopy cover had a strong but variable effect. The coffee blotch miner, serpentine leaf miner and antestia decreased with canopy cover, whereas the coffee leaf skeletonizer and other free-feeding herbivores increased with canopy cover. In contrast to the insect pests, coffee leaf rust and its hyperparasite, as well as coffee berry disease, differed strongly among shade tree species, with particularly high levels of coffee leaf rust and the hyperparasite underneath the canopy of the shade trees *A. abyssinica* and *C. macrostachyus*,

and coffee berry disease underneath the canopy of *A. abyssinica* and *P. fulva*. Our findings help to understand the variation in pest and diseases dynamics in natural forests and agroforests, and may also inform the selection of shade trees by coffee producers.

Keywords Shade tree identity, coffee, coffee leaf rust, pests and diseases

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Patterns of Pathogen Attack in Seedling Communities across a Neotropical Precipitation Gradient and Its Implications for Coexistence

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Numerous studies suggest that fungal and oomycete phytopathogens are important regulators of tropical tree species diversity and can attack seedlings in density-dependent or distance-dependent patterns. However, variation in the strength of phytopathogen regulation of plant communities across environmental gradients, such as moisture, is poorly understood, especially in the context of whole plant communities. We conducted surveys of pathogen infection in seedling communities across a precipitation gradient in the forests of Central Panama to determine how widespread pathogen attack is along an abiotic gradient positively associated with tree species richness. Surveys were conducted across three months during the wet season and two months during the dry season to understand seasonal variation in symptomatic pathogen infection. We expected an overall positive interaction between moisture variables (season and mean annual precipitation) and the strength of density and distance dependence. Surprisingly, we found that seedlings were more likely to be symptomatic of pathogen attack in the dry season rather than the wet season. We found large variation in the response of species to distance-dependent pathogen attack and no evidence for density-dependent pathogen attack. At the community level, there was a dry season trend towards positive distance dependence as annual precipitation increased, counter to our predictions. However, a subset of the species surveyed experienced negative distance dependence in the wet season, a pattern that intensified as mean annual precipitation increased, consistent with the expectations of pathogen regulation of species richness. Our results suggest that patterns of pathogen attack are highly variable among species in the whole tree community. Season and mean annual precipitation are both important contexts for seedling-pathogen interactions, capable of changing the direction and degree of the relationship.

Keywords coexistence diversity tree precipitation Janzen-Connell pathogen fungi seedling community

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Frugivory, Seed Dispersal, and Fruit-seed Traits: Ecology and Conservation

Session Recording: https://youtu.be/2UE3n28uv0g

The Effect of Population Size on Long-distance Seed Dispersal by an Endangered Macaw

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Defaunation affects not only the population of animal species but also their ecological functions in the ecosystem. Parrots, whose populations have been declining dramatically in the Neotropics, are traditionally considered antagonists of the plants they interact with, since they often behave as seed predators. However, recent studies have pointed to their role as mutualists in many interactions with large-seeded plants. Evidence that parrots can ingest viable seeds, disperse propagules through stomatochory and waste intact seeds in feeding grounds place them as promoters of seed dispersal. Moreover, the great mobility and wide home ranges make parrots potentially important in long-distance dispersal (LDD). Here, we sought to investigate the relationship between seed dispersal interactions and changes in the population size of an endangered macaw. The Lear's Macaw (*Anodorhynchus leari*) is an endemic species to North-eastern Brazil that feeds mainly on the seeds of the licuri palm (*Syagrus coronata*) and is often seen carrying the fruits across the feeding areas and sometimes to the nesting grounds. To obtain quantitative estimates of the potential effects of changes, we modelled this seed dispersal interaction under multiple macaw's population sizes scenarios and different assumptions about feeding behaviour, under the same realistic parameterization. We used individual-based models that allow estimating spatial patterns of seed dispersal and obtain potential seed-dispersal kernels. The model was parameterized with existing data on feeding behaviour and mobility and the individual movement was simulated under different movement models such as Lévy flights. Simulating seed dispersal varying macaw population densities (50 to 2000 individuals), we found that despite little changes in the shape of seed-dispersal kernels, the frequency of long-distance seed-dispersal events increases considerably with population size. The frequency of LDD events is more than 20 times higher in a population of 1000 compared to one of 50 individuals. This difference increases 50 times in the scenario of greatest abundance. The maximum dispersal distance is also much greater on average in simulations with larger populations, growing non-linearly with abundance. Long-distance dispersal is a rare event. Yet, when the abundance of seed dispersers is large even relatively rare events will occur frequently. Our results, besides helping us to understand the potential contribution of large parrots to the seed dispersal, highlight that maintaining large populations is necessary for the plant metapopulation dynamics. The depletion of parrots' populations may have direct effects on the persistence and spatial distribution of their interaction partners, with consequences for the ecosystem.

Keywords defaunation mutualists seed dispersal macaws stomatochory long-distance dispersal Neotropics movement models individual-based models functional extinction seed dispersal kernels large-seeded plants large-bodied dispersers

Characteristic of Reproductive Period and Physical-physiological Properties of Local Species Seeds at Mount Masigit-Kareumbi, Indonesia

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The potential and characteristic of local tree species seeds are important factors in restoring degraded forests such as phenology, types of fruit, seed size, and germination rate. However, data on local tree species are limited in many ecosystems prioritizing the need of research on potential target species for forest restoration. Mount Masigit-Kareumbi is situated in the sub-montane forest ecosystem (1000-1400 m above see level) has been prone to deforestation which is indicated by encroachment area around the forest. The aims of this study were to determine the reproductive characteristics and physical-physiological properties of three potential local species in Mount Masigit-Kareumbi, Indonesia: *Schima wallichii*, *Castanopsis argentea* and *Saurauia microphylla*. To do this, we had observed the flower-fruit presence and seed production, and measured seed physical properties and germination rates. We found that the estimation of seed collection time varied across species: *Saurauia microphylla* were December and June, *Schima wallichii* was November and *Castanopsis argentea* was February. We also found that seeds also varied in physical properties and germination rate. *Castanopsis argentea* have a bigger (length: 2 to 3 cm) and heavier seed than others so that the number of seed per kilogram (221 seeds per kg) less than *Schima wallichii* and *Saurauia microphylla*. The fruit types of local species in this study include three different types, namely: nut (*Castanopsis argentea*), berry (*Saurauia microphylla*) and capsule (*Schima wallichii*). These types of fruit have its own consequences for the seed collection activities and dispersal. Germination rates of the local species in this study classified into slow germinated seeds for *Castanopsis argentea* (27.73 days) and the faster was *Schima wallichii* (9.6 days). Differences of physical-physiological seed properties can be considered in conducting seed handling, seed processing and possibilities of seed storage. The results of this study will provide some recommendations on the possibilities of the three local species in terms of planting strategies, seedling production in nurseries and opportunities for implementing direct seeding on the restoration target areas.

Keywords germination, local species, physical-physiological seed properties, seed collection time

A Global Systematic Review of Frugivorous Animal Tracking Studies and the Estimation of Seed Dispersal Distances

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Movement is essential for all organisms, whether it be passive or active, or across local, regional, or global scales. Movement underpins almost all aspects of an animal's lifecycle, from the acquisition of food, mate choice, reproduction, and is intrinsically linked to broader ecosystem processes such as seed dispersal. Frugivorous animals move seeds from the parent plant to the site of germination. We can leverage recent technological advances in animal tracking to better understand frugivore movement and seed dispersal. The purpose of this study is to provide a unique, comprehensive review and synthesis of the existing primary literature of tracking studies that use either GPS or radio telemetry to monitor movement of frugivorous animals on a global scale. We aim to provide a historical overview of the evolution and expansion of tagging technology. Specifically, we also evaluate the quality and quantity of data collected through the use of different tracking methods, and how this has changed over time. Furthermore, we assess the seed dispersal distances of frugivorous animals and assess which species and environmental traits best predict seed dispersal distances. We provide both a quantitative and narrative synthesis of all current published literature that focus on the movement of frugivorous animals using tracking devices. We provide a comprehensive description of the study focus, the species of interest, the tracking method used, and the amount of data collected. We collated the mean and

maximum seed dispersal distances of species from all seed dispersal studies. A total of 148 peer-reviewed research studies were reviewed across a 42-year period. Of these, 62 studies focussed on seed dispersal and estimated dispersal distances. Our data illustrates that there has been a shift in tracking methods over time; with increased use of GPS tags post 2005, and especially for larger animals. GPS units have the potential to collect more data over longer periods. We found that seed dispersal distances increased significantly with body mass and ability to fly. We suggests ways in which future movement studies can be standardised to help aid analysis and future replications, for example reporting all raw movement data and remaining consistent with keywords. These results also emphasise the importance of understanding the movement patterns of frugivorous animals to characterise seed dispersal distances. Seed dispersal is essential for the effective regeneration of many plant species and improved understanding of frugivore movement can help us understand patterns of plant regeneration at the landscape scale.

Keywords Animal movement, Seed dispersal, Behaviour, Frugivores, GPS, Radio tracking, Review

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Exploring the Effects of Fruit Secondary Metabolites on Bat Foraging

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Introduction / Background /Justification: Fleshy fruits are not only rich in nutrients, but also in secondary metabolites (SMs). In contrast to primary metabolites, which function in central metabolism, SMs mediate interactions between plants and their environment. The occurrence of potentially toxic SMs in ripe, fleshy fruits was considered an evolutionary paradox, but several adaptive hypotheses have been articulated to explain their ecological roles. In herbivorous mammals, some SMs function as deterrence, while others encourage food consumption. However, the effects of SMs on frugivores have been largely overlooked. Using the Seba's short-tailed fruit bat, *Carollia perspicillata*, we conducted non-choice preference trials to elucidate the role of four fruit SMs on bat foraging. **Objective(s)/Hypothesis(es):** We addressed two questions: Do specific fruit SMs encourage or deter food consumption? And do bats avoid fruit SMs based on their concentration? We hypothesized that bats would avoid the consumption of these molecules and bats would eat more from the supplemented diet with the lowest metabolite concentration. **Methods:** The study was conducted at La Selva Biological Station, Costa Rica. Bats were housed in individual flight cages and fed with a synthetic diet consisting of mashed ripe banana, soy protein isolate, and supplements. To test how SMs affect the relative preference of *C. perspicillata*, we added four metabolites, piperine (alkaloid), eugenol, tannic acid (phenylpropanoids), and phytol (terpenoid), to the artificial diet at three ecologically relevant concentrations: 0.1, 2, and, 3% dry weight. We offered 5g of supplemented diet and we measured the amount of food consumed in 30 minutes. For each concentration, we conducted ten trials with ten different bats. **Results:** Compared to the control, the four compounds negatively affected food consumption, but only phytol and eugenol showed a statistically significant reduction. Regarding the metabolite concentration, only eugenol showed a deterrent, dose-dependent effect. **Implications/Conclusions:** We demonstrated the ecological costs of fruit chemical traits. Although the metabolites tested occur in Piper fruits, they reduced bat preference. The results are consistent with the trade-off hypothesis, which states that fruit SMs are mainly directed at pathogens, and negatively affect frugivores. In nature, these SMs could protect the fruit against microbes, but with a cost: a reduced preference of the effective seed disperser. Additional studies have confirmed the antimicrobial properties of the metabolites. Physiologically, bats have gastrointestinal adaptations that makes them prone to the absorption of fruit SMs. Our ongoing analyses will also quantify the amount of metabolite absorbed by the bats.

Keywords Chemical ecology, seed dispersal, animal behavior, frugivory

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Which Traits Shape Keystone Resources? A Large-scale Investigation of Fruit-frugivore Networks and Functional Traits of a Major Neotropical Keystone Resource

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The identification of keystone plant resources for frugivores is a contentious issue in ecology and conservation, with applications in restoration and management of tropical ecosystems. Despite recent advances provided by mutualistic networks, we still lack studies addressing large-scale identification of keystone plants and studies addressing the underlying functional traits of keystone resources. Here, we aim to: (1) identify the main keystone plant resource genera for avian frugivores across the Neotropical region, and (2) provide a comprehensive investigation of the functional traits conferring keystoneness. We elected as potential keystone resources genera that combined the highest scores on centrality indices in 38 fruit-frugivore networks in forest and open ecosystems from sea level to mountains. Then, we performed species removal simulations to compare changes in network descriptors (nestedness, modularity and niche overlap) between random removal simulations and removal of species within the potential keystone genera. Subsequently, we focused solely on the main Neotropical keystone genus identified. We explicitly investigated how diaspore morpho-chemical traits, fruiting phenology patterns and widespread consumption by frugivores contribute for the keystone role. From a total of 373 genera, only six were retrieved as potential keystone resources. The removal simulations revealed *Miconia* (Melastomataceae) as the top Neotropical keystone resource for avian frugivores, leading to significant changes in all three network descriptors more than expected by chance. The functional traits underpinning keystoneness for >350 Miconia species are: the production small berries with high pulp:seed ratios, water- and sugar-rich pulps, large crop sizes, and a sequential provision of fruits within communities in periods of resource scarcity. More than 640 frugivorous animals, distributed in five classes, 22 orders and 60 families, including birds, mammals, reptiles, fish, and ants consumed *Miconia* fruits. *Miconia* species are important components of Netropical vegetation, playing a remarkable role in maintaining the structure of fruit-frugivore interaction networks at a biogeographical scale. The sequential fruiting phenologies and wide taxonomic and functional diversity of frugivores consuming Miconia fruits contributes for the keystone role that this genus plays in the Neotropics. *Miconia* fruits are morphologically and chemically accessible to a variety of animals, constituting a reliable resource that sustain entire frugivore assemblages. We argue that the planting of keystone resources could intensify the attraction of frugivores to areas targeted for restoration, increasing seed rain density and diversity. Furthermore, prioritization of *Miconia* species in restoration projects could maximize natural regeneration in increasingly fragmented landscapes in the Anthropocene.

Keywords Ecological Networks, Frugivory, Melastomataceae, *Miconia*, Mutualism, Prioritization, Restoration, Seed Dispersal

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Fruit Shape Is Determined by Ecology More than Species Phylogenetic Relatedness in Neotropical Lauraceae

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Introduction: Fruits and seeds evolve to increase the probability of seed dispersal. Fruit size and shape are therefore influenced by a disperser's ability to ingest and disperse seeds. In bird-dispersed plants, fruits tend to have a conspicuous color, with an edible fleshy pericarp, and an elongate shape and small size. Birds drive selection on fruit by favoring ellipsoid fruits/seeds that can be easily swallowed or peeled in the throat. However, many dispersed seeds then need to grow and survive in the low light of a tropical forest understory, where bigger seeds tend to be more advantageous. We studied whether variation in fruit allometry is more influenced by the availability of dispersers or constrained by phylogeny. **Hypothesis:** Selection for bigger seeds, which survive and grow better, should favor fruit allometry leading to an increase in length but width

constrained by the regional habitat-dependent bird disperser pool. We used bird-dispersed species of Lauraceae to test if fruit shape and size are more influenced by dispersers, habitat, or conserved across the phylogeny. **Methods:** We measured the fruit length and width of 300 species of Supraocotea in the family Lauraceae from herbarium specimens and determined the forest type of the collection. We used linear mixed-effect models to evaluate the effect of forest type on fruit size, shape, and allometry. Within this sample, we also included 100 species from our latest phylogeny of Supraocotea. We therefore were able to estimate the relationship between fruit length and width, controlling for phylogeny for this subset of species. Results Following our hypothesis, species of *Ocotea* with large fruits tended to be more elongate than round, suggesting fruit shape was under selection from bird dispersers. Fruits from the Amazon were larger than fruits from the Atlantic forest and the Caribbean, reflecting different disperser pools. Interestingly, fruit size and shape were not phylogenetically conserved. **Conclusions:** Our results indicate that fruit shape is under selection from strong interactions with potential bird dispersers. The lack of a phylogenetic effect suggests that fruit allometry is flexible and adaptable to the local disperser pool.

Keywords Fruit allometry, frugivorous, Supraocotea

Diversity and Frequency of Trees Relying on the Largest Frugivore in a Madagascan Forest: Implication for Vulnerability to Forest Emptying

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Large-bodied frugivores often play critical roles for dispersing large quantities of various-sized seeds. Unsuccessful regeneration of large-seeded trees has recently been reported in empty forests where effective seed dispersers declined due to hunting or other human disturbances. There is an urgent need for forest conservation taking into account the vulnerable interaction between large frugivores and large-seeded plants. Forest ecosystems in Madagascar have poor frugivorous guilds, and Lemuridae is the sole disperser for seeds over 10 mm in diameter. In this study, we examine the diversity and frequency of trees that rely on the largest frugivore, the brown lemur (*Eulemur fulvus*, Lemuridae), for seed dispersal in a tropical dry forest of Ankarafantsika National Park in northwestern Madagascar, and discuss the potential vulnerability of the forest regeneration system that could be negatively affected by a decline of this largest frugivore. We conducted 1,212 hours of behavioral observations on one group of brown lemurs for 1 year, and recorded the fruit species foraged and their seed-handling behavior. We also analyzed 1126 fecal samples to identify the seed species and measured those sizes. A 15-ha forest plot was established in the same forest, and we identified all trees over 5 cm in the diameter at breast height (DBH) and measured the DBH. Brown lemurs consumed 70 species of fruits over a year, and 23 of them (including 14 woody species) have large seeds over 10 mm in diameter. In the 15-ha plot, we identified 35,757 individuals of 144 species with a total BA of 293.3 m^2. Of these, 34 species (59.7% of individuals and 60.2% of BA), including small-seeded trees, were dispersed by brown lemurs, and 14 species (16.6% of individuals and 29.0% of BA) were large-seeded plants without other dispersers. Among tree species dispersed by brown lemurs, we found that the species with larger seed size (length and width) had the larger maximum DBH. We found that the tree species which rely on brown lemurs for seed dispersal were the major components of the Ankarafantsika forest. In addition, because large-seeded trees can grow into larger trees, brown lemurs probably are responsible for regeneration of large trees through dispersal of large seeds. Unfortunately, illegal hunting of brown lemurs is still ongoing, and there is concern about the forest emptying in Ankarafantsika. If brown lemurs disappear, regeneration of large-seeded trees may be hindered and above-ground biomass and carbon fixation may be greatly reduced.

Keywords dry deciduous forest, seed dispersal, empty forest, lemur, Madagascar

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Does Seed Pubescence Facilitate Secondary Dispersal by Dung Beetles?

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Animal dispersal is the primary mechanism for seed dispersal in tropical forests. Most seed dispersal research is focused on primary dispersers such as mammals and birds. However, secondary dispersal may also be important in protecting seeds from predation and pathogen transmission by reducing seed densities. Dung beetles are secondary disperses attracted to a wide variety of mammal dung. When they bury dung of frugivorous mammals they also inadvertently bury some seeds. Dung beetles often remove large seeds from their dung balls. Seed size is an important trait in determining how the seed will be horizontally or vertically moved by a dung beetle. Such activity could move the seed to a safer or better microclimate, potentially reducing mortality by pathogens and predators and spurring germination. Apart from size, other seed traits such as surface and shape have not been examined concerning their inclusion in dung balls. Here surface traits are the outer layer of the seeds and they can be pubescent (covered in hairs or fibers), striate (with grooves and disrupted surface), or smooth (with a realativly undisprupted surface). During six months of opportunistic collection of dung balls and monkey fecal samples, we observed three species of dung beetles (*Oxysternon conspicillatum*, *Canthon angustatus*, and *Canthidium* sp.), all treating the large (2 cm long) *Spondias mombin* seeds defecated by a brown-headed spider monkey (*Ateles fusciceps fusciceps*) as though the seeds were dung. *S. Mombin* is approximately 1.6 times longer than seeds normally included in either *O. conspicillatum*'s or *Canthon angustatus*'s dung balls. *S. mombin* is covered in a coat of soft hairs (pubescent) which holds the dung and appears to deceive the dung beetles into thinking it is feces. This led us to hypothesize that pubescence might be an important seed trait that increases the acceptable seed size for dung beetles. Large pubescent seeds make up 94% (95%CI [0.80, 1.0]), of large seeds in dung balls and 38% (95%CI [0.17, 0.59]) of large seeds in fecal samples, suggesting that pubescence is an important trait in determining a seed's acceptance by a dung beetle. Furthermore, from the published literature we find that large, roundish, endozoochorous, mammal dispersed seeds were disproportionately pubescent at the genus level ($H2' = 0.147$, $p = 0.048$). Our data show that large seeds are more often pubescent ($p < 0.001$) and that large pubescent seeds are more likely to be included in dung balls. This may suggest that secondary dispersal by dung beetles can exert some selection pressure on mammal dispersed seeds.

Keywords Seed Dispersal, Dung beetle, Traits, Pubescence, Neotropical

Knowledge and Use of Tropical Plant and Animal Species

Session Recording: https://youtu.be/VGnTIg4u5Qo

Slimming Effect of *Ipomea* Sp: Study in Order to Valorization of This Specie.

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In the worldwide, the deaths of 2.5 million people each year was due to the obesity. In Madagascar, people use many medicinal plants such as *Ipomoea* sp. to heal obesity. However, they are not able to determine the appropriate dose, risking their lives due to poisoning. This research investigated the traditional use and activity of *Ipomoea* sp. on obesity. We studied the slimming activity of the extract of this plant in mice experimentally obese. We checked its activity on food intake, on the reduction of weight, and the reduction of fats on the target organs (perirenal, abdominal). After 10 days, we recovered the following mice weight: (i) 30.66 g 32 g for the controls mice; (ii) 30.5 g24 g for mice treated with 150 mg/kg of *Ipomea* sp.; (iii) 30.33 g24.66 g for mice treated with 300 mg/kg of Ipomea sp.; and (iv) 30.5 g24 g for mice treated with 600 mg/kg of *Ipomea* sp. We also recovered the following cumulative amount of food ingested: (i) 37g for controls mice; 25.66 g for mice treated with 150 mg/kg of *Ipomea* sp.; (iii) 23.66 g for mice treated with 300 mg/kg of *Ipomea* sp.; and, (iv) 21 g for mice treated with 600 mg/kg of *Ipomea* sp. Furthermore, the total mass of adipose tissue in the mice were as follows: (i) 0.93 g in the controls mice; (ii) 0.60 g for mice treated with 150 mg/kg of *Ipomea* sp.; (iii) 0.58g for mice treated with 300 mg/kg of *Ipomea* sp.; and (iv) 0.50g for mice treated with 600 mg/kg of *Ipomea* sp. Secondary compounds found in *Ipomea* sp. such as tannins, saponins, alkaloids and flavonoids have been shown to lead to significant slimming. When compared to other the chemicals used to treat obesity (i.e., cafeine), *Ipomea* sp. was shown to be very effective. This research highlights the potential of local plants for medicine, showing that native plants can have important implication for Malagasy public health. Nature-based solutions should be further explored in the country, which be important for the sustainable development of Madagascar.

Keywords *Ipomoea* sp, obesity, slimming

Vegetative Propagation of *Syzygium caryophyllatum* (L.) Alston, an Underutilized Fruit Species: Effect of Stem Cutting Types, Potting Media and Auxin

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Syzygium caryophyllatum (L.) Alston (S: Dan) is an evergreen tropical fruit plant that belongs to family Myrtaceae and found in the intermediate and wet lowlands in Sri Lanka. Generally, it is considered as an underutilized wild fruit due to the unawareness of the nutritional properties and economic value among general public. In order to bring this underutilized fruit species back into cultivation, establishment of a suitable propagation system for mass propagation is important. Therefore, the research was designed to determine a suitable potting medium, a stem cutting type and the requirement of auxin to establish a successful vegetative propagation system for *S. caryophyllatum*. Soft wood, semi hard wood and hard wood cuttings of *S. caryophyllatum* were planted in three different potting media (M1- top soil:sand 1:1, M2- top soil:sand:compost 1:1:1 and M3- top soil:sand:coir dust 1:1:1) with two treatments; T1- with the application of the rooting hormone indole-3-acetic acid (IAA) and T0- controls without IAA. Each experiment was conducted with 15 replicates. The cuttings were planted in individual propagators and were kept in a net house of 50% shading under room temperature. Growth performance of the stem cuttings was evaluated using the number of sprouted cuttings, number of shoots, shoot length and the number of leaves per cutting as growth parameters by the observations in regular intervals (every 28 days) for a period of six months. After the sixth month, fresh and dry weights of the whole plant, shoots and roots were measured using randomly selected plants from each treatment. In addition, the number of roots (tap root and lateral roots), length of the roots, and the length of the longest root were also measured. Data was analyzed using Two-way ANOVA in Minitab 17 software. According to the results of sprouting, survival, and growth parameters, the best potting medium for *S. caryophyllatum* was M1- top soil:sand (1:1). M2 and M3 potting media were not successful for the growth of stem cuttings of *S. caryophyllatum*. Both soft wood and semi hard wood cuttings under T1 treatment expressed higher sprouting (80% and 93%, respectively) and survival percentages (67% and 87%, respectively) while semi hard wood cuttings under T1 treatment has shown the highest sprouting (93%), survival (87%) and growth performance. Hence semi hard wood cuttings with IAA application can be considered as the best planting material for vegetative propagation of *S. caryophyllatum* while top soil:sand (1:1) is the best potting medium.

Keywords Growth performance, Potting media, Stem cuttings, *Syzygium caryophyllatum*, Vegetative propagation

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Potential Use of Philippine Tung (*Reutealis trisperma*) for Phytoremediation of Heavy Metal Contaminated Land

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During the last 5 decades, the rapid rural and urban development has led to a significant increase in the environmental pollution. In addition to industrial development in general, mining work is one of the factors that produces heavy metal contaminants in the environment. Gold mining, for example, at artisanal level, they produce a lot of mercury (Hg) contaminant, while for gold mining industries, they produce a lot of tailing with high amounts of lead (Pb). Both require extra attention to solve the environmental problem. This paper aimed to reveal the possible uses of underutilized non-edible oil producing plants to support the program of phytoremediation of heavy metal contaminants especially Hg and Pb. The experiments have been carried out using four species namely Jatropha (*Jatropha curcas* [Linn.]), Castor bean (*Ricinus communis*), Bead tree (*Melia azedarach*) and Philippine Tung (*Reutealis trisperma* [Blanco] Airy Shaw) with two type of experiments. The first experiment was carried out using water culture exposed with different concentrations of Hg and Pb, and the second experiment was applied directly using gold mine tailings in the pots. The initial experiment had also been started to use Dark Septate Endophyte (DSE) fungus as biological agent to support adaptability of those species to gold mine tailings. The morphological, anatomical as well as physiological parameters

were observed during the treatments to analyze response of those species to heavy metal treatments. The treatments using Pb and Hg, as well as gold mine tailings caused the decrease of shoot as well as roots growth and chlorophyll content of all the plants significantly, while they increased malondialdehyde (MDA) contents in the leaves, suggesting that all the plants underwent stress due to the treatments. In water culture experiment, even though all the species have ability to survive for several periods, but only *R. trisperma* had superior performance in Pb treatment, while under Hg treatment, *R. trisperma* and *Melia azedarach* were more adaptable than others. In gold mine tailing, *R. trisperma* was also found to be the most resistant species to gold mine tailings based on its ability to maintain growth even under 100% gold mine tailing. Inoculation using DSE fungus improved the performance of *R. trisperma* and *J. curcas* grown under gold mine tailing. These experiments proved that *R. trisperma* is resistant to Hg and Pb stress and can be recommended as a plant for heavy metal phytoremediation and soil reclamation purposes.

Keywords Environment; non-edible oil producing plants; *Reutelis trisperma*; mercury; lead

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Useful Plants of Colombia: A Taxonomic and Geographic Perspective

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Colombia is a country located in the Neotropics and it is considered a megadiverse country with more than 26,000 species of native plants. Many of them have been considered useful throughout the history of the country; however, a large part of the uses has been lost due to the jeopardizing and erosion of knowledge. Making visible and compiling this knowledge is of vital importance as a potential source for the bioeconomic development of the country, and as a part for the likelihoods of society. Similarly, centralizing knowledge of the use of species allows a greater understanding of the richness of useful plants and facilitates their study and understanding. Therefore, as part of the project "Useful plants and fungi of Colombia", the objective of this work was to compile a list of useful plants in Colombia from a systematic review of secondary information and gray literature from about 1500 references of uses registered mainly in Colombia. Based on this revision, the synonyms for the scientific names were checked, the uses of the species were categorized by general and specific categories, geographical distribution by Colombian regions and taxonomic classification by families and genera were recorded. As a result of this methodology, a list of 4204 species of useful plants (about 16% of the total plant species) belonging to 248 families and 1329 genera was compiled. Of these, those with the greatest number of useful species are Fabaceae family, followed by Asteraceae and Rubiaceae, and *Inga*, *Solanum* and *Passiflora* the most recorded genera. Regarding uses, the general category with the highest number of uses is medicines, followed by food use and materials (raw materials). At geographical level, the species are distributed mainly in the Andean and Amazon region of Colombia, and 287 are endemic to this country. From this analysis, it is possible to highlight that Colombia has a significant number of useful plants, most of which are not widely used in the country and constitute a potential resource of natural ingredients, especially in the most populated areas corresponding to the Andean region.

Keywords Useful plants, Colombia, regions, uses, categories, genera and families.

Ethnomedicinal Assessment of Herbaceous Plants in the Guineo-congolese Zone of Benin: Case of Pobè and Plateau Phytogeographic Districts

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In Benin, plants occupy a primordial place in the life of man in society with regard to its many functions in the food, medicinal, cultural, agro-forest and technological fields. However, knowledge of herbaceous plants used in the treatment of different diseases is not as popular as woody species. This study proposes (i) to identify the main herbaceous plants in two phytogeographic districts (Pobè and Plateau) of the Guineo-congolese zone of Benin and (ii) to assess the effect of socio-environmental factors such as age, sex, level of education, religion, ethnicity and the phytogeographic district determining knowledge of plants. A study is conducted through individual and semi-structured interviews with 159 people on medicinal herbaceous species in the Guinero-Congolese zone of Benin. The medicinal use values (UV) and the relative quote frequencies of each species have been determined. The Kruskal-Wallis inference test is carried out on socio-environmental factors to identify significant effect factors. The principal component analysis (PCA) has been applied to the variable value of medicinal use (UV) variables with significant effect. A total of 56 herbaceous species have been identified in the treatment of various diseases and which are grouped together in 35 families and 56 botanical genres with a significant effect of sex, ethnicity, religion and level of education. Of the 56 species identified, 05 species are more demanded in the treatment of diseases than others. This study can contribute to the preservation and conservation in a sustainable manner of natural resources and the strengthening of knowledge of herbaceous plants in the Guinero-Congolese zone of Benin.

Keywords Herbaceous plants, medicinal, Plateau, Pobè

Indigenous Knowledge on Forest Protection and Management: Focus on Obu-Manuvu of Davao City

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Forests are crucial for the health and well-being of people, wildlife, and our planet. It is also home to many cultures including the indigenous people. But, forests, and the people who depend on them, are now under tremendous pressure worldwide. Indigenous communities surrounding forest areas and other protected areas have developed patterns of resource use and management that reflect their intimate knowledge of local environments and ecosystems (Fernandez-Baca & Martin 2007). However, the use of indigenous knowledge, in general, has declined because of the interaction of mainstream science, technology and education, the knowledge, management practices, and the historical and cultural contexts of indigenous and local communities have been marginalized for generations. The aim of this study was to document and understand the indigenous knowledge of the Obu-Manuvu in Barangay Carmen, Baguio District, Davao City specifically on forest protection and management as a tool and source of knowledge for natural resource management. The descriptive research design was adopted for this study while purposive sampling was used in selecting the respondents. Literature review, key informant interviews (KII), focus group discussions (FGD), field observation (FO), site visits and immersions were used to attain the objectives. Results showed that the Obu-Manuvu community had a clear knowledge on resource utilization and practices that ensure long term forests resource protection and management. Their indigenous knowledge exists in harmony with nature and clearly defined in a framework called "Pusaka"- a long-standing practice of the Obu-Manuvu tribe of sanctifying items, animals and lands-all that are considered valuable to their culture and history. This study identified several best practices and highlighted cases on forest protection and management that can be replicated and harnessed for natural resource management. Recommendations include provision of information and avenue for the government, stakeholders and other concerned agencies in finding ways to resolve environmental issues and implement programs based on the indigenous knowledge and best practices of the indigenous peoples for sustainable natural resource management.

Keywords indigenous people, forest protection, natural resource management, indigenous knowledge, Obu-Manuvu, resource utilization, conservation, culture, "Pusaka", forests, framework.

Ethnozoological and Commercial Drivers of the Pangolin Trade in Benin

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Pangolins have been raised to the rank of conservation flagship species due to unsustainable volumes of trade, feeding local and global trade networks for meat consumption and medicinal use. Despite the recent 'evil label' wrongly attributed to pangolins as part of the COVID-19 pandemic, pangolin derivatives remain one of the key inputs of the Traditional Chinese Medicine. Pangolin derivatives are also widely sold in West African traditional medicine markets (TMMs), but the socio-dynamics of such trade have poorly been described. We assembled information about medicinal and spiritual uses of pangolins among different ethnic groups across Benin (West Africa), describeds the cohort of buyers involved in the pangolin trade and assess the economic values along the chain, as notably influenced by local (West African and Chinese) diasporas. We organised 54 focus groups in villages surrounding occurrence habitats of pangolins across Benin and conducted 35 individual interviews with vendors from five TMMs. Our questionnaire addressed the different uses of pangolins, the commercial value of pangolin items, the categories of clients and the related selling prices. Pangolin meat was strictly consumed as food. Scales, head, bones, tongue, blood, heart and xiphisternum were the items used by local communities as part of medicinal (65 % of the focus groups) and spiritual (37 %) practices. Scales were the most frequently used item (use value index = 1.56). A total of 42 medicinal and spiritual uses, covering 15 International Classification of Diseases (ICD) categories, were recorded among ethnic groups. The ICD and spiritual categories-based analyses of similarity showed a partial overlapping of ethnozoological knowledge across Benin, although knowledge was significantly influenced by ethnicity and geographic location. The pricing of pangolins both varied with the category of stakeholders (local communities vs. stakeholders of TMMs) and clients (local and West African clients vs. Chinese community), and the type of items sold. The Chinese community was reported to only buy pangolins alive and average selling prices were 3-8 times higher than those to West African clients. Our results confirm that pangolins in Africa are valuable and versatile resources for consumption and medicinal / spiritual practices. The pangolin trade in Benin is based on an endogenous and complex network of actors that now appears influenced by the specific, high-valued demand from the Chinese diaspora. Further investigations are required to assess the growing impact of the Chinese demand on the unsustainable pangolin trade and, more generally, African wildlife.

Keywords Ethnozoological knowledge, Spiritual use, Traditional medicine market, Wildlife trade, Pangolins

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Ethnobotany in Conservation Science: Assessment of the Change of the Relationship of Use Value and Ecological Availability of Woody Species

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In tropical Africa countries, to date the biodiversity conservation remains challengeable with the global change that includes climate change and human disturbance. Thus, the human people interaction with plant is important to be explored to help guide biodiversity conservation. Objectives: The study aimed to assess the relationship between use value and ecological availability of woody species according to the type of use, the grow form and the intensity of human disturbance. Methods: Two reserve forests with different human disturbance intensity (Wari Maro: weak level of human disturbance; and Bellefoungou: high level of human disturbance) were targeted. A semi-structured interview with 184 people (149 in Wari-Maro and 35 in Bellefoungou) was carried out for seven use categories (medicine, food, timber, fuelwood, construction, fodder and veterinary). Additionally, a forest inventory performed in rectangular plots (42 in Warr-Maro and 25 in Bellefoungou) of 50 m x 30 m consisted to inventory 57 and 41 useful woody species respectively in Wari-Maro and Bellefoungou.

The use value (UV) and the ecological importance value index (IVI) were computed. A simple generalized linear regression analysis was performed between use value and importance value index according to the type of use and the grow form at each human disturbance level. Results: The relationship between use value and importance value index is significant for the all uses categories except medicine at Wari-Maro forest. Unlike, at Bellefoungou, the usage value – importance value index is significant only for the timber use. It was also noted that the relationship use value–importance availability index depends significantly on the growth form of the woody species. The use value-importance availability index relationship at Wari-Maro forest reserve was not significant for the "shrub" whatever the type of use while the relationship was significant for the tree growth form for most types of use. The relationship was assessed at Bellefoungou forest only for the timber use and it was significant for shrub and was not significant for tree. Implications: The pooling of such findings will help to design woody conservation in a context of human use pressure.

Keywords Biodiversity Conservation, woody species, Ethnobotany, Use value, Ecological availability

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Ethnozoological Knowledge and Modeling of the Spatial Distribution of the African Civet in a Context of Climate Change

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The African civet (*Civettictis civetta* Schreber, 1776) is one of the four vertebrate mammals producing an aromatic drug present in the protected areas and natural ecosystems which is vulnerable in Benin. In order to understand the importance of African civet for the local populations of natural ecosystems, in particular those of the Guinean-Congolese zone, a survey was carried out among one hundred (100) people in ten (10) districts, namely Abomey-Calavi, Sô-Ava, Zè, Avrankou, Porto-Novo, Cotonou, Ifangni, Sakété and Zogbodomey. This survey phase was coupled with the occurrence data collection on the species in order to evaluate the favorable areas in the present and future under the RCP8.5 scenario by 2055 and by 2085. The results showed that ethnozoological knowledge of the species is held more by traders and traditional practitioners. The species is widely cited for its food value (100% of respondents), medicinal value (55.22% of respondents), spiritual value (42.40% of respondents) and ornamental value (2.38% of respondents). A total of 10 diseases are treated by the organs or products of the African civet involving twelve organs. The organs are used alone or in combination with other plant or animal products for the medicine's composition. The most commonly used organs are the skin (79%), the bones (68%) and the skull (60%). The diseases or pathologies most commonly treated are sickle cell disease (62%), locomotion disorders (45%) and sterility (34%). The evaluation of the extent of favorable areas for the species with maxent algorithm showed that areas with environmental conditions linked to the realization of its ecological niche have been identified throughout the country. The different models show that up to 2085, areas favorable to the realization of the species ecological niche exist but in small areas. All the predictive models obtained have an AUC value between 0.80 and 0.9; which confirms their good performance. For a sustainable conservation and management of the species and its habitats, the study suggests the implementation of an action plan including local populations in the conservation of the African civet, which will consider the prohibition of over-hunting, participatory monitoring of habitats and numbers, and the creation of Community Protected Areas for all the habitats of the African civet and other species of importance for biodiversity in the context of climate change.

Keywords African civet; Ethnozoology; Modelling; Conservation ; Ecological niche

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Edible Freshwater Mollusks as Bioresources from Northeast India

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Introduction/Background/Justification: Since the existence of hunter-gatherer societies, mollusks were consumed in many parts of the world. In both underdeveloped and developed parts of the world, wild populations of freshwater mollusks are extensively harvested for consumption. The tribal communities of northeast India routinely consume freshwater mollusks. These mollusks are in high demand among the locals as they are a cheap source of protein, provide food security, livelihoods and are also consumed for medicinal purposes. **Objectives/Hypothesis:** Our main objective was to document the diversity of freshwater mollusk species sold, their quantity, location of harvest, and other traditional knowledge associated with it from different states of northeast India. **Methods:** Market surveys were conducted in Assam, Meghalaya, Manipur, Mizoram, Nagaland, and Tripura between July 2018 and February 2021. We undertook structured interviews and informal interaction with the vendors selling mollusks as well as the locals and collected information on local names, medicinal importance, harvest, and price of these edible freshwater mollusks. Overall, twenty-three local markets were sampled. Minimum five individuals of each species sold in the market were collected and preserved in 100% ethanol for taxonomic authentication. DNA barcode analysis using mitochondrial COI marker was carried out for species belonging to the genera *Paludomus* (Paludomidae) and *Brotia* (Pachychilidae) since they show high variability in shell characters. **Results:** Seventeen species (fifteen gastropods and two bivalves) of freshwater mollusks belonging to five families and six genera were recorded from our studies. Molecular analyses show that six different species of *Paludomus* and five different species of *Brotia* were sold in the markets. In addition to these eleven species, *Pila olea* (Ampullaridae), *Filopaludina bengalensis* (Viviparidae), *Angulyagra* sp. (Viviparidae), *Cipangopaludina lecythis* (Viviparidae), and two bivalves, *Lamellidens marginalis* (Uninoidae) and *Lamellidens* sp. (Uninoidae), were also sold. The quantity and type of species harvested vary between seasons, and various states exhibit different patterns of medicinal importance of snails. **Implications/Conclusions:** This is the first study highlighting putative new species of *Paludomus* and *Brotia* sold in the markets of northeast India, which at present, are each sold as a single species. Most of the edible freshwater mollusks either have incorrect taxonomic status or are Data Deficient or Least Concern under the IUCN Red List Categories. Therefore, it is essential to document, study, research, and develop effective management strategies to conserve the freshwater molluscan biodiversity and their habitats. Understanding species harvest quantity, diversity, and population combined with the livelihood of tribal communities can help sustain natural resources.

Keywords Molluscs, sustainable, northeast, livelihood, traditional knowledge, diversity, harvest, least concern

Climate Change: Adaptation and Mitigation- Part I

Session Recording: https://youtu.be/ul9QlS00GeA

A Review on the Impacts of Climate Change on the Biodiversity of Sri Lanka

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Sri Lanka is a tropical island situated in the Indian Ocean and is renowned for its rich biodiversity as a result of the variation in climatic conditions, topography and soil conditions which creates a diverse range of ecosystems. However, there has been an increase in threats to the biodiversity, especially due to anthropogenic activities. Additionally, climate change is also having an impact on Sri Lanka's biodiversity. Therefore, a literature review was designed to evaluate the scope and comprehensiveness of existing evidence base on climate change impacts on biodiversity and identify research gaps and needs as well as gaps and needs related to integration into policy and legal framework in Sri Lanka. According to the existing body of research, Sri Lanka is considered as vulnerable to impacts of climate change which include prolonged droughts, heavy rainfall, floods, temperature variations and destructive winds. The island's climate primarily depends on the rainfall pattern however, according to recent studies, Sri Lanka has shown strong decreasing trends in changes in precipitation indices when comparing with other countries in the region which is likely to pose a huge threat to the biodiversity. Climatic changes such as the rise in temperature and prolonged droughts are affecting species in several ways. Distributional patterns of floral and faunal species are impacted, with the range of distribution of some species increasing but rendering areas unsuitable for others, especially the species living in higher altitudes who are threatened by extinction. Mass deaths of the endangered Pigmy Lizard (*Cophotis ceylanica*) have been observed around Hakgala and Nuwara Eliya. The increase in south-east monsoonal winds has affected several amphibian species in the country, which depend on moist conditions under rocks and boulders for breeding and residing. Overall, this research has identified major gaps in the available evidence of climate change impacts on biodiversity, with only a limited number of studies conducted within the country. There is also a lack of data on how climate change has affected individual species. National policies and regulations, including those related to climate change and sustainable development, acknowledge some of these knowledge gaps but do not yet comprehensively address them. Therefore, conducting research on these key areas is of high importance to identify the varied and diverse impacts of climate change on Sri Lanka's biodiversity. These findings will be helpful to enhancing conservation measures and protect key vulnerable species.

Keywords Climate Change, Biodiversity, Vulnerable

Impact of Human Footprint on the Climate FAPAR Relationships across Colombia's Ecosystems over the Last 21 Years

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Photosynthetic activity is a fundamental process that drives the terrestrial biosphere, regulates the carbon cycle, and impacts Earth's climate. Photosynthetic activity, often measured as the Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), is modulated by climate factors, such as solar radiation, temperature and precipitation, but also by the physiology of ecosystems and human activity. Because of the feedback mechanisms between photosynthetic activity and climate, it is important to better understand their interactions with human activity; especially in tropical regions with high biodiversity where natural ecosystems still exist. To do so, we analyze the spatiotemporal relationships of monthly precipitation and temperature with FAPAR using correlation analyses. To uncover the impact of human activity on these relationships, we evaluate the relationship of the human footprint index between 1999 and 2019 on the precipitation – FAPAR and temperature – FAPAR relationship. We find that FAPAR dynamics are in general driven by precipitation and to a lesser extent by temperature. However, the response of FAPAR across Colombia's ecosystems is diverse. Over large extents of the Carribean and the Andean region, FAPAR responds positively to both temperature and precipitation. Over the Amazon forest FAPAR is positively correlated with temperature, but shows a negative correlation with precipitation. This might be related to the occurrence of clouds during the rainy season that limit solar radiation and hence FAPAR. In the eastern great plains FAPAR is positively correlated with precipitation and negatively with temperature indicating strong droughts where the lack of water and high temperatures limit photosynthetic activity. Interestingly, the Amazonian deforestation hotspots in the department of Caqueta behave similar to the savannas of the eastern great planes. The Chocó biogeographic region, one of the most biodiverse places on Earth, shows all possible combinations of positive and negative correlations and no clear pattern emerges. Considering the effect of the human activity on the relationships between FAPAR and climate, we find that with increasing human footprint, ecosystems respond stronger and faster to precipitation. However, the FAPAR-temperature relationship is only weakly affected by the human footprint. Our analyses demonstrate how climate and human activity modulate photosynthetic activity under a wide range of climatic conditions in the neotropics. Our findings contribute to a better understanding how climate change and human activity impact ecosystem functioning in the tropics.

Keywords Colombia, FAPAR, Human Footprint, climate

Biodiversity Conservation versus Food Security in the Face of Climate Change: Case of the Mikea Foragers in Madagascar

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Protected areas are one of the most widely adopted conservation strategies across the tropics which have often been implemented to the detriment of their original occupants. These marginalised communities are also trying to cope and adapt to environmental changes including climate change. We used palaeoecological proxies including coprophilous spores and microscopic charcoal to investigate the response of forager communities from the southwest region in Madagascar, to the aridification of the region in the last millennia and how these might affects the conservation in this area. The results show that there was an increasing coprophilious spores at the near present period reflecting an increase in herbivory activities around the investigated site possibly related to activities conducted by pastoralists living within the area. However, charcoal records increased slightly but remained stable during the dry periods. This suggests that these communities have adapted their livelihoods from foraging only into a mixed livelihood by adding a seasonal use of fire for agriculture to increase their food resources during the drying periods. Yet, no significant changes in the vegetation were recorded linked to this change in the last century. In this talk, I will demonstrate how the inclusion of local communities into management strategies could allow not only to conduct effectively conservation strategies but also maintain and guarantee food security for these population and building resilience to future environmental crises.

Keywords Biodiversity conservation, indigenious communities, livelihoods, aridification, Madagascar

Combined Impacts of Climate and Land Use Change and the Future Restructuring of Neotropical Bats Biodiversity

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Forecasting the effects of climate and land use change on biodiversity are useful to examine threats operating at different scales in space and time and to locate vulnerable and important conservation areas. Here, we assess the projected impacts of climate and land use change on bat species by forecasting changes in environmental suitability, explicitly controlling for the effect of habitat type specialisation on vulnerability to changes. We also identify the most threatened bioregions and those that may offer future refugia. Combining ecological niche models and land cover filter masks under different scenarios of climate and land use changes and distinct dispersal assumptions, we generate projections of occupancy dynamics for 232 Neotropical bat species and investigate large scale diversity patterns. Range contraction of habitat-specialists were more common and stronger, under all dispersal simulations. The Amazonia is likely to suffer the highest turnover rates on bat species richness in the future, while the Andean grassland, Cerrado and Chaco will probably experience the greatest losses. The Dry Western (Northern Andean mountains) may receive a large number of bats on the move in the future. Five narrow-ranged endemic bat species will have no analog environments in the future. The expansion and spread of habitat generalists, which forage in open areas and commonly establish large colonies in manmade structures, coupled with range contraction of habitat specialists will homogenise bat communities across the Neotropics. Warm-adapted species might expand their ranges towards higher altitudes, while mountain-top specialists will run out of suitable climate. We also stress the urgent need for long-term monitoring of the responses of five endemic bats to future environmental change and the projected range expansion of two sanguivore bats into new bioregions. Dispersal will be the key for the future of bat diversity, thus safeguarding the refugia highlighted here, by expanding and connecting the existing network of protected areas, may allow species to move in response to climate change, ensuring at least some chance of persistence for several bats in the changing Neotropics

Keywords upward and upslope shifts, refugia, biodiversity re-distribution, megadiverse regions

Arboreality Drives Heat Tolerance While Elevation Drives Cold Tolerance in Tropical Rainforest Ants

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Introduction: Determining how species thermal limits correlate with climate is important for understanding biogeographic patterns and assessing vulnerability to climate change. The relationship between thermal tolerance and environmental temperatures has primarily been addressed at broad spatial scales such as latitude or elevation. But neither scale adequately captures finer scale temperatures that smaller organisms are exposed to. **Objectives:** Our study takes a multiscale approach to investigate how the vertical climate gradient created by trees (arboreality) interacts with elevation to shape the thermal ecology and climate change vulnerability of rainforest ant species in the Australian Wet Tropics Bioregion. We test whether the thermal tolerance of wild caught ants follow the predictions of the thermal adaptation and thermal niche asymmetry hypotheses at these two spatial scales. **Methods:** We tested critical thermal limits using ramping assays for 71 colonies of 40 ant species collected from terrestrial and arboreal habitats at lowland and upland elevation sites and recorded microclimatic conditions for one year. **Results:** Within sites, arboreal ants were exposed to hotter microclimates and on average had a 4.2°C (95% CI: 2.7 – 5.6°C) higher heat tolerance and 5.2°C (95% CI: 3.5 – 7°C) broader tolerance range than ground-dwelling ants. This pattern was consistent across the elevation

gradient, whether it be the hotter lowlands or the cooler uplands. Across elevation, upland ants had significantly lower cold tolerance, than lowland ants, whereas the change in heat tolerance was less pronounced, and thermal tolerance range did not change over elevation. **Conclusions:** Differential exposure to microclimates because of localised niche preferences drives divergence in heat tolerance while environmental temperatures along the elevation gradient drive divergence in cold tolerance. Our results suggest that both processes of thermal adaptation and thermal niche asymmetry are at play depending on the spatial scale of observation, and we discuss potential physiological and behavioural mechanisms underlying these patterns. Despite the broad thermal tolerance range of arboreal rainforest ants, lowland arboreal ants had the lowest warming tolerance and may be most vulnerable to climate change. More broadly, this signifies that ground and arboreal microhabitat choice is an important indicator of climate change vulnerability and should therefore be included in conservation management plans that are aimed at reducing climate change impacts on forest biota.

Keywords ants, arboreal, canopy, climate change, climate gradients, CTmax, CTmin, thermal

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Variability in Echolocation Calls of Insect-eating Bats as an Adaptation to Changes in Ambient Temperature

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Climate change is a major threat to biodiversity conservation; it generates impacts on geographic ranges, species turnover and abundance, and ecological interactions, among other effects. Still, there is a lack of information of how these changes will affect behavioural decisions that species make through their sensory systems. Insectivorous bats, for example, rely on echolocation calls to orientate, and to effectively capture prey, which makes it a fundamental sensory mechanism for species survival. However, the range over which these calls operate is a direct function of temperature and relative humidity, which determine sound attenuation. Hence, climate change may alter the distance over which bats can detect echoes to find food. An interesting possibility is that the vocal plasticity of bats will allow them to respond to shifts in temperature and relative humidity even at short temporal scales and adjust calls accordingly. We hypothesized that bats may decrease call frequency, increase call level, increase call duration, or any combination thereof to keep constant prey detection ranges. We recorded vespertilionid bats in pre-montane forests of Costa Rica with a four-microphone array inside a flight tent at three different combinations of temperature and relative humidity. We reconstructed flight trajectories to determine the position of the bats when they emit the call, and from each call, we analyzed call duration, call frequency, and call level, to assess the range of 'view' of each individual under the experimental temperature and humidity conditions. We found that each individual kept the detection ranges relatively constant, independently of weather conditions. Although we did not find specific differences in call parameters between experiments, we believe that the large variability of bat echolocation calls may allow them to quickly adapt calls to different environmental conditions. Our research is the first assessment that considers how changes in temperature and humidity affect call production under controlled conditions. It increases our understanding of the ability of insectivorous bats to adapt to climate change, and the potential effects on bat assemblages. We expect to broaden the knowledge of sensory ecology of Neotropical bats, and share insights of how prone they are to stay resilient despite changes in environmental conditions.

Keywords Acoustic variability, echolocation, insectivorous bats, sensory ecology, temperature

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Risk of Extinction of Two Populations of *Anolis tolimensis* (Dactyloidae) in the Colombian Eastern Cordillera

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Climate change negatively impacts some biological populations worldwide, particularly, for ectothermic organisms carrying out thermoregulation processes as the maximum levels of efficiency becomes more difficult. For tropical lizards, populations under different warming scenarios have been shown to vary their population size, with some predictions even pointing at the extinction of populations and species. Differential impacts of warming are seen in elevational gradients and, particularly for lizards, might be explained by interesting thermoregulatory adaptions at different altitudes. Andean system in Colombia for example is the perfect setting to understand the importance of height in thermoregulation processes. In this study we described some thermal ecology characteristics of *Anolis tolimensis*, an endemic and poor-studied species from Andean system in Colombia to investigate how its risk of extinction varies between two sites with different altitude. We included individuals from two localities at different altitude (1400-1800 masl, 1900-2200 masl) and with different vegetation attributes. We record body temperature and preferred temperature (Tpref) for 20 adult individuals. We incorporate this information in the estimation of models of extinction risk under different climate change. This type of study allows us to know from a physiological perspective the different responses to which the lizard populations will be subjected in the Neotropics. Our study highlights the importance of estimating the risk of extinction of endemic taxa using ecophysiological models taking advantage of tools that include thermoregulatory aspects of the species, these being of vital importance for the fitness of the species.
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Keywords Lizards, Physiology, Neotropics , Climate Change, *Anolis*, extinction

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Local Hydrological Gradients Structure High Intra-species Variability in Plant Hydraulic Traits in Two Dominant Central Amazonian Tree Species

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Understanding the sensitivity of tropical trees to drought is key to predict how climate change might influence the distribution of species across environments. Knowledge of Intra-specific trait variability is important to address this challenge but notably understudied in the Amazon, especially in relation to plant hydraulic traits that are often used to project drought responses. Here we quantified intra-specific variability for two dominant central-Amazonian tree species along gradients of water table depth and canopy exposure to light, while accounting for tree age and height. We included plant-economic spectrum traits (leaf mass per area, and wood density) and hydraulic traits (xylem embolism resistance: P12, P50, and P88). Surprisingly we found a high intra-specific variation in hydraulic traits (e.g., P50) comparable to the whole-community variation. Individual trees of both species growing on plateaus with deep water tables showed higher embolism resistance than trees in valleys with shallow water tables. While intra-specific variations of economic traits were lower ($\sim 1/3$ to $1/2$ of the tree community variation), did not coordinate with hydraulic traits, and were modulated by the crown light exposure associated with plant height. Our findings suggest that the hydrological environment played an important role in regulating embolism resistance in both species while economic traits are species-dependent structured by size and light. These variations may lead to differential within-population climate change sensitivities along environmental gradients.

Keywords Light environment; hydrological environment; tree rings; central Amazon; hydraulic; environmental

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The Yin & Yang of Forest Elephants: Ecosystem-engineering and Opportunities for Conservation

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Introduction: The African forest elephant (*Loxodonta cyclotis*) plays an important ecosystem-engineer role in central African rainforests by interacting with plants and its environment. For example, the presence of forest elephants has been linked with increased aboveground biomass in Congo basin's forests. By reducing plant density, elephants allow adult trees to become larger and store more carbon. Elephant movements and browsing preferences are also important factors shaping forest structure and species composition. A growing body of literature on forest elephants is available but a quantitative overview of their ecosystem engineering role is lacking. Additionally, the influence of elephant feeding and seed dispersal on above ground carbon has not been evaluated. **Objective:** Our first goal was to provide an overview of the ecosystem engineering role of forest elephants based on quantitative estimates found in literature. Additionally, we tested the hypothesis that elephants prefer to feed on low wood density species as these are fast-growing trees which invest less in herbivory defenses. Finally, we evaluated if tree species primarily dispersed by elephants have higher wood density and quantified their contribution to aboveground biomass in central African forests. **Methods:** We reviewed published studies on elephant feeding preferences and their effect on forest properties and processes such as plant mortality and canopy openness. We also included unpublished feeding data collected in Ndoki-Noubale National Park (Republic of Congo). Forest inventories from different sites in the Congo basin were coupled with wood density and dispersal-mode data to evaluate the relationships between wood density, tree size, feeding preferences, and dispersal mode. **Results:** In the literature, the effects of elephants were quantified for small plant mortality, tree toppling, branch breaking, average tree size as distance from trails, and elephant presence as a function of tree size, stem density, and understory openness. Elephants feed more frequently on low wood density trees and elephant-dispersed trees are larger with higher wood density compared to species with other dispersal modes. **Conclusion:** Ecosystem-engineering of forest elephants has only been quantified for a few ecological processes but many others are still unknown such as nutrient redistribution. Elephants contribute to increasing aboveground carbon not only by reducing plant density but also by feeding on low wood density species and dispersing high wood density trees. Our study confirms the transformative role of elephants in African rainforests. Their significant contribution to carbon sequestration has important implications for protecting a nature-based solution for climate change.

Keywords Carbon cycle, megafauna, nature-based solutions, plant-animal interactions, seed dispersal

Climate Change: Adaptation and Mitigation- Part II

Session Recording: https://youtu.be/Mw58wl0feh0

Climate-growth Correlations of Congeneric Tree Species Are Modulated by a Neotropical Vegetation Gradient in Northeastern Brazil

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Tropical forests are among the main climate regulators on the planet and are essential to numerous ecosystem services. Despite this, little is known about how climatic variations affect the growth of these forests. Tree-ring analysis can be used to address this question and clarify how climate affects growth along vegetational or climatic gradients. It also allows to assess abrupt growth changes and responses to extreme events, as a proxy of the vulnerability of forests to environmental changes. Yet, the number of tropical tree-ring chronologies is still limited, and few studies include distinct forest types simultaneously. Here we seek to understand growth patterns and their relationship with climate of trees from congeneric triplets of the genera *Aspidosperma* and *Handroanthus* along a gradient of tropical forest types in northeastern Brazil: wet forest, savannah, and dry forest. We hypothesize that growth responses to climate are modulated by this water-deficit / seasonality gradient and that dry forests will show the most climate-sensitive growth variation. We collected 20 individuals per species $\times$ forest type. Samples were polished, scanned and their growth rings were measured. We correlated ring-width chronologies for each species with local precipitation and temperature data, as well as with global Sea-Surface Temperatures (SST) and calculated growth deviations for all species. We obtained chronologies of up to 77 years with strong within-species synchronization (intercorrelation of 0.56-0.64). Precipitation was the main growth-influencing factor, and the strongest correlations were found in dry forests ($r = 0.77$). Ocean temperatures in El Niño related areas also strongly affected species growth, with prominent growth reductions during dry El Niño years that were strongest in the dry forest (up to 66%). Our results reaffirm the strong influence of precipitation on tropical forests tree growth under seasonal climate. They also suggest differential responses of the different forest types to predicted climatic changes, with dry forest being the most vulnerable to precipitation reductions and the adverse effects of increasing El Niño events. These results can be applied to underpin decision-making, and they reinforce the need to prioritize dry-forest conservation as these may be the tropical forest with the greatest vulnerability to climate change.

Keywords Dendrochronology, tropical forests, climate vulnerability

Vulnerability Assessment of Mangroves to Climate Change and Sea-level Rise. Study Case in Sayung Mangrove Conservation Park, Indonesia

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In Indonesia, climate change has affected most of the mangrove ecosystems in the northern coastal parts of Java Island. Based on this concern, this study was conducted to assess the vulnerability of mangroves to climate change, and further determine various adaptation actions to facilitate strategic management planning in Sayung Demak Conservation Park, which has been planned as a touristes destination. The vulnerability of mangrove ecosystem was evaluated by Climate Change Vulnerability Assessment by Ellison (2015). There were three factors of vulnerability to be assessed i.e., exposure, sensitivity, and adaptive capacity. Data was collected from various sources such as Indonesian Agency for Meteorology, Climatology and Geophysics. Data for exposure vulnerability was assessed based on projected changes in precipitation and the rise of sea level. The sensitivity factors were assessed by measuring basal area of mangrove, counting mangrove plant recruitment and measurement of seaward edge retreat and changes in mangrove area based on satellite imageries year 2014 and 2019. Adaptive capacity factor was analyzed based on elevation above mangrove data by processing DEM (Digital Elevation Model) satellite imagery. All data was given a score 1-5 according to the level of vulnerability. The results of Sayung Mangrove Conservation park's vulnerability to climate change were 3.7. This signifies a moderate to high vulnerability with the vulnerability scores ranged from 3-5. Detailed is as follows: the projected change of precipitation in the Demak region has been decreased to -20%. Furthermore, the relative sea-level rise was quite high, at 7.4 cm/year. The vulnerability score for exposure was 4, while the basal mangrove of area was 14.17 m^2/ha. In the area, *Avicennia marina* was identified to only have 8 seedlings, therefore mangrove recruitment would be considered high risk. According to satellite imagery, there has been a retreat of 10,57 ha area of seaward edge, with a reduction of 2,5 ha of mangrove areas. The satellite imagery also classified the unavailability of elevation above the mangrove area, with a vulnerability of adaptation score at 5. It is determined that adaptation efforts need to be prioritized through planning of land migration areas, which are further supported by managing mangrove accretions. Mangrove zones areas within the tropical countries of Asia, Africa and South America bear the most critical components to various vulnerability of this assessments. The results would allow continued assessments of the complex dynamics of climate change impacts, as well as provide an information foundation for strategic management decisions.

Keywords mangrove, climate change, vulnerability, assessment, Sayung Demak Conservation Park

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Is There Functional Adjustment of an Amazonian Herb to a Local Hydrological Gradient?

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Individuals of widely distributed species face different environmental conditions and the ability to thrive in a wide range of environments may be associated with the ability to adjust their functional traits. Intraspecific adjustments to hydrological gradients, both climatic - at the range scale, or topographic - at the local scale, have been documented for tropical trees. Our question is whether the intraspecific variation in the functional traits of an Amazonian herbaceous species with wide regional and local distribution (Ischnosiphon arouma (Aubl.) Körn. - Marantaceae) is linked to hydrological variation on a local scale, to understand if there are adjustments that allow the occupation of wide environmental gradients. Research was conducted in an Amazonian terra-firme forest, with high topographic variation, from plateaus, with more limited access to water, to valleys, with high water availability. Differences in water availability were expected to condition morpho-anatomical adjustments, with consequences for plant growth and thus plant size. We measured traits related to the acquisition and conservation of resources such as leaf thickness (LT), specific leaf area (SLA), leaf dry matter content (LDMC); hydraulic regulation (stomata size and density) and growth (number of stems and height) on 23 to 72 individuals well distributed along topography. As a proxy for the access of plants to water, we used the terrain elevation. We found an association between most of the functional traits and

the hydrological gradient. SLA and number of stems decreased with elevation , while LDMC and LT showed the opposite pattern. Variation in plant height, and stomata size or density were not associated with the hydrological gradient. Therefore, there are intraspecific adjustments along the plant economics spectrum, with an acquisitive tendency in the valleys (higher values of SLA and number of stems), indicating greater growth capacity, while in the plateaus a pattern of structure conservation is revealed, given the highest LT and LDMC values. We conclude that there is intraspecific variation associated with the water gradient considered, even on a small spatial scale (6 km^2). This ability to adjust on a local scale may enable the wide range distribution of the species across the Amazon, and may provide the necessary capacity to adjust to climate changes.

Keywords Reserva Ducke, intraspecific variation, Ischnosiphon arouma, plant economics spectrum

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Are Mountain Passes Higher in the Tropics? Revisiting the Climate Variability Hypothesis Suggests Microgeography More Important than Latitude

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Background/Question/Methods: The climate variability hypothesis posits that relatively stable climate, such as that of the tropics, induces distinct thermal bands across elevation that render dispersal over tropical mountains difficult compared with temperate mountains. Yet small-scale landscape features buffer thermal variance locally, which may play a greater role in driving mountain thermal regimes than latitude. Although the climate variability hypothesis has been studied extensively, few works have employed thermal data that capture microclimate– such as conditions within forest, soils, and topographically rugose regions– instead relying upon weather tower data or satellite estimates. Here we provide an extensive investigation of temperature drivers from fine to coarse scales to revisit classic assumptions concerning species' distributions and range limits. We compiled an open-access database of empirical temperature data on 29 mountain ranges spanning six continents (cumulative 11,775,331 measurements and 524 sampling years) to characterize thermal overlap (similarity in temperature at high and low elevations) as it varies across vertically stratified microhabitats, biomes and owing to seasonal changes in foliage. We then constructed a series of mixed effects models to compare the roles of macro-, meso-, and microgeography in driving mountain thermal regimes. **Results/Conclusions:** We demonstrate that the degree of similarity in temperatures at high and low elevations, and therefore how much a mountain acts as a physiological barrier, is more driven by vegetation cover, snow depth, and height above or belowground than by latitude of the mountain. Impressively, an increase of 1 m of height above ground generates an average increase in thermal overlap equivalent to a 5.3º change in latitude. In addition, forested mountains have reduced thermal overlap–149% lower– relative to non-forested mountains. Thus, rather than focusing on how macroclimate across latitude influences thermal tolerance, biogeographers should more seriously consider the importance of local-scale climate even when posing macroecological questions. We provide evidence in support of a climate hypothesis that emphasizes microgeography as a determinant of dispersal, demographics, and behavior. We use this research as a case study of how integrating some of the fundamental intuitions from meteorology may cause us to reconsider widely-held ecological assumptions.

Keywords mountains, biogeography, microgeography, microclimate, elevation, latitude, global, synthesis, temperature, dispersal

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Planning a Climate Resilient Conservation and Restoration Strategy for *Isoberlinia tomentosa* (Harms) Craib & Stapf in Benin

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Introduction: Predicting the distribution of a species in the face of climate change can be the key to its conservation, and to developing effective restoration strategies in a changing environment. In Benin, approximately a loss of 1.59% ha of forest area in 2020. Among the affected species, is that of our research; *Isoberlinia tomentosa* which is one of the six priority species for preservation. Indeed, it is a species of high ecological and economic value whose exploitation is becoming more and more abusive. **Objectives:** (i) Evaluate the spatio-temporal dynamics of suitable habitats to *I. tomentosa*; (ii) Identify priority areas less vulnerable to climate change for the conservation of *I. tomentosa*. **Hypotheses:** (i) The spatio-temporal distribution of suitable habitats to *I. tomentosa* would be specific to the Sudanese and Sudano-Guinean zones (ii) There are nevertheless areas less vulnerable to climate change for the conservation of *I. tomentosa*. **Methods:** Our study is done in Benin. The points of occurrence combined with twenty-one bioclimatic variables and the soil variable were introduced in MaxEnt 3.4.1 to assess the suitable habitats to the species. The average set of regional climate models (RCM) was used for climate projections up to 2055 under the two most realistic scenarios: RCP 4.5 and RCP 8.5. These results then made it possible to identify priority areas for the conservation and restoration of the species in the face of climate change under Zonation 4.0. All maps and area estimates were done on ArcGIS 10.5. **Results:** About 61.77% of the habitats are currently verry suitable to the cultivation of *I. tomentosa* with a high concentration in the Sudanese and Sudano-Guinean zones, thus confirming our first hypothesis. By 2055 these habitats will increase by 19.93% under RCP 4.5 and 21.80% under RCP 8.5. Two climatic zones associated with their protected areas are able to participate in its conservation and restoration. The Guinean-Congolese zone is not at all adequate. Less than 50% of Protected Areas have priority. These results seem to confirm our second hypothesis. **Conclusion** All the national territory is suitable for the cultivation of *I. tomentosa* but two climatic zones including the protected areas belonging to them are adequate for its conservation and restoration by 2055. These results indicate that *I. tomentosa* is slightly influenced by climate change. It will be important to set up participatory action plans in priority conservation areas plus a special reflection on unprotected areas.

Keywords *Isoberlinia tomentosa*, Climate change, suitable habitat, priority habitat,

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Lianas Are Increasing in Dominance and Water Use in Tropical Rainforest

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Global change is impacting forests worldwide, leading to shifts in forest dynamics and functional composition. However, identifying the drivers of functional composition linking with community change is rare. Here, we evaluated the changes in the liana community and trait composition over a five-year period (2014-2019) in a Chinese tropical rainforest and assesses the underlying putative mechanisms. We monitored $>$ 20,000 lianas in a 20-ha plot, and analysed community changes for each of the twenty 1-ha plots. To identify the putative drivers underlying community change we used community-weighted mean trait values of 18 functional traits that are important for liana performance. During the 5-year period, liana density decreased by 12.6% because of the high mortality of small lianas, whereas liana basal area increased by 5.8% because of high survival and growth of large lianas. Liana communities showed a trait spectrum from slow to fast carbon, nutrient, and water uses. Suggesting liana community changed toward more, large, acquisitive lianas with rapid water use. These results indicate that the liana community is undergoing succession, possibly driven by increased CO_2 fertilization, which could enhance insights into mechanisms of forest succession for future study.

Keywords climbers, demography ecosystem functioning, functional traits, liana community, tropical forest

Modeling the Present and Potential Future Distribution of a Tropical Andean Treeline Species

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Weinmannia fagaroides is a widespread tree species in biodiverse neotropical Andean treeline ecotones, especially in the Colombian cordilleras. For this reason, it is expected to represent a good indicator for mesoclimatic conditions and distribution shifts caused by changing climatic conditions in High Andean forests. In this study, the current and potential future distribution of *W. fagaroides* in the forest belts of the northern high Andean region is modeled for the first time. Differences between three available climate datasets used for projecting the potential distribution of *W. fagaroides* were analyzed. By employing Generalized Linear Models (GLM), Random Forests (RF) and MaxEnt algorithms in the Biomod framework, we examined the environmental factors influencing the species current distribution. The predictive ability of climate data derived from different statistical methods as well as algorithm performances were evaluated. The climatic dataset and algorithms which retrieved higher evaluation scores were selected to calculate projections for the present and the future, averaging models from five different Global Circulation Models (GCMs). No statistically significant difference among climate datasets performances were detected. However, Chelsa 1.2 prediction of the current distribution of *W. fagaroides* retrieved slightly higher model evaluation metrics. The algorithms RF and MaxEnt offered a higher predictive power than the GLMs. Minimum coldest month temperature, mean annual precipitation, and bulk density were identified as main environmental drivers constraining the present distribution of *W. fagaroides*. Moreover, for the period 2060-2080, the distribution range of *W. fagaroides* is predicted to shrink by 38%, with a substantial elevational upward shift. Given that *W. fagaroides* can be a representative species for other high Andean treeline species, and that at present only around 23% of its modeled distribution area is situated in protected areas, we recommend that conservation efforts should aim at an expansion of protected areas in the high Andes to include forest/grasslands ecotones to an appropriate extent.

Keywords *Weinmannia fagaroides*, Cunoniaceae, Biomod, distribution model, Chelsa, Worldclim, Climate Change

The E-phenology Network: Integrating Time and Space to Track Climate Change in the Tropics

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Monitoring and detect plant responses to environmental cues remains a challenge in the tropics and a crucial issue for climate change research. The traditional direct, manned phenological observations are arduous, takes time, and restricts monitoring to few areas, usually at monthly intervals. More recently, the near-surface remote phenology using repeated photographs taken from digital cameras (phenocams) reduced the human labor, increased the frequency of observation (hour to daily), improving the quality of information at individual tree, species, and community scales. Phenocams allows for simultaneously monitoring of several study sites, from species to ecosystems, accurately accessing daily leaf change patterns, further related to climate drivers. Therefore, we established a network for near-remote phenology monitoring. The network allows tracking vegetation responses to climate across contrasting climates and tropical biomes When associated to flux towers and other measurements, near-remote phenology offer insights on the role of phenology regulating patterns

of gross primary productivity and their environmental cues. Here we discuss how the combination of new technologies with traditional phenology, integrates time and space enhancing the capabilities of phenological observations to detect changes on vegetation phenology at various scales in the tropics, reducing methodological disparities and inconsistences. Our studies have been carried out in distinct Brazilian tropical ecosystems, from dry forests to rainforests, cerrado and grasslands, all holding high species richness and endemism. We argue that the combination of technologies framed within a e-science research project for big-data and using machine learning among other computational tools improved our accuracy to relate phenology to environmental cues and, as a consequence, to predict potential responses to climate changes.
Financial support: FAPESP – CNPq - CAPES

Keywords climate change, dry forest, rain forest, cerrado, big-database, leafing.

Functional and Structural Components of Tropical Ecosystems - Part I

Session Recording: https://youtu.be/VeZ6gXF1zPk

Coarse Woody Debris: An Under-examined Structural Component of Monsoon Tropical Forests

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Background: Globally, coarse woody debris (CWD) functions as a key driver of forest biodiversity and promotes ecosystem functioning. Evidence on CWD is scarce in tropical forests in general and almost absent for Asian forests. Estimating CWD carbon (C) stocks and decay-class dynamics is required for C cycling assessments. Quantifying and qualifying CWD habitats is crucial for understanding tropical biodiversity. **Objectives:** We quantified volumes, structural diversity, and C stocks of CWD in old-growth tropical monsoon forests. **Methods:** The study was carried out in Vietnam in lowland Dipterocarp forests in the Bu Gia Map national park, and in mixed montane wet forests in the Bi Doup - Nui Ba national park. The CWD characteristics were inventoried on 64 30-50 m long and 4 m wide transects. The interrelationships between decay class, wood density and C fraction of CWD were examined based on the analyses of 517 CWD samples. **Results:** Dipterocarp forests stored almost two times less CWD than mixed montane wet forests (on average 44 vs 78 m^3 ha^{-1}). The CWD volumes varied depending on elevation and forest type. In montane forests, mean CWD volumes increased in the order: cloud forests (34 m^3 ha^{-1}), floodplain deciduous forests (61 m3 ha-1), mixed coniferous-broadleaved forests (79 m^3 ha^{-1}), *Pinus kesiya* dominated forests (88 m^3 ha^{-1}), mixed coniferous-broadleaved forests with *Fokienia hodginsii* (109 m^3 ha^{-1}). Lying logs dominated among CWD types. The share of lying logs and large branches averaged 31 and 42%, and 33 and 8% in the Bu Gia Map and Bi Doup - Nui Ba, respectively. The CWD distributions by decay class were bell-shaped with a maximum in the 2nd decay class. In the lowland Dipterocarp forests, the termite infestation averaged 73% by number and 32% by volume of all CWD pieces indicating the prevalence of termite-driven decomposition. In montane forests, microbial decomposition prevailed. The signs of invertebrate activity were recorded in the 3% of CWD pieces. The C fraction did not depended on decay class and averaged 42 and 47% in the Bu Gia Map and Bi Doup - Nui Ba, respectively. The CWD C stock averaged 11.5 Mg C ha^{-1}, which is ca. 10% of the C accumulated in living tree biomass. **Implications:** Our results provide insight into CWD patterns in Monsoon tropical forests. The unknown tree mortality and CWD decomposition rates and pathways in these forests provide challenges for future research.

Keywords dead wood, decomposition, termites, necromass, bulk density, carbon, Vietnam monsoon

Biotic and Abiotic Controls on Seedling Growth: Combining Experiments with Long-term Field Data in the Andaman Islands, India

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Seedling establishment in tropical forests directly influences future structure and functioning of forests. This process is mediated by both abiotic factors like light and biotic factors like neighborhood density and diversity. In mixed-deciduous forests, co-existing evergreen and deciduous canopy trees create heterogenous microclimates for seedlings in the understory potentially impacting growth and establishment. To predict and manage for long-term changes in forest structure like shifts to drier, deciduous forests, stronger mechanistic insight into seedling growth is essential. In the Andaman Islands, India, we conducted a year-long shadehouse experiment with 6 native species of tree seedlings to measure the interactive effects of light and seedling neighbourhoods on their growth. In a fully crossed experiment with 3 levels of shade (permanently "closed", permanently "open" or "deciduous", i.e. closed in the wet and open in the dry season) and 3 levels of plant diversity (1, 3 or 6 species), we made monthly measurements of individual plants in plots (plot n=54, total plant n=972) and recorded the basal area, height, number of leaves and level of leaf damage for each individual. We combined these data with 25 comparable long-term seedling plots set up through the Long-term Ecosystem Monitoring Network in a mixed-deciduous forest in the landscape. Through our experiment, we show that the monthly increase in total plot basal area is significantly and independently impacted by both canopy treatment (repeated measures ANOVA $F(2, 534)=6.7$, $p=0.001$), and by manipulated plant diversity ($F(2, 534)=2.38$, $p=0.094$). We also find evidence for a parallel biotic mechanism; canopy treatment had a significant effect on the proportion of damaged leaves (ANOVA $F(2)=9.09$, $p<0.001$), which impacts seedling growth. A structural equation model (SEM) of the total biomass gain in the experimental plots showed significant effects of light and plant damage, but no significant evidence of the influence of plant diversity (Fisher's C=1, p-value=0). On the other hand, an SEM of the data from the long-term forest plot showed significant effects of both field-measured canopy closure and plant diversity on plot basal area. Taken together, our results show that seedling growth in both regenerating and steady state forests can be significantly impacted by the light environment. However, the effect of biotic mechanisms like plant diversity and enemy damage can be different in regenerating and steady state forests. Our results provide baselines to understand change in structure and functioning in mixed deciduous forests and informs the management of these forests.

Keywords forest dynamics, field experiment, biodiversity-ecosystem functioning, light, plant diversity

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Functional Traits Explain Orthophosphate Fluxes in Scattered Trees from Fragmented Andean Landscapes in Colombia

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The availability of the nutrients in ecosystems is generally conditioned by their natural availability on the earth´s surface and the efficiency of the transport mechanisms that mobilize them. Tropical ecosystems in South America, for example, are limited in phosphorus due to its depletion during long-term pedogenesis as well as the lack of phosphoric rocks in the continental geology. This limitation is sufficient to limit productivity in old and eroded soils that characterize part of the tropical biomes, particularly in the mountains where geomorphology and climate lead to high rates of soil erosion. This loss is exacerbated with forest fragmentation and forest loss. For instance, in small scattered forest fragments or leftover trees after forest fragmentation, higher nutrient contents in the soil are observed, potentially related to the capacity of trees (and forests) to effectively mobilize nutrients. More specifically, previous studies have illustrated how individual trees intercept and transport rainfall into the soil surface, as well as to intercept aerosols that are important sources phosphorus in old and infertile soils. However, few studies have quantified the relationship between structural functional traits for different species of scattered trees, evaluating their capacity to intercept and move phosphorus through hydrological processes. In this study, we determined the association between plant functional traits and phosphorus movement from the canopy into the in twenty individuals of five tree species scattered in a

modified landscape: *Croton magdalenensis*, *Tibouchina lepidota*, *Vismia Baccifera* and *Quercus humboldtii*, which are native to the Tropical Andes, and an exotic species *Eucalyptus globulus*. We quantified PO4 phosphate concentrations in precipitation, throughfall, and stem flow in all trees for a group of 14 individual rainfall events. We found higher concentrations of PO4 in stemflow and throughfall than in precipitation; where the foliar traits show significant relationships with the concentration PO4. *C. magdalenensis*, had significantly higher PO4 concentration values in the throughfall and stemflow, compared to the same flows in the other species. This condition potentially results from a particularly higher epiphyte load and their leaf characteristic. In addition, we found associations between species based on their functional characteristics, that potentially facilitate biogeochemical exchange and improve ecological functions, associated with the early stages of forest recovery. Overall, our results highlight the complex biogeochemical interactions that occur in these highly biodiverse ecosystems where functional traits of plants can be useful in describing ecosystem function at the landscape scale.

Keywords Precipitation, Phosphorus Interception, Nutrients Limitation, Scattered Tree, Functional Traits.

The Growth-reproduction Tradeoff in Central Amazonian Trees

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Like in many other organisms with indeterminate growth, the allocation tradeoff between growth and reproduction has profound implications for the life-history of trees. While some tree species have specialized into reproducing as early as possible, thus having a small size at the onset of maturity (SOM), others will delay their first reproductive event (large SOM). We thus hypothesize that early reproduction comes at the cost of future growth, which limits the size of adult trees, thus confining the species to the forest understory. Because these short trees will have reduced access to light, they should also reproduce less often than trees with crowns fully exposed in the forest canopy. This demographic tradeoff between reproductive potential and generation time may help to maintain the huge species diversity in tropical rainforests. We can then predict that both species' maximum adult size (Smax) and maximum probability of reproducing (Pmax) will be positively correlated to SOM. To test these predictions, we monitored for 26 months >600 trees from 263 species in a hyperdiverse, Central Amazonian forest. We measured tree stem diameter at breast height (DBH) as a proxy of tree size, and included all trees with DBH>10 cm found within four 0.25-ha plots. Trees having flowers or fruits at any point during the monitored period were considered to be reproductively mature (R=1), and the rest was assumed to be immature (R=0). R was then modeled as a function of DBH with species-specific models fit by a hierarchical Bayesian analysis. Species' SOM and Pmax were then derived from these species-specific models. Smax was estimated as the 95th quantile of species DBH distribution within the sampled plots and in another nearby 25-ha plot. We found a great variance in species reproductive strategies, with SOM ranging from 7-41 cm and Pmax ranging from 31-99%. As predicted, we found that both SOM and Pmax were strongly positively correlated to Smax, indicating that there is indeed a strong demographic tradeoff in this forest. This tradeoff has the potential of reducing fitness inequalities across species, which could ultimately make stable coexistence more likely. This in turn would explain both the apparent neutrality of tropical forests, as well as the maintenance of their high species diversity. Lastly, it was surprising to learn that $\sim$ 48% of the trees were reproductive during the monitored period, which is considered one of the least productive forests in the Amazon basin.

Keywords life-history tradeoff, maximum adult size, reproductive potential, tree fecundity

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Fruit Scent as an Honest Signal for Fruit Quality

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Background: Fleshy fruits evolved to attract seed dispersers through signals such as color and scent. Signals can evolve through different trajectories and have various degrees of reliability. The strongest substrate on which reliable signals evolve is when there is an inherent link between signal and reward, rendering cheating costly or impossible. It was recently proposed that aliphatic esters in fruit scent may provide an honest signal to sugar content due to their synthesis from products of sugar fermentation. Objective/hypothesis: We test the hypothesis that aliphatic esters are an honest signal for fruit quality on a wild lemur-dispersed fig species (*Ficus tiliifolia*) from Madagascar. **Methods:** We quantified sugar levels and the amount of ester and non-ester compounds in *F. tiliifolia* scent, generating the largest available dataset of within-species variation in fruit scent. We used linear regression and generalized mixed effects models to examine whether ester levels predict sugar concentration. As a control, we also examined the relationship between sugar and non-ester scent compounds. We tested these relationships both between and within individuals, i.e. between individual figs. **Results:** We show a strong positive correlation between signal (esters) and reward (sugar), both between and within individual trees. We also show that non-esters in fruit scent do not indicate sugar levels, which implies that this relationship is not simply a product of fruit maturation wherein more mature fruits emit more scent and contain more sugar. **Implications/conclusions:** While based on a single taxon, these results strongly support the hypothesis that a biochemical link between signal and reward may render the ester fraction of fruit scent an honest signal for fruit quality, with consequences for animal sensory and feeding ecology, and the evolution of plants in the context of seed dispersal.

Keywords Seed dispersal; Olfaction; Fruit scent; *Ficus*; Animal-plant interactions

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Ecological and Architectural Traits Structure Rolled-leaf Beetle Communities on Costa Rican Wet Forest Zingiberales

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Current global threats to biodiversity include habitat fragmentation and destruction, climate change, and invasive species. Plants and their associated herbivores are major components of terrestrial biodiversity. Understanding the factors structuring plant and herbivore assemblages is fundamental for managing and protecting biodiversity under these constantly changing scenarios. Components of herbivore assemblage structure on plants are the associated herbivore species identity, richness, diversity, and abundance. Neotropical rolled-leaf beetles (*Cephaloleia* and *Chelobasis*) complete their entire life cycle in the new rolled leaves of Zingiberales species. Neotropical Zingiberales species comprise five closely related monophyletic families (Heliconiceae, Cannaceae, Marantaceae, Costaceae and Zingiberaceae). The diets of these beetles are well known at the lowland forest study site, La Selva Biological Station, in Costa Rica. We studied the effect of Zingiberales' ecological and architectural traits on rolled-leaf beetle species' richness, abundance, diversity, and community structure at La Selva in a phylogenetic context. The ecological traits tested were soil type, habitat, local abundance, elevation, and geographic range size, and the architectural traits were plant height and leaf width, as a measure of leaf size. We found a significant positive effect of leaf width on beetle species richness (55% variation), abundance (28% variation and 57% when habitat was included in the model), diversity (37% variation), and community structure (6% variation, and 21–26% when taxonomic family was included in the model). No other factors were significant. When analyzed at the level of individual Zingiberales family, we found a trend suggesting leaf width has a positive effect on beetle species richness and diversity in Heliconiaceae and Marantaceae but not in Costaceae and Zingiberaceae. For beetle abundance, the trend suggests that leaf width has a positive effect across all Zingiberales families. Our study demonstrates that leaf size and habitat are important for structuring

rolled-leaf beetle assemblages on Zingiberales at the study site. Previous studies suggest that leaf size could decrease with climate change and that plants in drier habitats host fewer herbivore species. Therefore, changes in leaf morphology and habitat under global change scenarios might affect the structure of this plant-herbivore assemblage. If leaf size decreases and habitats change, it is likely that herbivore assemblages will be negatively affected. Understanding how plant ecological and architectural traits structure herbivore assemblages is critical for developing faster and more precise actions to manage and protect biodiversity.

Keywords *Cephaloleia*, *Chelobasis*, Chrysomelidae, Coleoptera, La Selva, Neotropics, monocots, plant-herbivore interactions

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Wood Density Variation and Its Relationship with the Environmental Space Occupied by Trees Species in Central Amazonia

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Wood density (WD) is a key trait associated with tree growth and survival, and an indicator of ecological strategies. WD is considered a phylogenetically conserved trait, however, it may vary within species due to environmental contrasting conditions. Between species, it is known that lower WD presents a more acquisitive resource use strategy, and could be expected to occur in environments restricted to greater resource availability. In contrast, higher WD species are more conservative in the use of resources and should be able to also occupy more limiting environments. Here, we investigated the variation patterns of WD values within and between widespread tree species in central Amazonia that occur over different resource availability gradients. We hypothesized that (H1) the greater the variation in WD values within species, the greater is the environmental space occupied by the species, assuming individuals can adjust to different environmental conditions. If WD is invariable within species, we hypothesize that (H2) species with higher WD occupy a greater environmental range, due to their higher tolerance to low resource availability compared to low-WD species. We investigated these hypotheses with a WD database of 285 trees, of 18 species (4-39 individuals/species) sampled in 16 permanent plots spread over 500km in central Amazonia. To confirm species identification, we analyzed near-infrared (NIR) spectral measurements of all individual leaves. We evaluated (H1) the relationship between the coefficient of variation of species WD and the environmental space variation occupied by each species, using linear regressions. Species environmental space variation was calculated using 12 variables related to water availability and soil properties. To test H2, we evaluated the relationship between the average WD of species and the environmental space variation occupied by the species. Our results showed that species occupying higher environmental variation do not have a higher variation in WD, confirming low WD intraspecific variation. Contrary to our expectations, we found that species occurring in reduced environmental spaces tend to have higher WD, and species occurring in more variable environmental spaces, generally have lower WD values. This indicates that species with lower WD and acquisitive strategies are more generalist and more able to thrive in contrasting environments than higher WD conservative species. The global change scenario of extreme events changing water and nutrients availability in Amazonia may favor low WD species survival, and alter tree species composition to forests with lower carbon storages.

Keywords wood density, trait variation, environmental space, intraspecific, interespecific, Amazonia

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Plant Trait Associations with Abiotic and Biotic Factors in Tropical Mountain Forests

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The distribution of plant traits in communities is shaped by both abiotic and biotic factors. So far, the relationship between plant traits and environmental factors has mostly been studied at large spatial scales. However, it is less known how different types of plant traits, such as seed and leaf traits, vary on regional scales in diverse tropical forest ecosystems. Here, we investigate plant trait associations with abiotic and biotic factors for a metacommunity of animal-dispersed plants in the tropical mountains of Southern Ecuador. We measured quantitative seed and leaf traits on 18 and 33 fleshy-fruited plant species, respectively. For each of these plant species, we recorded its abundance on nine 1-ha forest plots, located at different elevations (around 1000 m, 2000 m, 3000 m asl). On the same plots, we measured abiotic factors such as soil properties (soil CN ratio, soil P), and climatic conditions (temperature, rainfall). Moreover, we recorded biotic factors such as herbivory and the frequency of avian fruit removal. We conducted PCA and RLQ analyses to identify the main axes of trait variation and the co-variation between plant traits and the different environmental factors. We identified the seed-number vs. seed-size trade-off and variation along the leaf economic spectrum as the main axes of trait variation for seed and leaf traits, respectively. Both the distributions of seed and leaf traits were significantly associated with the abiotic and, to a lesser extent, with the biotic factors. Plants produced many small seeds and fruits in habitats with high soil CN, whereas seed size increased with increasing rainfall. In turn, fruit rewards were negatively related to fruit removal, suggesting less investment into costly fruits where fruit removal was more frequent. In terms of leaf traits, costly long-lived leaves were associated with low temperatures, while leaf area decreased with increasing rainfall. Leaf toughness tended to be negatively related to herbivory, consistent with a higher herbivore defence of tough leaves. Our study reveals close associations between plant traits and environmental conditions in a diverse tropical forest ecosystem. We conclude that species sorting in response to both abiotic and biotic factors shape the plant trait distribution in this metacommunity. Our study provides a baseline for predicting changes in plant traits in highly diverse tropical communities in response to global change and associated changes in abiotic and biotic factors.

Keywords Animal-dispersed plants, avian fruit removal, herbivory, soil properties, temperature, rainfall

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What Influences Bark Conductance to Water Vapor in Neotropical Plants?

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Background: Bark conductance to water vapor (g_{bark}) is an important determinant of drought performance in tropical trees. Hence determining species differences in bark conductance can provide useful information about the resilience of tropical trees in the face of ongoing climate change. Values of g_{bark} have been found to be positively related to stem photosynthetic rate in desert species, suggesting that traits that make barks permeable to water vapor may also influence carbon assimilation by photosynthetic stems. **Objective:** To determine whether stem morphometric traits, bioclimatic variables and/or shared evolutionary history, help explain variation in g_{bark} among tropical species. **Methods:** We surveyed 92 woody species from lowland wet and mid-elevation seasonal forests in Panama and measured stem traits related to structural carbon investment such as specific stem area, bark thickness and wood density. We used WorldClim to extract significant bioclimatic variables that could help explain variation in g_{bark}. **Results:** No single morphometric trait measured was related to g_{bark}, neither were bioclimatic variables related to amount, extreme values, and seasonality of rainfall. However, g_{bark} was positively related to temperature seasonality, i.e. the standard deviation of monthly mean temperature. Individuals in highly seasonal sites, above 0.65 °C of temperature seasonality, had an average g_{bark} value of 10 mmol m^{-2} s^{-1}, whereas individuals from sites with temperature seasonality lower than 0.65 °C had a significantly lower average g_{bark} of 6.5 mmol m^{-2} s^{-1}. Furthermore,

there was a significant phylogenetic signal in g_{bark}, with closely related species resembling each other more than distantly related species. **Conclusions:** Our results suggest that the carbon investment in stem and bark structure does not explain interspecific differences in g_{bark}. However, g_{bark} reflects shared evolutionary history and responds to temperature seasonality. In a warmer and drier world with increased frequency of extreme weather events, including heat waves, g_{bark} may determine the ability of plants to survive drought periods, as water loss through the stem bark is the remaining path for whole-plant water loss after leaf stomatal closure and leaf senescence.

Keywords bark thickness, climate, phylogenetics, temperature, trees, Tropics, water loss

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Disentangling Facilitation and Functional Complementarity Effects on Biomass Production and Community Functioning during Forest Restoration

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Introduction: Semiarid environments under intense degradation have been devastated by desertification problems. The application of effective restoration methods in these contexts is fundamental and urgent. The use of ecological theories of assembly rules and community dynamics can be critical to ensure the success of restoration programs. **Objectives:** This work aims to provide rules for the assembly of plant communities in restoration programs, understanding the relative role of facilitation and functional complementarity in plant biomass production and community functioning. Once they commonly considered equal parts of the complementarity effect, facilitation was rarely measured. We expect however that each variable will play distinct roles in community responses, and that facilitation should be a strong predictor of community performance. **Methods:** This restoration work was conducted as a large-scale experiment in Biodiversity and Ecosystem Functioning - TreedivNet. We built 147 experimental restoration communities in the world's largest and highly diverse seasonally dry tropical forest, Brazil's semiarid forest called Caatinga. The communities were composed of 45 different compositions of associated species in five levels of diversity (1, 2, 4, 8 and 16 species). Across all diversity levels we built communities on a gradient from low to high level of facilitation, using tree species that had their facilitation skills previously measured. The biomass production of all transplants was monitored for 2 years after the implementation of the experiment and used to calculate the response variables of community, productivity and functioning. We also measured the functional traits of all the studied plant species in order to calculate community functional complementarity. We performed a generalized linear mixed model testing how facilitation, functional complementarity, functional identity and species diversity affect the productivity and functioning of restored communities. **Results:** Facilitation was fundamental in explaining the productivity and functioning of restored plant communities. The functional identity related to traits that allow plants a greater capacity for growth and water uptake positively influenced productivity and functioning. Functional complementarity was important in explaining community functioning but not community productivity. Most species presented higher productivity in mixtures than in monocultures, but biomass production did not increase with plant community diversity. **Conclusions:** Our study shows that facilitation effects are of great importance for the success of restoration and should be treated as an effect independent of functional complementarity. We believe that the results found in our study will contribute to the theoretical understanding of community dynamics and the advancement of urgent restoration practices in ecosystems.

Keywords Semiarid restoration, Caatinga, Facilitation, Functional complementarity, Plant-plant interaction

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Faunal Diversity in Thangappuwa, Knuckles Mountain Range, Sri Lanka

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The Knuckles Mountain Range [KMR] harbours a wide range of unique fauna and flora in Sri Lanka. Thangappuwa in the KMR lacks biodiversity records and data through a proper survey. Therefore, a primary Visual Encounter Survey [VES] was undertaken in 15 days (both day and night) from October 2019 to February 2021 to document the diversity of several selected faunal groups (Birds, Butterflies, Amphibians, Reptiles, Mammals and Fish) in Thangappuwa. The recorded avifauna is comprised of 43 species, which included endemic *Cecropis hyperythra*, *Megalaima flavifrons*, *Pomatorhinus melanurus*, *Chrysocolaptes festivus tantus*, *Zosterops ceylonensis* (nationally near threatened), *Gallus lafayettii* and *Eumyias sordida* (nationally vulnerable and globally near threatened). Further, nationally near-threatened *Dicaeum agile* and *Ictinaetus malayensis* and nationally vulnerable *Nisaetus nipalensis* were recorded. Seventeen species of Butterflies were observed. Seven out of eight species of amphibians recorded were endemic. Whereas *Pseudophilautus marcropus* is critically endangered, *Pseudophilautus sarasinorum* is endangered, *Pseudophilautus fulvus* is nationally critically endangered and globally endangered, *Pseudophilautus alto* is endangered, *Pseudophilautus popularis* is nationally near threatened and globally vulnerable, *Lankanectes corrugatus* is nationally vulnerable and globally endangered and *Uperodon obscurus* and *Indosylvirana temporalis* are near threatened. Five reptiles were recorded during the survey and of them, *Eutropis madaraszi* is endemic and nationally vulnerable whilst endemic *Ceratophora tennentii* is nationally critically endangered and globally endangered and *Calotes liolepis* is endemic and endangered. From the four mammals recorded, *Semnopithecus vetulus* which is endangered and *Funambulus layardi* which is vulnerable are endemic. Whereas *Muntiacus muntjac* is nationally endangered. From the two fish species recorded *Garra ceylonensis* is endemic and nationally vulnerable and globally near-threatened whereas *Schistura notustigma* is near threatened. Although small in extent, the observations of this survey indicates that there are a wide variety of microhabitats in Thangappuwa, which harbours great diversity. Few anthropogenic activities like unauthorised agriculture on cardamom plantation, cattle farming and unawareness of the residents possess a threat to this valuable ecosystem. If such trends continue it may lead to the extinction and extirpation of several faunas in this area. Therefore, we will be continuing to systematically survey the area (beyond the VES method to record more species which is not observed by this method) to provide detailed information of species richness and abundance that is vital in understanding the biodiversity in the area to adopt sustainable biodiversity conservation and management actions in the Thangappuwa, KMR, Sri Lanka.

Keywords Fauna, Thangappuwa, Knuckles Mountain Range, Sri Lanka, Endemic, Endangered, Biodiversity, Visual Encounter Survey, Extinction, Extirpation

Functional and Structural Components of Tropical Ecosystems - Part II

Session Recording: https://youtu.be/mYZtyqaiz8c

Functional Traits Shape Tree Species Distribution in the Himalayas

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Plant functional traits determine plant performance and have therefore the potential to shape and predict species distributions along environmental gradients. This study aims to analyse how traits affect tree species distribution along a 4 km elevational gradient in the Himalayas in Nepal. We addressed three questions: 1) what plant strategies can be distinguished among tree species?; 2) how are plant traits and strategies associated with elevation?; and 3) what plant traits are the best predictors of species positions along elevational gradient? We quantified for 31 tree species a comprehensive set of 39 plant traits related to resource uptake, use, and conservation. The traits clustered into five different functions; (1) efficiency in vertical expansion, (2) efficiency in horizontal expansion, (3) efficiency in metabolism, (4) physical defence, and (5) tree functional groups (conifers versus broadleaf species). A Principal Component Analysis of species traits showed two plant strategy axes. The first strategy axis reflects a trade-off between multiple safeties and efficiencies and was tightly linked to elevation; highland species had trait values that increase safety against freezing induced cavitation, high solar radiation, and strong wind and that increase resource conservation under harsh conditions whereas lowland species had trait values that increase efficiency of resource acquisition, metabolism, expansion and growth (trait cluster 1-3) under benign conditions. The second strategy axis reflects a trade-off and phylogenetic split between highland Gymnosperms with soft tissues and Rhododendrons with tough tissues (trait cluster 4-5). An all subsets regression analysis showed that a small set of traits best explain species distribution: highland species had a smaller stature (low basal area), safer hydraulics (low conduit diameter), and lower leaf and branch display efficiency (low leaf area per xylem area and specific branch length) to persist under harsh conditions. Remarkably, leaf traits were poor predictors of species' elevational positions. Synthesis: Multiple trade-offs in plant size, hydraulics, and light competitiveness shape species distribution along the elevational gradient. Along this extreme environmental gradient, long-lived stem and branch traits that integrate plant functions are better predictors of species distribution than short-lived leaf traits.

Keywords conservative-acquisitive paradigm, elevational gradient, Nepal, plant strategy, trade-off, tropics

Is There a Latitudinal Gradient in Sapling Growth Strategies?

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Light is one of the most limiting resources for plants growing in forests globally. Yet, latitudinal variation in the angle of incidence of light may limit the availability of this resource even further, thus affecting the growth strategies of trees. Canopy trees, e.g., tend to have thicker crowns in higher latitudes to intercept light more efficiently. Combined with lower angles of light incidence, thicker crowns greatly limit light penetration into the forest understory, also limiting the number of foliage strata of the forest and, thus, the complexity of its light regime. This variation in light regime, therefore, must impact the regenerative strategies of tree species, including sapling growth strategies, which can range from shade-avoidance (optimistic) to shade-tolerance (pessimistic). Because pessimistic saplings (short-stature, large crowns) are believed to outperform optimistic (tall, small crowns) ones in shadier areas and vice-versa, we predict that there will be a latitudinal gradient in sapling architecture and allometry, with optimists dominating the tropics and pessimists being more common polewards. To test this prediction we used a published global database on sapling architecture (height and crown width and depth), together with new data from two study sites in the Central and Western Amazon. We found that the sapling architectures from higher latitudes were related to those found in tropical forests, which had several different growth strategies. As expected, saplings from the similar latitudes tended to have similar architectures (Mantel $r = 0.19$; $p = 0.001$). Moreover, sapling optimism did decrease polewards, especially due to increasing crown thickness relative to sapling height ($R^2 = 0.20$; $p < 0.001$). This agrees with the notion that plants in higher latitudes have to make deeper crowns in order to intercept light at lower incidence angles. Interestingly, deep-crowned saplings are also common in the tropics, maybe because light incidence angle varies along a single day in the lower latitudes as much as it varies year-round in higher latitudes. The diversity in light incidence angles might thus explain the large diversity of sapling growth strategies in tropical forests, which in turn helps to explain the great number of plant species found there. Next, we will take into account environmental variables that may affect light regimes inside forests, such as topography or forest disturbance. We will also account for sampling effects in our results, as higher latitude forests have only a small fraction of the richness of tropical ones.

Keywords sapling growth strategies, light regime, latitudinal gradient, crown architecture

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Ecological Strategies in the Caatinga Seasonally Dry Forest and Woodland

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The ecological CSR strategies in plants reflect functional spectra. Understanding the organization of these strategies is fundamental to understanding plant communities. Our objective was to determine ecological strategies for species and tree-shrub communities in the Caatinga. We hope that these species would be concentrated in the S space of the Grime's triangle, due to the water deficit present in this seasonally dry region. The work was developed in one of the largest blocks of seasonally dry forest in South America. Functional data was obtained from articles, theses and large databases (TRY, BIEN, KEW). The classification of the strategies was obtained using the three-way trade-off between functional traits (LA, LDMC and SLA), through the StratyFy global CSR analysis method. In addition, we tested what types of strategies are associated with functional attributes, taxonomic classifications, abundance subregions and physiognomies types at the level of species and communities using ANOVAs with logit-transformed data. The species in the Caatinga are mostly concentrated in the competitor-stressor space, with most species tending to express stress-tolerant strategies. When comparing the components and predictor variables, all functional variables and vegetation classifications showed significant differences in their categories with at least one of the components of ecological CSR strategies. In the Caatinga, the broad distribution of strategies between species, and the predominance of stress-tolerant and competitive strategies, in addition to their association with functional aspects of species and physiognomic distribution of vegetation, indicate that quite distinct ecological strategies find niche spaces in the domain, which nonetheless impose stress-regional tolerant trends.

Keywords Communities, CSR, drylands, species, traits, vegetation

Multiple Fine Root Trait Syndromes May Coexist, Effectively Balancing Nutrient Acquisition Costs in Similar Soil Conditions

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Fine roots can show high variation along multiple axes of structure, physiological activity, symbiotic reliance and longevity. A given plant species could have any combination of trait values; however, we propose that it is far more likely that certain trait values are coordinated and can be grouped into syndromes. In theory, there may be a single optimal strategy for resource acquisition in a given environment, though studies along environmental gradients often express contradictory results or fail to show clear patterns. This could arise because multiple co-existing strategies with diverging values for a given trait may occur within a community and tend to obscure response patterns. Evidence from multiple spatial scales suggests that syndrome co-existence is likely, particularly in nutrient-poor tropical soils where both biodiversity and complexity of soil nutrient forms are high. Thus, we utilize low-phosphorus (P) tropical soils as a case study to look for evidence of syndrome co-existence by synthesizing existing literature. Initial trait values were obtained from studies of tropical woody species in P-poor soils that reported significant interspecific root trait variation. Studies often measure few traits or trait types simultaneously, so we extrapolated other trait values using findings of correlative studies to infer syndromes that unify physiological, morphological and phenological axes while considering functional trade-offs. Five potentially coexisting syndromes are hypothesized with qualitative trait values (i.e. high or low) that could result from niche partitioning (e.g. of soil nutrient forms), phylogenetic constraints, or functional trade-offs. Syndromes are primarily distinguished by symbiotic association type, root morphology, their interactions and implications for root functions. (1) Thick-rooted arbuscular mycorrhizal (AM) species have greater longevities but rely more on symbionts to absorb inorganic P; (2) thin-rooted AM species are more self-sufficient with lower longevities and specialize in simple organic P. (3) Thin-rooted ectomycorrhizal (ECM) species have lower longevities and specialize in organic P of intermediate complexity, i.e. phosphomonoesters and phosphodiesters; (4) thick-rooted ECM species have greater longevities and access complex organic P forms due to greater enzyme production by ectomycorrhiza. (5) Non-mycorrhizal, cluster-root-forming species are entirely self-sufficient and access organic P in small pockets of soil via high, localized physiological activity at high costs. We conclude that fine root functional diversity of co-existing species may be underappreciated, despite implications for species coexistence, trait variation along gradients, representation in earth system models and species selection for restoration efforts. To address this, our framework presents testable hypotheses and guidelines for syndrome research.

Keywords fine roots, plant traits, nutrient acquisition syndromes, coexistence, resource partitioning

Mountain Uplift Shapes Elevational and Phylogenetic Patterns of Functional Trait Variation in Trees

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Introduction: Key questions at the interface of biogeography and community ecology are how the emergence of large-scale environmental gradients shapes the distribution of species and the evolution of phenotypes, and how the effects of these biogeographic events "trickle-down" to shape local communities. In the Neotropics, the uplift of the Andean mountains created striking elevational and environmental gradients with profound consequences for global biodiversity. Yet the mechanisms by which the recent uplift of the Andes generated its

enormous diversity in species and their functions remain largely unknown. Such a knowledge gap represents a major challenge for understanding the historical assembly of the Neotropical biota. **Objectives:** In this study, we evaluated how the uplift of the Central Andes during the past 30 million years shaped the evolution of plant functional traits, which in turn influenced the distribution of species and assembly of communities across elevations. Specifically, we studied how the variation in these traits is partitioned among phylogenetic scales. If the uplift of the Central Andes provided opportunities for adaptive diversification, most of the variation in these traits should occurs within clades that evolved after mountain uplift. In contrast, if the uplift of the Central Andes facilitated the immigration of clades that were pre-adapted to the emerging environments, most of the variation should occur among clades that diverged from one another before mountain uplift. **Methods:** We combined novel functional trait data with distributional information for $>$ 600 tree species occurring in the Central Andes of Bolivia. We used phylogenetic regressions to identify what functional traits explain the elevational distributions of species. Then, we estimated how much of the variation in these traits occurs among clades of pre-Andean origin (older than 30 my) versus among species within those clades. **Results:** We found that functional traits explain much of the elevational distribution of tree species. Moreover, the variation in these traits is disproportionately concentrated deep in the phylogeny, driven by differences among clades that evolved before mountain uplift. These results support the idea that the environments created during the uplift of the Central Andes were likely colonized by clades of species that were pre-adapted to the emerging environments. **Conclusions:** Our results highlight the importance that niche conservatism has in shaping modern patterns of community assembly and diversity, suggesting that these patterns are strongly influenced by species' abilities to move rather than by their abilities to evolve in response to large-scale environmental change.

Keywords Madidi, community assembly, elevation, mountain uplift, functional trait

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Functional Traits Predict Tree-level Phenological Strategies in a Mesic Indian Savanna

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Introduction / Background / Justification: Leaf phenology influences terrestrial primary production by determining the period of carbon uptake. While dominant leaf habit (evergreen/deciduous) is predictable at large scales based on environmental factors, there is substantial variability in the timing of key events such as leaf flush and senescence at smaller site-level scales. Understanding this variability is key to how different species will respond to future climate change. **Objective(s)/Hypothesis(es):** So we asked - How much of this variability is explained by species functional traits related to a plant's carbon economy? Specifically, we related leaf functional traits and wood density to the (i) timing of leaf flush, leaf maturity, peak canopy and senescence, (ii) duration of leaf deployment, (iii) duration from start of senescence to leaflessness, and (iv) time to attainment of peak mature canopy following leaf flush. We expected species that use resources conservatively (low specific leaf area, high leaf dry matter content, low leaf nitrogen and high wood density) to senesce later and retain their leaves longer. **Methods:** We monitored leaf phenology for 113 individual trees of eleven dominant species in an Indian mesic savanna. We scored the above phenological variables by visually observing the canopy, and functional traits were collected at the species-level. **Results:** For all species, leaflessness was most pronounced in early dry season and leaf flushing occurred in the late dry season. Species with high leaf carbon and dry matter content showed earlier leaf maturation, attained peak mature canopies sooner and deployed leaves for longer. Species with high specific leaf area, leaf nitrogen and low wood density did show earlier senescence but relationships, were weak. In this mesic savanna, phenology at fine scales was indeed associated with species functional traits relating to carbon investment, but these relationships were strong only when intra-specific variation in phenology was low. **Implications/Conclusions:** The relationships between phenological variation and functional traits in our study are consistent with how trees recoup carbon investment made in leaves. Overall, leaf phenology in this system was best explained by leaf carbon investment. High variation in leaf phenology and habit within species underscores the importance of considering multiple phenological metrics in understanding phenological strategies. Our results also suggest that a single 'tropical

deciduous tree' functional type in dynamic vegetation models may not be adequately capture these diverse strategies.

Keywords leaf habit, leaf phenology, dry season-flushing, carbon investment

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Response of Functional Traits of Preserved and Fragmented Riparian Forests in the Southern Amazon

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Background: In the tropics, native forest fragmentation alters the microclimatic conditions of the remaining forests, potentially impacting vegetation structure and function. In response to these biotic and abiotic modifications, plant species with high phenotypic plasticity may either persist or become locally extinct. However, little is known about the plasticity of functional attributes of tree species, or which ecological strategies are adopted in response to the new environmental conditions imposed by fragmentation and land-use change. We hypothesized that land-use change would shift species to a more resource-acquisitive strategy because deforestation promotes changes in riparian forest species structure and diversity in agricultural landscapes and that more species with high plasticity would be pervasive with land-use change. Objectives Our objective was to assess whether functional attributes of tree species in riparian forests in southern Amazonia change in response to fragmentation and distance of the stream from surrounding forests. **Methods:** We assessed 12 functional attributes of woody species in six riparian forests in agricultural landscapes and four from intact areas. We then compared these functional attributes between the two land-use types taking into account that: a) 64 tree species were common to both environments while, b) 33 species were restricted to the agricultural riparian forests and 26 species were restricted to the intact riparian forests. **Results:** Of the woody species common to both environments, leaf thickness, plant height, leaf area, specific leaf area, phosphorus, magnesium and potassium content displayed the greatest phenotypic plasticity. Species restricted to intact riparian areas showed greater specific leaf area than species restricted to agricultural landscapes but had similar values for others functional attributes. Overall, there was greater variability of functional attributes in species common to both preserved and fragmented forests, suggesting that these species have greater plasticity than those restricted to one of the two environments. In intact forests, species tend to adopt acquisitive strategies, whereas in fragmented forests species tend to adopt resource-conserving strategies. In response to deforestation and occupation by agriculture around riparian forests, some tree species may modify functional attributes or be replaced by species better adapted to the new condition. **Implications/Conclusions:** In response to deforestation and occupation by agriculture around riparian forests, some tree species may modify functional attributes or be replaced by species better adapted to the new condition. Thus, further understanding which species have low vs. high plasticity will help inform which conservation strategies.

Keywords agriculture, trees, phenotypic plasticity, functional traits, land use.

Tracking Leaf Trait Differentiation of Newly Diverging Subspecies of Chenopodium Oahuense on the Hawaiian Isla

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A single native *Chenopodium* species, *Chenopodium oahuense*, can be found throughout the Hawaiian archipelago. Subpopulations of this species can be found in a wide range of habitats that differ greatly in temperature, humidity and elevation. Field observations and experiments in common gardens suggest that large climate differences across the population range are driving distinct morphologies. These morphological differences are likely associated with physiological adaptations to the local climates of the subpopulations, however, physiological comparisons have not been done. By utilizing a common garden, we will compare previously observed differences in gross plant structure with functional differences in whole plant water use strategies and couple this to an environmental niche model based on data from GBIF, iDigBio, and field surveys. Our main objective is to document *Chenopodium oahuense* leaf traits (e.g. leaf size, stomatal density, leaf hydraulic conductance, osmotic potential at full turgor and leaf level capacitance) for the different sub-populations and between juvenile and adult growth forms. We are able to understand the relationship between leaf structure and function by imaging the leaf surface, measuring stomatal conductance, and conducting pressure-volume curves. We also intend to elucidate how variation in each sub population's home environment has led to adaptive shifts in plant water use strategies. Preliminary results suggest that the environmental niche differences such as elevation, rainfall, and annual temperature experienced by each subpopulation are strongly coupled to differences in water use strategy. Pressure volume curve analyses of the different subpopulations are showing differences in osmotic potential at full turgor and turgor loss point. Preliminary stomatal conductance and leaf size measurements also indicate differences between juveniles and adults within populations. In conclusion our preliminary data suggest differences in plant water use strategy are linked to the population's distinct environmental conditions. Increasing our understanding of diversification and evolutionary adaptations within a specific lineage has broad implications for understanding other ecological systems with diverging sub populations. Our results allow for more informed conservation decisions for *C. oahuense* that will, in turn, impact the conservation of other organisms that rely on them.

Keywords Ecology, Diverging Leaf Traits, Plant Physiology, Speciation, Chenopodium oahuense

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Root Functional Traits and Microbial Variations across a Gradient of Foliar Disease Incidence in Agroforestry Systems

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In tropical agroforestry systems, root functional traits are important indicators of ecosystem functioning, including nutrient cycling and soil trophic interactions. These trophic interactions are important for crop health, as they can assist plants via enhanced nutrient uptake, improved performance under drought conditions, and altered susceptibility to phytopathogen attacks. While previous research has investigated the response of root functional traits and soil-microbial processes to nutrient availability, little work has investigated root response to aboveground plant disease and the role that management plays in moderating these relationships. The main objective of this study is to determine variations in root functional traits and root endophytic fungal populations across a gradient of plant-level foliar disease incidence in a variety of amendment regimes. Using Coffea arabica (coffee) as a model species, we measured key coffee root functional traits and characterized root endophytic fungal populations across a gradient of coffee leaf rust (CLR) incidence – a fungal disease prominent in coffee systems – under contrasting but widespread management conditions in biodiverse agroforestry systems. Preliminary results suggest that both coffee root traits and fungal community composition expressed significant variability across three agroforestry management regimes, where fungal community composition was significantly related to select root functional traits and site conditions. However, variability in fungal communities and root functional trait expression were not different between different levels of CLR incidence. These results suggest that patterns in foliar disease incidence do not disrupt belowground resource acquisition strategies via root traits or microbial associations; rather, site conditions, including soil moisture and bulk density, dictate variability in these belowground strategies.

Keywords agroforestry, Coffea arabica, Hemileia vastatrix, functional traits, root fungal endophyte

Linking Taxonomy and Macroecology: The Impact of 300 Years of Taxonomic Reclassification on Observed Species Richness of the Amazonian Flora

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The importance of taxonomy for ecology is undisputed. Key aspects of ecological research, from understanding biodiversity to identifying conservation targets, depend on how we classify organisms. Yet, ecologists spent surprisingly little attention to understand how progress in the classification of organisms impacts their models and empirical findings. Here we explore how taxonomic reclassification affects our knowledge of species richness of the Amazonian flora. We integrate the available checklists of Amazonian plants, compile information about their synonyms from different nomenclatural databases, and track historical nomenclatural changes by consulting botanical monographs. We then zoom in and investigate how such nomenclatural changes for Lecythidaceae and Arecaceae — two of the most dominant families in Amazonia — unfolded in the past 300 years. We focus on these two families because they are relatively well-studied and have been recently monographed. Our results show that the ca. 10 000 currently accepted species names of the Amazonian flora are associated with 45 000 synonyms. The number of synonyms associated with individual species names varies enormously across genera and families. It may require up to a century for taxonomists to first describe and then revise the classification of a given species. Moreover, taxa are at different odds of being revised, with several of them having been rarely assessed by botanical monographs. Our findings expose the inherent taxonomic uncertainty associated with species names. Incorporating such uncertainty in ecological models would allow quantifying the impact of taxonomic progress on ecological predictions. These findings provide a first insight of a more comprehensive research into the evolution of taxonomic knowledge in the Amazon rainforest. They can also contribute to a probabilistic view on species names and highlight taxa that deserve fresh botanical monographs.

Keywords Amazonian flora, taxonomy, taxonomic monographs, species richness, nomenclatural databases, Amazonia

Functional and Structural Components of Tropical Ecosystems - Part III

Session Recording: https://youtu.be/rQHZQAPexGk

Tree Diversity Recovery in Costa Rican Production Forests

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Tropical forests constitute biodiversity hotspots: they host 50-70% of the terrestrial species. They account for nearly half of the world's forest ecosystems and play a crucial role in the provision of many ecosystem services. These forests have been disturbed, resulting in a significant increase in post-disturbance complex landscapes, representing nearly 2/3 of the current tropical rainforest areas. In a global context of biodiversity erosion, investigating the response of these hyperdiverse ecological systems to anthropogenic disturbances is a crucial issue to predict their fate. In this context, our work specifically focuses on the understanding of tree biodiversity trajectories in production (logged for timber) forests. We define biodiversity trajectories as the potential dynamics of tree diversity and composition indices over time in permanent sampling plots (PSPs). We aim at characterizing biodiversity trajectories in tropical production forests. To assess the impact of logging on the studied tropical production plots, we compare their trajectories to the ones of intact primary tropical forest plots. We worked in Costa Rica, which accounts for 5% of global known species on 0.03% of Earth's surface. We used 32*1ha PSPs (5 in intact primary forest, 27 in production forest) within the rainforest ecoregion, where trees with a diameter at breast height 10cm were inventoried at least 5 times over 20 years. We built tree diversity trajectories for each of the PSPs and found that (1) intact primary forests differed in species richness between sites; (2) tree diversity trajectories were stable for intact primary forests within the study years; (3) tree diversity trajectories were affected by different logging intensities and sylvicultural treatments, but after a post-logging decrease in species richness, all the production forest plots recovered their pre-logging species richness within the 20 years of study; (4) pre-logging species richness, logging intensity and treatments played a major role on post-logging species richness levels over the study years. Environmental restrictions applied for timber production in tropical forest in Costa Rica led to species richness recovery in less than 20 years in the study production forests plots. As they retain values of diversity comparable to that of their primary neighbours, these disturbed ecosystems should be considered in conservation plans, due to their large extent, and the mixed results obtained by protected intact forest areas. Sustainable forest management could therefore be a mixed strategy allowing production, biodiversity recovery and conservation.

Keywords Tropical forest, tree diversity, anthropogenic disturbance, conservation, Costa Rica

Selective Logging Alters Forest Understory Structure Diversity: A Natural Experiment in an African Tropical Forest

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Selective logging affects at least 20% of tropical forests worldwide and has clear impacts on tropical forests: it removes trees of selected species and sizes, with associated damage from roads, skid trails, and tree falls. However, the ecological consequences of these impacts are unclear, with evidence of positive, negative, and negligible effects on diversity and forest structure, likely because of differences in specific management plans and forest type. My study explores the impacts of selective logging in tropical forests of northwestern Gabon. I compared forest structure and diversity in the seedling, sapling/small tree, and adult/large tree and liana communities of unlogged forest with forest that had been logged 1 year and 10 years before. I found that selective logging changes some aspects of forest structure and diversity that persist in the forest over time. For example, recently logged forests have greater canopy openness. Older logged forests have greater small tree/sapling densities, higher small tree/sapling diversity, and greater small/sapling-sized liana relative abundances; but have no significant differences in the seedling or adult layers of the forest. Changes to forest structure and diversity can affect ecosystem function, such as carbon storage, evapotranspiration and temperature regulation, as well as the availability of suitable animal habitat. Examining the immediate and persistent effects of selective logging on forests is critical if we want to understand the long-term impacts that humans have on tropical forests.

Keywords selective logging, forest structure, species diversity, trees, seedlings, central Africa

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Tree Diversity, Dominance, and Topography Drive Biomass in a Mixed Dipterocarp Forest of Sri Lanka

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The direction of the diversity – ecosystem function relationship in forests is often thought to be driven by two opposing mechanisms. High ecosystem function can be achieved through niche partitioning and more efficient resource uptake in diverse forests, a process known as niche complementarity. Alternatively, less diverse forests that are dominated by a small number of highly productive species can also have high ecosystem function through mass ratio effects. In addition, abiotic conditions such as topography may both directly impact ecosystem function and indirectly modulate it through variation in species composition across environmental gradients. In this study, I examined the role of taxonomic diversity, functional diversity, functional dominance, and topography in driving one important measure of ecosystem function – aboveground biomass (AGB) – in a hill mixed dipterocarp forest of Southwest Sri Lanka. I used data from long-term forest plots located along an elevation gradient and a combination of indices that measure taxonomic diversity and functional diversity in wood density and stature. Overall, I found that aboveground biomass was not influenced by taxonomic diversity, but increased with both community weighted mean (CWM) of wood density and functional richness in stature, indicating the presence of both niche complementarity and mass ratio effects acting via two different traits. In addition, aboveground biomass decreased slightly with slope and was significantly greater at high elevations compared to low elevations. In particular, the two most abundant taxa in the forest – *Mesua nagassarium* and Dipterocarpaceae – dominated at the opposite extremes of the elevation gradient, with *M. nagassarium* driving the mass ratio effects at low-elevation plots. My results suggest that niche complementarity and mass ratio effects are not necessarily mutually exclusive processes and propose the need for more integration of taxonomic diversity, functional diversity of individual traits, and underlying environmental gradients in diversity – ecosystem function studies.

Keywords biodiversity, biomass, functional traits, dipterocarp, Sri Lanka

Floristic Diversity and Carbon Stock Estimates of a Novel Community Forest Ecosystem in Sri Lanka

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Areas where for natural forest has been cleared often regenerate as novel ecosystems. This is often because local communities enrich forests by planting preferred species and managing these forests collectively ("community forestry"). There are few studies of these community managed novel forest ecosystems in Sri Lanka. We studied a community forest at 'Solai Amman Temple' in Chavakachcheri area of Thenmaradchy Division in Jaffna district (dry zone), Sri Lanka. The study was aimed to assess the floristic diversity and carbon stock in the forest reserves. Since the total forest area is small, full enumeration was done in the forest reserve with a division of square plot at the dimension of 20 m $\times$ 20 m. A total of 1.16 ha with 29 plots was demarcated by using GPS coordinates in the study area. For the assessment of floristic diversity, Shannon-Weiner Index (SWI), species richness, and evenness were used, similarly, for the species dominance, the importance value index (IVI) was calculated. Pantropical allometric equations were used for tree carbon stock estimation. Results of the study showed that a total of 40 species including trees, saplings, seedlings, and 4 lianas were recorded from 29 families. The population density of trees, saplings, and seedlings were 495, 2,307, and 5,160 stems/ha. SWI of trees, saplings, and seedlings was 2.19, 1.91, and 1.36, respectively and this result showed that tree diversity was higher than saplings and seedlings. Similarly, the evenness of the above categories was greater than 0.5 and this indicated that trees, saplings, and seedlings had less uniform distribution. Based on the IVI, the dominant species in the community forest was *Mimusops elengi* L. (70) followed by "Sadavakkai" (51) and G*arcinia spicata* Wight & Arn. (47). The mean value of the tree carbon was 218.8 MgC/ha and it was contributed substantially by the dominant species in the forest reserve. Correlation analysis showed that basal area was significantly ($p<0.001$) a strong positive correlation with tree diameter (0.82) and total carbon (0.95). The species-area curve was represented that species richness had a significant ($p<0.001$) strong correlation (0.98) over the area. The mean value of soil organic carbon was 4.67 % and this showed that forests had the highest soil organic carbon than other land-use systems. There was a significant ($p<0.001$) strong positive correlation between carbon stock and tree diameter (0.84) or basal area (0.95).

Keywords Carbon stock, Community forestry, Floristic diversity, Jaffna, Tropics

Rarity in Woody Plants of the Madidi Region (Bolivia)

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Local abundance, geographic range size, and habitat breadth of species have distinct effects on extinction risk (hereafter referred to the three axes of rarity). Determining how species are arranged in the space of these three axes of rarity will give insights into whether species can escape or not extinction risk. This information can be also used for practical conservation purposes. We focus on three major hypotheses, i. No correlation among the three axes of rarity, ii. Positive relationship among the three axes of rarity, and iii. Negative relationship between geographic range size and abundance, and between abundance and habitat breadth, and a positive relationship between geographic range size and habitat breadth. We tested these hypotheses using a regional pool of 1,700+ woody plant species in the Madidi region of the Bolivian Andes. We used a network of 48 1-ha forest plots and 442 0.1-ha forest plots to measure local abundance and habitat breadth of 1,700+ species (from 100+ plant families), and occurrence records of individual species across the Neotropics to measure geographic range size. We tested predictions derived from these three hypotheses using a set of

bivariate relationships and a multivariate principal component analysis. Bivariate analysis suggested a negative association between geographic range size and abundance, on the other hand, associations between geographic range size and habitat breadth, as well as between abundance and habitat breadth were both positive. The multivariate analysis produced two significant derived axes that accounted for 78.8% of the variation. Both geographic range size and habitat breadth have significant positive loadings on the first principal component, and geographic range loads negatively in the second, while abundance loads positively. We did not find support for any of the hypotheses proposed. However, these results suggest that species with narrow geographic range sizes can compensate for this type of rarity with high local abundance or a more uniform distribution of abundance within their range. It seems that this pattern is found especially in regional species assemblages characterized by a high proportion of narrowly distributed species such as the Madidi region of Bolivia. On the other hand, species with narrow geographic range sizes occupy few habitats, implying that these species are in double jeopardy of extinction risk. Nonetheless, more efforts need to be made to understand the processes and mechanisms involved in these rarity patterns to better apply conservation efforts, especially in the face of a changing world.

Keywords Rarity, Plants, Tropics, Geographic range size, Abundance, Habitat breadth, Conservation

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Decoupling of Adult and Sapling Niches Helps to Explain Tree Hyperdiversity in a Central Amazon Forest

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Forest vertical stratification is a classical example of how tree species can differentiate into contrasting adult niches. The diversity of such vertical niches is nowhere else more apparent than in tropical rainforests, which may boast up to six different strata. Trees, however, tend to clump at certain points along the vertical light gradient, as opposed to being evenly distributed. Stratification also cannot explain the diversity of species found within each single stratum. We thus propose that within-strata coexistence can be maintained by the spatial segregation of species' saplings through two mechanisms: 1) coupling of adult size and sapling architectures, with competitive exclusion among neighboring saplings with too similar architectures; or 2) decoupling of adult size and sapling architectures with environmental filtering segregating saplings with different architectures. We tested these hypotheses by first estimating adult height (Hmax) for >400 species from a 25-ha plot in a hyperdiverse forest in the Central Amazon. We then described saplings' growth strategies and allometry by fitting species-specific allometric models describing how saplings change their architecture (height, crown width, and crown depth) as they grow in stem diameter. Using a hierarchical Bayesian framework we could then estimate the architecture of thousands of saplings that were mapped in the plot. With that data we could test if: 1) species' Hmax was indeed clustered into strata (cluster analysis); 2) Hmax was correlated to sapling architecture; and 3) saplings were spatially aggregated or segregated according to their architectures (positive or negative spatial autocorrelation, respectively). We found evidence for the stratification hypothesis, with our cluster analysis showing that there are 4-5 discrete groups of species based solely on their Hmax. The average height of each of these groups matches closely what is described in the literature. We also found evidence for a very weak correlation between Hmax and sapling architecture and allometry, with crown depth being the sapling trait that was most correlated to Hmax. This points to a relaxation of the coupling between adult and sapling niches seen in other less diverse forests. In practice, this means that species sharing the same strata can vary substantially in their regeneration niches. Finally, we found a positive spatial auto-correlation of saplings' architecture, which could be evidence of light habitat filtering of these saplings. Together, these results point to habitat filtering as an important mechanism of within-strata coexistence, which was only made possible by the decoupling of adult and sapling niches.

Keywords spatial coexistence, sapling architecture and allometry, forest stratification, allocation tradeoffs

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High Species Richness and Endemism Characterize the Butterfly Fauna of Vietnam's Central Highlands (Lepidoptera, Papilionoidea)

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Butterflies are sensitive to environmental changes, and they are excellent indicators of tropical forest disturbance. Previous studies suggest a relationship between butterfly diversity and environmental quality/habitat disturbance. The butterfly fauna of Vietnam is affected by its biogeographic position. Tropical mountains are packed with more species per unit area than almost any other terrestrial habitat on earth, and many species are endemic to high elevations. While much research effort has focused on the Andes in South America , Mt. Kilimanjaro in Africa , and Mt. Kinabalu in Malaysian Borneo, few studies have examined the biodiversity of Vietnam's Central Highlands. In this study, we test the hypothesis that high butterfly species richness and endemism in Vietnam's Central Highlands is related to the Highlands' climate and other environmental factors, which are unique within the region. The range size of butterfly species found in the Highlands is also assessed to gauge the endemicity of the fauna. We further provide an updated checklist of butterflies in Kon Ka Kinh N.P., including many new records. The study was conducted at Kon Ka Kinh N.P., Central Highland Vietnam, where has a tropical monsoon climate with warm winters and summer rain. Butterfly assemblages were sampled using the Pollard Walk method, and we used correspondence analysis (CA) to examine the effects of environmental covariates on the presence of butterfly species in each family. A total of 368 butterfly species from 6 families were recorded during three rounds of surveys in Kon Ka Kinh N.P. in 1999, 2014-2016, and 2018-2019. Nymphalidae is the dominant family with 154 species (41.8% of total species recorded) of the total alpha diversity, followed by Hesperiidae (20.1%), Lycaenidae (18.8%), Pieridae (9.0%), Papilionidae (6.8%), and Riodinidae (3.5%). Three species of Faunis and three Stichophthalma species co-occur in the park. Two lycaenid species of the subfamily Miletinae were recorded in Vietnam for the first time Logania watsoniana and Taraka mahanetra. Our results demonstrated that microhabitat conditions influence the occurrence of species in different ways depending on the butterfly. In the species-rich families of Hesperiidae, Lycaenidae, and Nymphalidae, opposite environmental variables were strongly negatively correlated. The two axes of each ordination plot explained 80 – 90% of variation in occurrence. Endemic and restricted-range species comprised a higher proportion of the diversity at higher elevations ($>$ 1,200 m) than at mid-elevations (800 – 1,200 m). The proportion of restricted-range species (categories I and II) at high elevations and mid-elevations representatively occupied 32.7% and 11.6% of the sampled specimens, respectively.

Keywords Lepidoptera, ecology, endemic, biogeography, biodiversity, species richness, tropical mountains

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Spatio-temporal Pattern of Vegetation Distribution in a Hydrologically Altered Tropical Coastal Lagoon

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Lagoons are highly productive areas and very sensitive to climatic and human activities. Moreover, rice cultivation in some regions down south, Sri Lanka has inverted the natural hydrological cycles of coastal lagoons decreased water salinities for over many years. During the last three decades, a noticeable shift of the aquatic vegetation has occurred in the Embilikala lagoon. Still, little information on the status and Spatio-temporal variation is available after the change. We studied the aquatic plant community, the composition, and structure of which are known to be good indicators of environmental changes. Embilikala lagoon was divided in to 3 sectors as Embilikala North (EN), Embilikala Middle (EM) and Embilikala South (ES). It has two inlets at the EN section and an outlet at the ES section. The plants were categorized with particular reference to their habit, namely, free-floating plants, submerged plants, emergent plants, and plants attached to the substrate and have floating leaves. A coordinate grid was used to study the spatial distribution of different plant communities within the lagoon. In each grid, sampling location (latitude, longitude), aquatic vegetation type, major weeds, and minor weeds were recorded according to the cover. According to the results, 20 aquatic plant species belonging to 18 families were recorded during the study. This includes 5 submerged

species, 7 emergent species, 5 free-floating species, and 3 plants attached to the substratum and has floating leaves. The aquatic vegetation was algal or macrophytic, and the vegetation cover is polyspecific. The total number of plant species observed in EN, EM, and ES was 16, 11, and 10, respectively. The surface water of the lagoon was covered mainly by *Nymphaea stellate*, which was found in all the sections. However, *Eichhornia crassipes* also had a noteworthy contribution to the coverage of surface waters of the EN section. The benthic region of the whole lagoon was principally invaded by *Chara vulgaris*, but the southern region was dominated by *Potamogeton crispus*. *Typha angustifolia* occupied the littoral zone of the lagoon. Alterations of vegetation composition and distribution of the lagoon were noted in different seasons. These changes seemed short-time temporal fluctuations. The variations were further found to be appeared due to hydrological dynamics. In contrast, most of the species identified in the Embilikala lagoon were aquatic weeds. They were predominantly freshwater species that indicate the current salinity regime in the Embilikala lagoon is optimal for the distribution of freshwater plants.

Keywords Coastal lagoon, Macrophytes, Salinity alteration

Clustering of Spatially Associated Species: a Methodological Approach towards Understanding Patterns in Species Distributions

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Understanding the way in which species and communities are spatially structured is a central goal of ecology. It makes sense then to classify species into biodiversity units based on their interspecific spatial associations (ISA), thereby forming groups of species with uniquely similar geographical distributions. In doing so, such groups will not only enable more nuanced analyses of spatially related threats (e.g., deforestation) but also provide important insights into the spatial structuring of communities. Yet, largely absent from the literature are approaches or frameworks aimed at forming such groups. Here, we aim to develop and illustrate a methodological approach towards clustering species based on their geographical distributions, allowing the formation of spatially meaningful biodiversity units. We developed the Clustering of Spatially Associated Species (CSAS) approach, and explored the effects of different ISA measures, clustering algorithms and stopping rules to determine the most optimal number of clusters. Using Borneo as a case study, we modelled the distribution of 385 tree species, calculated their dissimilarities in geographical space and clustered them based on those dissimilarities. Each cluster was considered a unique biodiversity unit, and species within each were aggregated to evaluate the impact of land-use change on species distributions. Using the CSAS approach, we were able to form species clusters based on their geographical distributions. Although the clustering outcome varied depending on the clustering algorithm, ISA measure, and stopping rule applied, we selected the methods that performed best to classify species into several distinct biodiversity units. Land-use change was found to have differential effects on each cluster, where those with distributions traditionally associated with coastal and peat swamp forest suffering the greatest decline. The impacts also differed temporally, with shifting trends indicating potential land-use regime shifts in 1996 and 2004. We propose that the CSAS approach is likely to offer greater insights into the spatial structuring of species communities, their vulnerabilities to spatially relevant threats like deforestation and climate change, and provide the formation of meaningful biodiversity units that could better inform conservation and management priorities. Our results also highlight the potential variability in clustering output, where careful consideration of the ISA measure, clustering algorithm and stopping rule is required to produce ecologically meaningful clusters of spatially associated species.

Keywords interspecific spatial associations, species distributions, clustering, biodiversity units, spatial structure

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Validation of Computational Models Forecasts

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With enough time and dispersion, the species move to favorable thermal environments or adjust to new environments by behavioral, physiological or adaptation plasticity. Alternatively, the failure to adjust or adapt culminates in demographic collapse and extinction.The use of computational models (CM) for predicting these dynamics are based on the effects of physiology over demography, extinction, niche displacement and species-area relationships. The increasing usage of CM to forecast species displacement related to global climatic change avails a substantial quantity of data in need of validation. The presentation talks about validation of CM predictions, in the context of the influence of the climate over the biota, to approach the forecasting accuracy. These CM are important for assessing the impact of changes on fauna, predicting new occurrences of a species by filling in geographic information gaps, understand biological invasion processes, analyze the potential expansion of agricultural diseases or pests, among other potentialities. Regardless of the type of the model, its purpose is to increase the understanding of a system and emphasize gaps in its knowledge, rather than making predictions accurately. It is a real concern that a CM do not have perfect accuracy and its validation would be very useful.

Keywords Species modeling, Computational models, Fauna distribution

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The Fragile Limestone Island Forest Characteristic in Gam Island, Raja Ampat

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The small island and karst ecosystem are considered to be vulnerable regions. Gam Island, on the west side of Waigeo Island in Raja Ampat, is a fragile limestone island with many forest habitats comprising coastal forest, mangrove, semi-permanent swamp forest, and lowland limestone forest. The objective of this study was to characterize the floristic composition and structure of the tree component on limestone forest, located in Gam Island. We set up six sample plots, each of 0,25 ha, which were placed in three habitat types (ecotone mangrove-lowland forest, lowland forest, and semi-permanent swamp forest). All woody individuals 5 cm diameter at breast height (DBH) had their diameter and height measured. The tree community was composed of 131 species with a density of 120 individuals ha^{-1} (30 cm DBH), 316 individuals ha-1 (15-30 cm DBH), and 958 individuals ha^{-1} (5-15 cm DBH). Vegetation is dominated by small-diameter trees with an average of 9.37 $\pm$ 2.54 cm. The limestone forest on Gam Island has a four-canopy structure with a height ranging from 4,1 to 45,2 m. The richest families were Myristicaceae with 13 species, followed by Moraceae and Fabaceae (8 species). Characteristics of tree communities on Gam Island with limestone substrates were dominated by *Anisoptera thurifera* (Dipterocarpaceae) with an IVI value of 19.78% associated with *Sterculia* sp. (Malvaceae) - 14.73% then *Intsia bijuga* (Fabaceae) 12.91%. This study finding the limestone island forest characteristics in order to improve understanding and promote sustainable development in the fragile small island.

Keywords limestone forest, Gam Island, tree diversity, structure, community

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Part IV

Open-format sessions

Designing a collective prototype of future tropical and subtropical science

Organizers:
Gracielle Higino, University of British Columbia

The practice of science, although inserted in a common system, is experienced in very different ways by scientists depending on their social, economical and political contexts - among a myriad of other factors. Being a scientist from a tropical or subtropical country is a unique experience, with its own challenges and opportunities, but it is often normalized that a successful scientific career can not be pursued in our home countries. As a hyper-diverse region, it is important to acknowledge the equally diverse stories behind each scientist so we can understand the history and redesign the future of an inclusive global science.

In this session we aim to promote a collaborative speculation experiment to prototype the future of the next generation of tropical scientists. Inspired by the From the Futures immersive art experiment by Columbia DSL, we will invite attendees to assess stories of Early Career Researchers (ECRs) from tropical and subtropical regions, which will be assembled through an online survey before the ATBC meeting. Attendees will work in groups to reflect on challenges and privileges mentioned in the stories, remix them (removing obstacles, adding inclusive policies, enhancing and potentializing the opportunities), and design the next chapter of tropical/subtropical science (reflecting on future challenges and opportunities, and consequences of policies applied in the present). Finally, we will collectively transform these stories about the future into guidelines, and identify what can be done from now on to rewrite the next generation's story in our home countries.

This session aims at providing a safe place for tropical and subtropical ECRs to rewrite their own stories and openly share their hopes for their careers, and therefore attendance is restricted to this group. Secondly, we want to assess the diversity of challenges and opportunities frequently hidden in tropical science, while envisioning a strategy to diminish the challenges and potentialize the opportunities. At the end of the session we will have an outline of clear measures that can be taken to diminish any obstacles and potentialize the opportunities we might have in tropical science, which should be further used as evidence and direction to better support young researchers.

Because this is a session designed for ECRs, it is important that attendance is restricted to this group of researchers. Our definition of "ECR" is open, and we strongly request that attendees do not disclaim their career status during the session.

Session Recording: `https://youtu.be/oI3oKxRVrzQ`

Emerging Frontiers In Tropical Ecology: Voices from the Next Generation

Organizers:
Maria-Natalia Umana, University of Michigan
Sofia Rodriguez-Brenes Organization for Tropical Studies

ATBC and OTS student awards have a great impact on fostering the research of new generations of tropical ecologists and conservationists. This symposium will highlight some of the projects that have been recently awarded by ATBC and OTS.

With this symposium, we want to highlight the research of the newest generations of tropical researchers that have recently obtained awards from ATBC (Biotropica) or The Organization for Tropical Studies OTS. ATBC and OTS are two key institutions that have provided great research opportunities for many generations of researchers. In this opportunity, we want to emphasize the importance of new generations in building new knowledge in distinct areas within tropical ecology and conservation. ATBC together with Biotropica has a well-known awards program for recognizing outstanding papers published in Biotropica by young investigators. Additionally, in 2020, ATBC started a new grants program: ATBC Seed Research Grants to promote research for the earliest generation of researchers. Similarly, the OTS institution is renowned for its graduate and undergraduate courses and for providing opportunities for a new generation of scientists to conduct research at its research stations in Costa Rica and South Africa. The OTS also has an awards program for recognizing young investigators with outstanding publications. In the long term, the SECSCI committee would like to do this symposium annually.

Session Recording: `https://youtu.be/hfvUfvpT768`

Young voices and visions in tropical restoration science

Organizers:
Trisha Gopalakrishna University of Oxford
Tina Christmann University of Oxford

The UN Decade of Restoration provides a valuable policy window to accelerate restoration science and implementation. Moving ahead, the responsibility of science, policy, finance and/or on-the-ground implementation, depends on the future leaders - current young researchers striving to create a resilient, adaptive, socially just and equitable future. Furthermore, many young researchers, especially doctoral students, face barriers related to lack of opportunities to present their research, access funding, engage in effective outreach, build collaborations and learn to deal with the pressures of research, which have been exacerbated by the COVID-19 pandemic. Hence, it is vital that we share our knowledge and experiences and foster a community, who will in the future collaborate to address the big challenges of restoration science.

In this session, we aim to provide a platform for doctoral students to showcase their research and vision for restoration science in tropical landscapes and to engage interactively with the tropical restoration community.

The goals of this sessions are two-fold- (1) to build a community of young restoration science researchers working towards a sustainable future and (2) to present and share a vision for the future of tropical restoration science by interactively including the wider community of young researchers, underrepresented in the speaker panel.

The objectives of this session are (1) to present research highlighting novel analyses of various aspects of restoration science in different tropical ecosystems and contexts and (2) give everyone, especially young researchers from the Global South, a platform to share their visions for the future of tropical restoration science using an interactive mind mapping tool and (3) synthesize the outcomes of the session and produce a peer reviewed conference paper on the vision of the young generation of restoration scientists and next steps for the upcoming UN decade of restoration.

Together, we will present on advances, challenges and lessons learned in restoration science in tropical landscapes. We will present case studies encompassing mountains, agricultural landscapes and forests in the tropics. We will expose the audience to a range of methodologies including the use of remote sensing, functional ecology, field methodology and data, governance and market- based instruments that are advancing restoration science. Lastly, each presenter will conclude by presenting their vision for the future of tropical restoration.

Session Recording: `https://youtu.be/6cuwGxZc128`

Integrating defaunation with other key drivers of structure and diversity of tropical forests

Organizers:
Claudia Paz Sao Paulo State University
Yuri Silva Souza Sao Paulo State University

Redford's metaphor of the empty forest prevails on the minds and souls of tropical ecologists and conservationists alike. Yet, almost 30 years on since Redford's seminal publication we continue with limited evidence on the impacts and mechanisms of defaunation effects on the structure and function, diversity and ecosystem functions of tropical forests. A key missing gap in this body of evidence pertains how large herbivore effects integrate and scale with direct indirect linkages among above and belowground organisms and abiotic properties. For instance, beyond intuitive trophic interactions, large vertebrates might affect plants through non-trophic interactions (e.g. trampling) and overrun or compensate the effects of invertebrate foliar herbivores and seed predators, microbial root symbionts and pathogens, contingent on the local soil fertility or other abiotic features. In face of rapid global changes (e.g. species extinctions, land-use, biological invasion) the outcome of such interactions can change, but characterizing the mechanisms involved and their importance needs further attention given the alarming levels of defaunation and threats to hyper-diverse and dynamic tropical forests.

This exciting session will integrate the latest and more robust experimental evidence about the importance of conserving large terrestrial vertebrates aiming to preserve the structure and diversity in tropical systems, building on evidence from three continents (America, Africa and Asia). Through a walkabout through different large vertebrate exclosure and natural experiments we will explore how the presence of tropical forest's largest ecosystem engineers integrates with other key above and belowground processes to ultimately define the structure and function of tropical forests. We will do so with an interactive and "funky" session, in which the audience will learn, think and have loads of fun.

Session Recording: `https://youtu.be/qUr6O0SYIts`

Tropical zoogeochemistry: alchemists of the wild

Organizers:
Nacho Villar Netherlands Institute of Ecology NIOO-KNAW
Elizabeth le Roux Aarhus University, Centre for Biodiversity Dynamics in a Changing World (BIOCHANGE)

Imagine thousands of wildebeest crossing the Mara river in their migration to more fertile grasslands, the thousands of carcasses left at the river by the ones who could not make it and the nutrient input caused by this process. Think about the hippos that subsidize this very river with their excreta, and their impact downstream. The rhinos and giraffes, zebras and gazelles, browsing and grazing and differentially defecating in different savannah habitats depending on their daily routines and the landscape of fear and disgust. Travel to heart of the jungle, and think about the large herds of peccaries and the tapirs voraciously seeking for fallen fruits, and the trampled and defecated trail left behind.

The above are a few intuitive examples of how large tropical vertebrates can modify habitats and ecosystems through the movement and mobilization of nutrients. Whilst classical ecology has devoted a great deal of attention to trophic interactions (e.g. trophic cascades including antagonistic agonistic interactions), an important, yet largely unexplored, subject is how ecosystem and landscape engineering results from the movement and mobilization of nutrients within ecosystems and across ecosystem boundaries by large vertebrates. Such processes, operating simultaneously at different spatiotemporal scales, modify ecosystem function and services, and might strongly affect geochemical cycles and climate change, though much of these effects have been neglected in the absence of a comprehensive body of evidence.

In this exciting session young emerging leaders in zoogeochemistry will showcase comprehensive studies from different tropical systems (savannahs, land-water interface tropical forests), aiming to stimulate the audience to think "out of the box" and spark interest on the understudied subject of tropical zoogeochemistry. We will do so with an interactive and "funky" session, in which the audience will learn, think and have loads of fun.

Session Recording: `https://youtu.be/tG69u8xPH2w`

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